AVRDC Report

AVRDC–the World Vegetable Center

AVRDC Report 2002

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The World Vegetable Center

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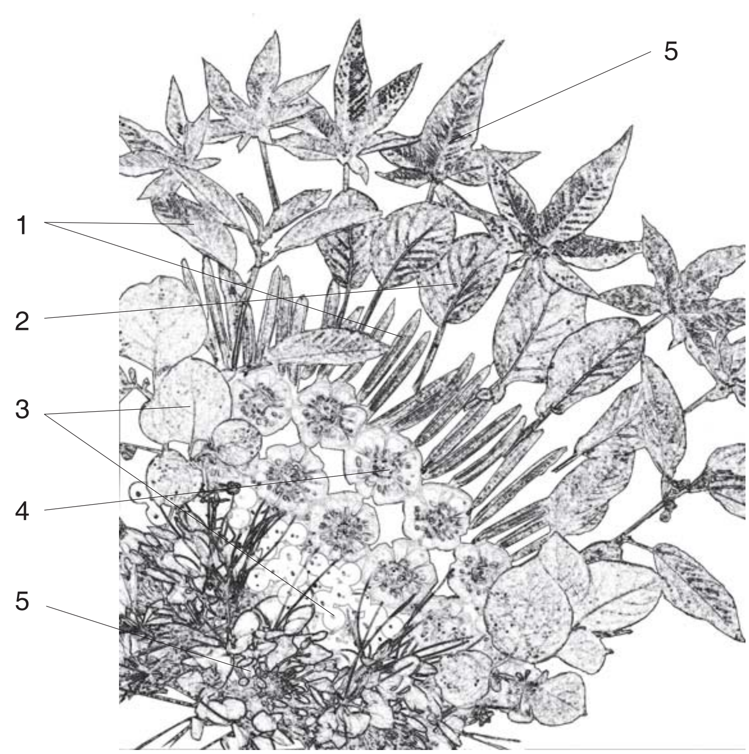


About the cover:
AVRDC is a world leader in the collection, evaluation, and conservation of indigenous vegetables. Shown here are some of the most promising indigenous vegetables from Africa:

1. *Corchorus olitorious* (jute mallow)
2. *Brassica carinata* (Ethiopian kale)
3. *Solanum scabrum* (African nightshade)
4. *Solanum aethiopicum* (African eggplant)
5. *Cleome gynandra* (spider flower plant)

Contents

Foreword

AVRDC—The World Vegetable Center is pleased to present our accomplishments for 2002. During the past year, our scientists made remarkable advancements that are leading to increased yields, improved stability of vegetable supplies, and greater food safety in the developing world.

Among the many success stories described in this document is how we used the speed of molecular-based breeding tools to develop lines that resist several major diseases of tomato and pepper—in less than half the time used in conventional breeding methods. These lines are already doubling yields and reducing the use of pesticides in the developing world today. In mungbean research, farmers have eagerly accepted our early maturing, disease-resistant lines and AVRDC's partner agencies are producing tons of seed to meet the demand. These mungbean lines will be sown on over one million hectares in South Asia, enriching the lives of millions of families. Also in 2002, new IPM strategies were developed that allow pesticide-free production of leafy vegetables and eggplant, two of the most heavily sprayed food crops. Working with partner agencies, AVRDC added thousands of new indigenous vegetables to our genebank, which is already the largest vegetable genebank of its kind in the world. Also in 2002, AVRDC trained more people and provided more educational materials to persons around the world than ever before.

In this document you will see extensive reports from Africa and other outreach stations, an indication of the expanding outreach of AVRDC—The World Vegetable Center. Indeed, our new name reflects our commitment to reach out to regions facing nutritional distress and suffering, anywhere in the world. Regions passed over in terms of economic development, afflicted by HIV/AIDS, and decimated by drought and war will draw our focus. As the world's only international center focused on vegetables, we will not neglect any region that calls for our expertise and technologies. I invite you to read this document and welcome your partnership in working together to fight poverty and malnutrition in the developing world.

Thomas A. Lumpkin
Director General

Program I

Vegetables in cereal-based systems

Program I works to increase the efficiency of cereal-based vegetable production systems through the development of improved cultivars. The goal is 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 applicable 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;
- increase the availability of safe vegetables for human consumption, especially in off seasons;
- diversify incomes, regularize cash flow, and reduce risk;
- increase efficiency in using labor and other resources; and
- serve as a catalyst for infrastructure development and growth of local service industries.

Program Director: S Shanmugasundaram

Project 1. Breeding of Solanaceous crops

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

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

In the hot-wet season, stresses caused by 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 economical management practices, must be developed to overcome these constraints and extend tomato production into the hot-wet season. Management of bacterial wilt (BW) has received considerable attention because of its importance in the hot-wet season.

In hot-dry environments, production of tomato is limited by tomato leaf curl virus (ToLCV)—developing resistance to this virus complex is a priority at AVRDC.

Sweet peppers struggle under hot temperatures and AVRDC is working to develop heat-tolerant lines. For chili pepper, AVRDC is increasing yield and yield stability by developing improved lines and management practices designed to overcome diseases, especially cucumber mosaic virus, chili veinal mottle virus, tobamoviruses, phytophthora blight, and anthracnose.

Among other solanaceous crops, Project 1 is identifying eggplant lines with resistance to major insect pests (particularly eggplant fruit and shoot borer) and characterizing the *Solanum nigrum* complex.

Project Coordinator: P Hanson

Fresh market tomato lines for the tropics

The whitefly-transmitted geminiviruses (WTG) and bacterial wilt are the two most important tomato disease problems confronting farmers in the lowland tropics and subtropics. Farmers often resort to frequent and heavy insecticide applications in vain attempts to control WTG and few options besides resistance are available for bacterial wilt control. Consequently, farmers will benefit from tomato cultivars possessing resistance to both diseases, in addition to high yield potential and fruit qualities acceptable to the market.

Two observational yield trials (OYT) were conducted at the AVRDC during the late summer season to identify superior inbred lines for international distribution. OYT1 entries were determinates and OYT2 entries were indeterminates. Both OYTs were sown on 16 July 2002, transplanted on 14 August, and harvested three times from 12 November to 10 December. Trial plots of OYT 1 consisted of a 1.5-wide bed with one 4.8-m-long row per bed including 12 plants. OYT 2 plots consisted of single beds with two 4.8-m-long rows per bed (24 plants). Plants in all trials were staked but only OYT1 was pruned. OYT entries were replicated twice and arranged in a randomized complete block design (RCBD).

Environmental conditions from transplanting through flowering/fruit set (approximately 14 August to 30 September) were: mean maximum/minimum temperatures of 33.6/25.4°C, mean relative humidity of 79% and total rainfall of 96 mm. Despite temperatures unfavorable for fruit-set, several OYT1 inbred line entries yielded exceptionally well, particularly CLN2460F, CLN2469C, and CLN1962B1F7-A-3 (Table 1). Fruit weights of most entries fell in the 60–70 g range, but CLN2469C and CLN1962B1F7-A-23 stood out with fruit weights exceeding 100 g.

Except for the CLN1962 entries, geminivirus resistance in all the above lines is conditioned by the *Ty-2* gene mapped to the bottom of chromosome 11 and derived originally from H24. Geminivirus resistance of the CLN1962 entries originated from *L. chilense* accession LA1932, of which the number and location of resistance genes is presently unknown. In addition to geminivirus resistance, most entries expressed high or moderately high levels of bacterial wilt resistance, and carry tobacco mosaic virus (TMV) resistance conditioned by the $Tm2^2$ allele. After further tests for reaction to fusarium wilt (*Fusarium oxysporum* f.sp. *lycopersici*) and gray leaf spot (*Stemphylium solani, S. lycopersici*), we will select two or three entries for seed multiplication and inclusion in our set of determinate inbred lines for international distribution. We anticipate seed for international distribution will be available February 2004.

Outstanding indeterminate lines in OYT2 included CLN2463O, CLN2460G, CLN2460H, and CLN2460J with yields ranging from 30–34 t/ha (Table 2). Fruit

Table 1. *Yield and horticultural characteristics of geminivirus-resistant determinate tomato lines*

Entry	Marketable yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	BW survival[3] (%)
CLN2468D	31.7	34	104	67	4.3	0.35	2.20	89
CLN2468A	36.5	29	103	72	4.8	0.29	2.21	100
CLN2468B	26.0	30	102	71	4.8	0.28	2.15	100
CLN2468C	26.6	32	104	67	5.0	0.31	2.10	85
CLN2469C	39.9	18	103	113	4.5	0.39	2.09	100
CLN2460F	49.0	25	103	60	5.5	0.49	2.13	89
CLN2467E	21.8	26	103	62	4.7	0.39	1.99	67
CLN2467F	32.4	40	102	57	4.8	0.37	2.04	67
CLN2467G	32.2	29	103	65	4.6	0.42	2.04	45
CLN1962B1F7-A-3	41.9	20	101	44	5.1	0.53	2.23	5
CLN1962B1F7-A-23	30.7	41	103	151	4.4	0.37	1.99	74
PT4721BC1F5	36.9	35	103	64	5.6	0.45	2.22	0
PT4723 (hybrid ck)	54.8	29	102	73	4.7	0.39	2.32	
FMTT847(hybrid ck)	53.4	26	101	95	4.6	0.34	1.99	
Means of all entries	37.6	29	102	77	4.8	0.37	2.12	
LSD (5%)	17.7	17	3	12	0.8	0.09	0.19	
CV (%)	22.1	27	1	7.4	0.7	11.0	4.27	

Transplanted 14 August 2002 at AVRDC
[1]Equivalent of citric acid
[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than zero. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.
[3]Percentage of healthy plants after drench inoculation with the bacterial wilt pathogen in a separate greenhouse trial

Table 2. *Yield and horticultural characteristics of geminivirus-resistant indeterminate tomato lines*

Entry	Marketable yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	BW survival[3] (%)
CLN2460G	31.3	42	101	56	4.5	0.37	2.03	80
CLN2460H	34.0	30	101	54	4.4	0.39	1.96	59
CLN2460I	26.3	28	100	55	4.8	0.38	2.06	79
CLN2460J	30.2	34	100	58	4.6	0.42	2.00	73
CLN2463O	34.3	24	101	12	5.6	0.33	1.42	85
CLN2463P	18.7	10	102	12	6.3	0.38	1.75	67
CHT1372 (ck)	48.1	36	95	12	6.2	0.44	1.67	
ASVEG #4 (ck)	37.0	18	101	76	4.8	0.34	1.76	
ASVEG #10 (ck)	31.2	9	101	105	4.7	0.39	1.92	
Means of all entries	31.5	26	101	51	4.99	0.37	1.80	
LSD (5%)	16.5	17	5	13	0.22	0.04	0.13	
CV (%)	23.8	29	2	11.5	2.04	5.14	3.30	

Transplanted 14 August 2002 at AVRDC
[1]Equivalent of citric acid
[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than zero. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.
[3]Percentage of healthy plants after drench inoculation with the bacterial wilt pathogen in a separate greenhouse trial

weights of CLN2460 lines ranged from 50–60 g while the CLN2463 lines produced cherry tomato-sized small fruit. All lines carry geminivirus resistance conditioned by *Ty-2*, moderately high bacterial wilt resistance, and TMV resistance. After further evaluation of OYT2 entries for resistance to fusarium wilt and gray leaf spot, we will select several entries to include in the AVRDC set of indeterminate lines for international distribution. We anticipate seed for international distribution will be available February 2004.

In the near future WTG resistance will become a standard component of AVRDC tomato lines, along with heat tolerance and resistance to tobacco mosaic virus (TMV) and bacterial wilt. Our next step is to broaden the genetic base of our WTG resistance by incorporating additional and complementary resistance genes and combine WTG resistance with larger fruit size and processing types.

Geminivirus-resistant, hybrid tomatoes for specialty markets

Tomato farmers in the tropics require cultivars capable of setting fruit at high temperatures, possessing resistance to bacterial wilt and other diseases, and producing fruit with desirable qualities. Specialty fruit types may satisfy the special needs and desires of targeted consumers. For example, high β-carotene cherry tomatoes may be especially useful in vitamin A deficient areas of Africa and Asia. Fresh market tomatoes with dark green shoulders are preferred by most consumers in Taiwan and are popular in specialty markets worldwide.

Tomato production throughout Southeast Asia is now threatened by whitefly-transmitted geminiviruses (WTG), especially when warm and dry conditions favor high whitefly (*Bemisia tabaci*) populations. Consequently, WTG resistance has become a necessary component for tomato cultivars in the region. The objective of this research was to identify new cherry tomato and fresh market hybrids with special fruit qualities and resistance to WTG.

High β-carotene cherry and fresh market tomatoes

One preliminary yield trial (PYT) and one advanced yield trial (AYT) of high β-carotene cherry tomato hybrids were conducted during 2002 at AVRDC. All experimental hybrids were resistant to WTG. For the PYT, entries were indeterminate hybrids. This trial was sown 25 January, transplanted 26 February, and harvested five times from 9 May to 30 June. Plots consisted of a single raised bed with two 4.8-m-long rows per bed (total of 24 plants). Plants were staked and pruned. The experimental design was RCBD with two replications.

The AYT was sown on 12 July, transplanted 21 August, and harvested three times from 5 to 25 November. Plots consisted of two raised beds with two 4.8-m-long rows per bed (total of 48 plants). Plants were staked and pruned. The experimental design was RCBD with three replications.

Favorable temperatures during fruit set and plant growth in the PYT resulted in high marketable yields ranging from 25–107 t/ha (Table 3). Outstanding entries yielding more than 90 t/ha included CHT1421, CHT1438, and CHT1441; soluble solids contents for these lines were 6.0, 5.8, and 6.2%, respectively. All entries carry the dominant allele, *Beta*, that conditions high β-carotene content at the expense of lycopene and results in orange-colored fruit. Consequently, mean beta-carotene content of the high β-carotene hybrids was about two to three times greater than normal pigmented check ASVEG #6. The best six entries from the PYT will be tested in an AYT in Summer 2003. Superior hybrids from this AYT will be recommended for possible release.

Yields of the cherry AYT entries ranged from 32–58 t/ha (Table 4), which are high for a late summer trial. Noteworthy entries included CHT1358 and CHT1372. These lines yielded more than 50 t/ha and possessed high soluble solids contents.

Dark green-shoulder fresh market tomato

The AYT was sown on 16 July, transplanted on 14 August, and harvested four times from 12 November to 10 December. Plots consisted of two raised beds with two 4.8-m-long rows per bed (total of 48 plants). Plants were staked and pruned. The experimental design was RCBD with three replications. Results showed that FMTT904, FMTT907, FMTT935 yielded nearly double the mean of checks FMTT33 and FMTT 593 (Table 5). These three lines are recommended for further testing.

Table 3. *Yield and horticultural characteristics of high β-carotene cherry tomato hybrids evaluated in a preliminary yield trial*

Entry	Marketable yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	Lycopene (mg/100g)	β-carotene (mg/100g)	WTG reaction[3]	BW survival[4] (%)
CHT1400	83	64	106	15	6.5	0.51	0.56	0.72	2.98	R	–[5]
CHT1402	69	59	106	14	6.5	0.51	0.52	0.70	3.12	R	40
CHT1403	70	71	105	14	6.0	0.49	0.47	0.72	3.18	R	–
CHT1407	77	65	105	16	6.3	0.53	0.56	0.63	2.88	R	–
CHT1409	82	68	106	16	6.7	0.51	0.56	0.77	3.22	R	–
CHT1410	80	76	106	14	5.8	0.47	0.50	0.60	3.11	R	51
CHT1417	76	86	105	10	5.6	0.49	0.22	0.13	3.03	R	13
CHT1421	96	82	105	13	6.0	0.52	0.29	0.20	2.94	R	19
CHT1438	107	92	105	11	5.8	0.46	0.26	0.12	2.76	R	41
CHT1441	96	81	99	14	6.2	0.55	0.42	0.32	2.96	R	–
CHT1442	60	87	105	12	6.1	0.57	0.34	0.22	3.15	R	25
ASVEG #6 (ck)	25	53	85	12	6.3	0.49	1.08	2.05	1.20	S	0
CHT1201 (ck)	39	64	99	13	6.3	0.46	0.32	0.24	2.84	S	–
Means of all entries	67	69	103	13.6	6.2	0.50	0.43	0.50	2.87		
LSD (5%)	19	12	11	3	0.1	0.05	0.13	0.21	0.57		
CV (%)	13	8.3	5	10.0	4.7	5.22	13.8	19.30	9.50		

Transplanted 26 February 2002 at AVRDC
[1]Equivalent of citric acid
[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than zero. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.
[3]R = resistance, S = susceptible
[4]Percentage of healthy plants after drench inoculation with the bacterial wilt pathogen in a separate greenhouse trial
[5]– = not tested

Table 4. *Yield and horticultural characteristics of high β-carotene cherry tomato hybrids evaluated in an advanced yield trial*

Entry	Marketable yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	WTG reaction[b]	BW survival[4] (%)
CHT1312	44	47	84	12	7.3	0.50	1.75	R	25
CHT1313	57	45	84	13	6.5	0.46	1.70	R	10
CHT1358	55	44	84	11	7.2	0.51	1.81	R	5
CHT1372	58	48	84	14	6.7	0.48	1.78	R	18
CHT1374	55	40	85	12	6.2	0.46	1.69	R	13
CH154NS (ck)	32	37	85	9	6.0	0.37	1.67	S	0
CHT1127 (ck)	56	45	84	11	5.6	0.39	1.78	S	5
CHT1130 (ck)	47	37	85	11	5.4	0.37	1.77	S	0
Means of all entries	51	16	84	12	6.4	0.44	3.70		15
LSD (5%)	13	12	1	2	0.3	0.03	0.11		17
CV (%)	15	43	0.7	8.6	2.4	4.07	1.74		41

Transplanted 21 August 2002 at AVRDC
[1]Equivalent of citric acid
[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than zero. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.
[3]R = resistant, S = susceptible
[4]Percentage of healthy plants after drench inoculation with the bacterial wilt pathogen in a separate greenhouse trial

Table 5. *Yield and horticultural characteristics of dark green-shouldered fresh market tomato hybrids evaluated in an advanced yield trial*

Entry	Marketable yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	WTG reaction[3]	BW survival[4] (%)
FMTT904	44	33	91	102	4.8	0.40	2.17	R	80
FMTT906	40	32	92	106	4.6	0.41	2.05	R	90
FMTT907	38	30	91	112	4.6	0.40	2.16	R	86
FMTT911	38	34	93	109	4.1	0.32	1.85	R	91
FMTT914	37	26	94	117	4.1	0.32	2.02	R	92
FMTT934	36	29	91	111	4.6	0.40	2.12	R	91
FMTT935	41	23	91	103	4.8	0.36	2.11	R	81
FMTT33 (ck)	28	14	94	102	5.2	0.40	2.06	S	45
FMTT593 (ck)	17	17	94	110	5.2	0.40	2.28	S	36
Means of all entries	35	27	92.1	108	4.7	0.38	2.09		
LSD (5%)	10	10	0.5	12.3	0.4	0.07	2.19		
CV (%)	16	21.7	0.4	6.6	5.2	10.1	5.3		

Transplanted 14 August 2002 at AVRDC
[1]Equivalent of citric acid
[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than zero. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.
[3]R = resistant, S = susceptible
[4]Percentage of healthy plants after drench inoculation with the bacterial wilt pathogen in a separate greenhouse trial

Evaluation of heterosis in tomato for yield and quality characters in the summer

Summer tomato production in the lowland tropics and subtropics is beset with numerous problems including low fruit set and yield, diseases such as whitefly-transmitted geminivirus (WTG) and bacterial wilt, and poor fruit quality. Development of inbred lines combining heat tolerance, multiple disease resistance, and good fruit quality has been difficult. Heterosis is often associated with increase in yield, earlier maturity and improved adaptation, and hybrids designed for summer season may provide higher yields, improved fruit quality, and a greater spectrum of disease resistance compared to inbred lines. The objective of this research was to measure heterosis for yield, fruit quality, and biomass of selected tomato hybrids and inbred parental lines in the summer season.

Treatments included nine determinate tomato hybrids and their parental lines (Table 6), and heat-tolerant check line CL5915-93D4. Each hybrid had at least one geminivirus (WTG)-resistant parent (Table 6). The experiment was sown on 16 July 2002 and transplanted on 15 August. The experimental design was RCBD with three replications. Plots were two, 20-cm-high beds with one row per bed. Spacing was 40 cm between plants within rows and 150 cm between beds. Beds were covered by gray plastic mulch and covered by rice straw. Plants were staked but not pruned. A basal application of 120N–52P–100K–32Mg kg/ha and a total of 210N–90P–174K–56Mg kg/ha was applied over four sidedressings. Pesticides were used to control insects and furrow irrigation was applied as needed. Three plants per plot were selected at random in each plot and the total number of clusters, flowers per cluster and fruit set per cluster were counted on 21 October. Fruit set was calculated as the number of fruit or enlarged pedicels divided by flower number. The three plants were cut and separated into stems, leaves and fruits, and weights of each component were measured. Dry weights were determined after stems and leaves were oven dried for four days at 60°C. Twenty mature fruits per plot were taken for analysis of color, pH, and solids contents. Statistical analyses were performed using Statistical Analysis System (SAS). Percent heterosis was determined in two ways: $(F_1 - MP)/MP \times 100$ where $MP = (P1 + P2)/2$ (mid parent value); and $(F_1 - HP)/MP \times 100$ where HP is the value of the respective high parent.

Table 6. *Entries, pedigrees and whitefly-transmitted geminivirus (WTG) reactions*

Entry	Pedigree	WTG reaction[1]
FMTT847	CLN2413B x CLN2467A	R
FMTT848	CLN2418A x CLN2467A	R
PT4756	CLN2318B x CLN2123NP2	R
PT4764	PT4719A x CLN2123NP2	R
TLCV1	CLN2443B x CLN2123C	R
TLCV2	CLN2443B x CLN1621L	R
TLCV4	CLN2443B x CLN2396A	H
TLCV15	CLN2498A x CLN1621L	R
TLCV29	CLN2495C x CLN2443D	R
CLN1621L	Parental line	S
CLN2123C	Parental line	R
CLN2123NP2	Parental line	R
CLN2318B	Parental line	S
CLN2396A	Parental line	S
CLN2413B	Parental line	S
CLN2418A	Parental line	S
CLN2443B	Parental line	R
CLN2467A	Parental line	R
CLN2495C	Parental line	H
CLN2498A	Parental line	H
PT4719A	Parental line	S
CL5915-93D4-1-0-3	Heat-tolerant check inbred line	S

Transplanted 15 August 2002 at AVRDC
[1]R = resistant, H= segregating, and S= susceptible

Mean maximum/minimum temperatures during fruit set were 32.2°C/22.9°C, which are optimal for tomato fruit set. Almost all F_1 hybrids showed heterosis for marketable yield over their high parents, ranging from 109% (TLCV15) to –1% (TLCV1) (Tables 7, 8). Average yield of all hybrids was 21.0 t/ha compared to an average of 12.8 t/ha for the inbred lines. Average heterosis over the HP for yield was 42% and 70% above the MP value. Heterosis over the MP for fruit set percent was noted in seven of nine hybrids with an average value of 41%. Six of nine hybrids demonstrated heterosis over the MP value for fruit weight, ranging from –8% (TLCV15) to 40% (FMTT848), and five hybrids showed heterosis over the HP value. Average heterosis above the MP for fruit weight was 9%.

Yield is the product of fruit number per plant and weight per fruit. Four of the high yielding hybrids in the study, TLCV15, TLCV2, TLCV29, and PT4756, demonstrated heterosis over their MP values for fruit set and fruit number but only in TLCV2 did we also find heterosis for fruit weight over the MP value; fruit weight of the other three hybrids fell below their respective MP values. In contrast to these four hybrids, FMTT847 produced fruit larger than either of its parents but fruit set and fruit number were below MP. This would indicate that heterosis for yield can arise from increases in different yield components. It is noteworthy that several of the outstanding hybrids were crosses of a small-fruited, heat-tolerant parent such as CLN1621L and a larger-fruited parent with geminivirus resistance. Inclusion of at least one heat-tolerant parent is important in obtaining high yields in the summer. Geminivirus resistance was expressed in those hybrids with one resistant parent, indicating dominance gene action for resistance. With the exception of TLCV2 and PT4764, all hybrids produced less vegetative dry matter than their parents, indicating that hybrids shifted dry matter to reproductive tissue at the expense of leaves and stems. On average, hybrids yielded more than inbred lines and development of hybrids targeted for the summer may increase yields under high temperatures compared to inbred line cultivars. However, among the hybrids in this study only TLCV15 yielded significantly more than the best inbred, CLN1621L. Consequently there is also potential to develop high yielding inbred lines for farmers although obtaining both high yield and large fruit size remains elusive.

Table 7. *Yield and horticultural characters of F_1 hybrids and parents for yield, yield components, and horticultural and fruit characters*

Generation	Entry	Days to flower[1]	Days to maturity[1]	Fruit weight (g)	Fruit set (%)	Fruit no./ plant	Marketable yield (t/ha)	Dry weight (g)	Fresh weight (g)	Solids (°Brix)	Color[2]
F_1	FMTT847	52	99	101	24.2	36	21.0	136	569	4.6	1.82
P1	CLN2413B	52	104	85	18.2	37	15.0	161	745	4.8	1.76
P2	CLN2467A	49	96	64	35.6	46	11.7	147	810	4.9	1.97
F_1	FMTT848	54	100	83	27.6	37	16.9	116	417	4.6	1.73
P1	CLN2418A	54	108	55	23.7	49	12.6	99	360	4.3	1.55
P2	CLN2467A	49	96	64	35.6	46	11.7	147	810	4.9	1.97
F_1	PT4756	49	103	73	21.1	53	22.7	138	707	5.0	1.97
P1	CLN2318B	57	119	87	22.7	34	9.9	163	668	5.2	1.83
P2	CLN2123NP2	49	108	71	12.3	58	14.2	149	680	4.7	1.82
F_1	PT4764	48	105	65	19.7	55	16.9	188	648	5.0	1.81
P1	PT4719A	52	132	61	7.3	20	3.4	171	1014	4.4	1.29
P2	CLN2123NP2	49	108	71	12.3	58	14.2	149	680	4.7	1.82
F_1	TLCV1	48	105	62	17.5	53	15.1	136	682	5.1	1.69
P1	CLN2443B	48	110	59	12.5	39	9.5	162	841	5.3	1.63
P2	CLN2123C	48	106	63	14.3	67	15.2	156	833	5.0	1.79
F_1	TLCV2	48	98	62	21.5	66	24.9	273	690	5.0	1.88
P1	CLN2443B	48	110	59	12.5	39	9.5	162	841	5.3	1.63
P2	CLN1621L	48	95	42	20.4	77	21.7	246	784	4.9	1.91
F_1	TLCV4	48	104	66	19.5	50	19.1	180	763	4.8	1.87
P1	CLN2443B	48	110	59	12.5	39	9.5	162	841	5.3	1.63
P2	CLN2396A	50	119	60	10.1	44	11.8	211	1109	5.2	1.73
F_1	TLCV15	48	103	69	18.6	67	30.0	171	860	5.0	2.04
P1	CLN2498A	60	122	108	9.5	38	12.0	199	1008	4.4	1.86
P2	CLN1621L	48	95	42	20.4	77	21.7	246	784	4.9	1.91
F_1	TLCV29	50	99	62	33.7	51	22.1	84	472	4.6	1.92
P1	CLN2495C	56	117	57	19.7	58	10.6	141	716	4.9	1.45
P2	CLN2443D	48	110	59	12.5	39	9.5	162	841	5.3	1.63
ck	CL5915	48	95	44	17.6	92	22.1	158	823	4.9	1.80
Mean all entries		51	107	70	19.4	51	16.3	163	736	4.8	1.77
LSD (5%)		3	4	31	5.7	17	6.1	89	260	0.61	0.24
CV (%)		3.5	2.3	27.0	17.8	19.9	22.6	33.0	21.4	7.6	8.36

Transplanted 15 August 2002 at AVRDC

[1]Days after sowing

[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than zero. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.

Table 8. *Percent heterosis of hybrids above their respective mid-parent (MP) and high-parent (HP) values for yield components and horticultural characters*

Hybrids	Days to maturity MP/HP	Fruit weight MP/HP	Fruit set MP/HP	Fruit number MP/HP	Marketable yield MP/HP	Dry weight MP/HP
FMTT847	–1/3	36/19	–10/–33	–13/–22	57/40	–11/–15
FMTT848	–2/4	40/30	–7/–23	–23/–25	39/34	–6/–21
PT4756	–9/–5	–8/–16	21/–7	14/–9	88/60	–12/–15
PT4764	–12/–3	–2/–9	101/60	40/–5	92/19	18/10
TLCV1	–3/–1	2/–2	31/22	–1/–22	22/–1	–15/–16
TLCV2	–5/3	23/5	30/5	13/–15	60/15	34/11
TLCV4	–9/–5	11/10	73/56	20/13	79/62	–3/–15
TLCV15	–5/8	–8/–36	24/–9	17/–13	78/38	–23/–31
TCLV29	–13/10	7/5	109/71	6/–12	119/109	–44/–48
Average	–7/2	9/1	41/16	8/–12	70/42	–5/–17

Transplanted 15 August 2002 at AVRDC

Application of molecular markers on tomato breeding

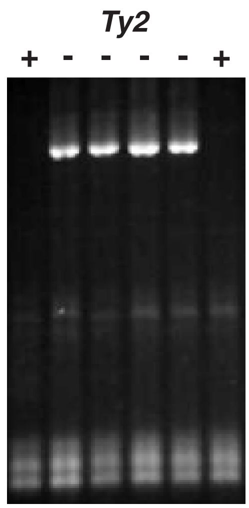
TYLCV resistance

Restricted fragment length polymorphism (RFLP) markers for *Ty*-1 (tolerant to tomato leaf curl virus [TYLCV]) and *Ty*-2 (TYLCV-resistant) genes had been routinely utilized in breeding programs to assist pyramiding these genes into our elite tomato lines. This year 17 out of 57 plants pyramided with both genes had been confirmed in BC_2F_3 pedigree. Advanced selection for plants homozygous at both loci as well as favorable traits is ongoing. Based on the analyzed data, linkage between RFLP markers and *Ty*-2 gene is satisfactory. Though RFLP markers are co-dominant and highly reliable in nature, they are technically demanding and require substantial quantities of good quality genomic DNA. These factors make screening large populations time-consuming and laborious.

Development of polymerase chain reaction (PCR)-based markers is considered an alternative in the future for technical simplicity and speed. Recently, techniques based on PCR reaction had been used in addition to or in place of traditional RFLP markers in genetic analysis. Konieczny et al. (1993) reported a simple PCR-based strategy to generate markers (i.e., cleaved amplified polymorphic sequences [CAPs]). This technique employs primers derived from cDNA sequences to provide informative anchor points on linkage maps. After PCR amplification, the amplified products were digested with a restriction endonuclease followed by agarose gel electrophoresis to reveal polymorphism within mapped genes. This approach will be further applied to develop PCR-based markers for TYLCV resistance.

Sequence information for *Ty*2 marker TG36 was downloaded from the internet. Primers were designed and tested against parents resistant (H24 and CLN21116) and susceptible (CLN399, CLN2026 and CH154) to TYLCV. A polymorphic band around 3 kb was produced for all susceptible lines but not for resistant lines (Fig. 1). This implies TG36 reveals polymorphism between R and S parents; however, the polymorphism (produced by susceptible parent) does not provide informative sequence background from the resistant parents. Testing of this primer set with segregating population also suggests no correlation of this band with TYLCV reaction.

To target other regions anchored by TG36, two extra sets of primers were synthesized along inner region of TG36 for PCR assay. Reciprocal combinations of these primer sets were tested on two resistant (H24 and CLN2116) lines and one susceptible (CLN2026) line. Most of these primer combinations produced polymorphic bands in S lines as previously described, however two combination (e.g. TG36R/TG36FB, TG36RB/TG36FB) produced co-dominant bands between R and S lines (Fig. 2). CAPs approach will be processed on these amplified bands and test their correlation with TYLCV reaction using segregating population.



From left to right: H24, BL982, CH154, CLN399, CLN2026 and CLN2116

Fig. 1. *PCR amplification of six tomato lines with* Ty2 *marker TG36 forward and reverse primers*

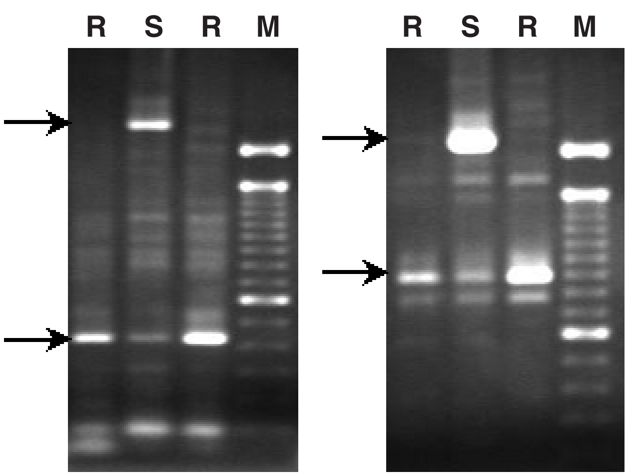


Fig. 2. *PCR amplification of Ty2 positive and negative lines with TG36R/TG36FB primer set (left) and TG36RB/TG36 F primer set (right)*

Root knot nematode resistance

CAPs marker for tomato *Mi* gene was acquired from Cornell University. To detect *Mi* gene, genomic DNA was first amplified with *Mi* forward and reverse primers followed by digestion of *Hinf*I enzyme and electrophoresis on 2% agarose gel. Resistant plants were expected to produce a single (700 bp) fragment and susceptible plants were expected to produce two fragments (480 and 220 bp). This marker had been employed to detect 18 BW-resistant processing lines derived from crossing CLN2026 with H8892, Sausalito and H9497, respectively. The results turned out to be all *Mi*-negative, including H9497, which was regarded to be nematode-resistant (Fig. 3).

The other test was conducted for TYLCV F_2 families derived from cross of CLN 2123A(*Mi*-) with *Mi*+ lines BL1302, 1303, 1305 and 1306, respectively. Twenty seeds from each of the F_2 lines were sown in the greenhouse. DNA was extracted from bulked leaves of each F_2 progenies for testing of *Mi* inheritance.

Among the 17 F_2 lines, line CLN2640-233-12 showed homozygous resistance (Fig. 4, Lane 5), eight lines were *M*i negative, seven lines carried heterozygous *Mi* (Fig. 4). Genotypes for five nematode-resistant sources were Rr, RR, RR, Rr and Rr from BL1302 to BL1306 respectively. Individual F_3 plants from CLN2640-233-12 were further analyzed to confirm the homozygosity. A total of 11 plants confirmed to be homozygous resistant will be further multiplied. Although the *Mi* marker had been analyzed in our breeding program, the good of fitness have not been confirmed with bioassay data. To use the marker confidently, the bioassay data needs to be implemented.

Genetic transformation of tomato using a bruchid-resistant gene from mungbean

Molecular biology methodology and genetic engineering technology have been used to clone pest-resistant genes from rice, soybean, cowpeas, sweet potatoes, and mungbeans, and some of these genes are being used to create pest-resistant cultivars. Plant defensins have been proposed to denote the proteins related to plant defense mechanisms. A defensin, which is a type of cysteine-rich peptide, is commonly believed to be a major line of defense against pathogenic microbes. A new definsin known as VrCRP was isolated from a bruchid-resistant isogenic line of mungbean, VC6089A, by Dr. Chen Cheng-san (Institute of Botany, Academic Sinica, ROC). VrCRP (cysteine-rich protein of *Vigna radiata*) encodes a protein of 73 amino acids, containing a 22 amino acid signal peptide and 8 cysteines. Artificial mungbean seeds containing 0.2% VrCRP completely inhibited the development of bruchid larvae. In addition, VrCRP is also a potent inhibitor of protein synthesis and arrested growth of cells from *Escherichia coli* and *Rhizoctonia solani*.

The objective of this study is to transform tomato with bruchid-resistant *VrCRP* gene and then to evaluate

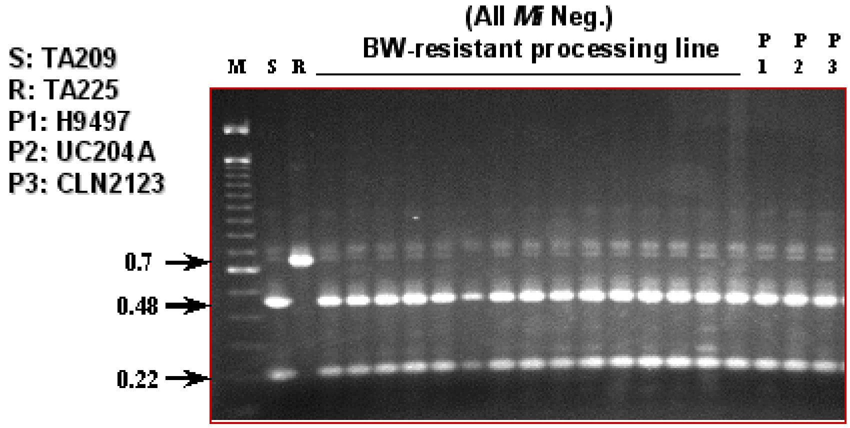


Fig. 3. Test of Mi *inheritance among bacterial wilt-resistant processing lines derived from cross between H9497, UC204A and CLN2123*

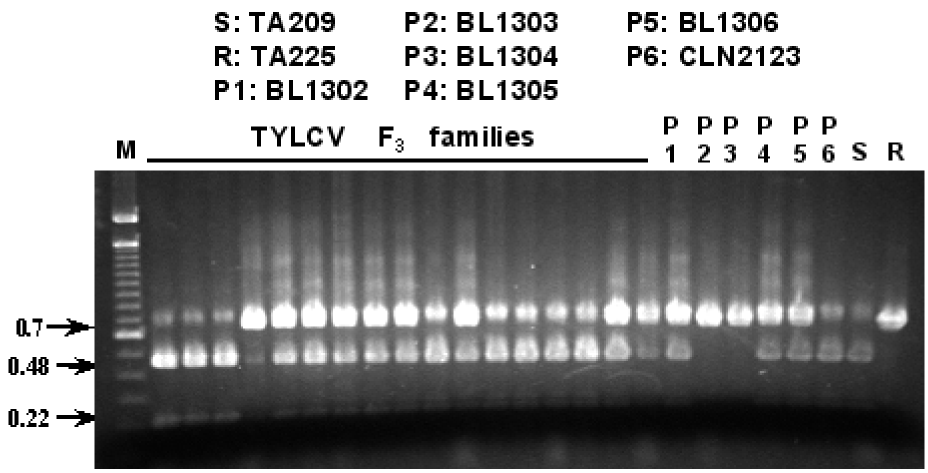


Fig. 4. Mi *gene test for TYLCV-resistant F_2 families derived from cross between CLN2123A (*Mi-*) with* Mi+ *lines BL1302, 1303, 1305, and 1306*

the progeny's capacity to resist pests and diseases. *Agrobacteria*-mediated transformation was used to transfer *VrCRP* gene in sense orientation into tomato line CLN1558A. A total of 724 cut cotyledons were infected by *Agrobacterium tumefaciens* strain LBA4404 with plasmid carrying *VrCRP* gene. Regeneration and selection procedure for transgenic tomato was as previously described, and 55 putative transgenic explants were generated.

These transgenic tomatoes were confirmed by PCR and Southern blot analysis. Plant genomic DNA isolation from young leaves followed the standard CTAB (hexadecyltrimethyl ammonium bromide) method. PCR with primers VrCRP4 (5' acctcaacaattcatcactcatgg 3') and VrCRPas4 (5' agcagtgatg ctgctatatt tatttgtg 3') was carried out to detect the presence of the *VrCRP* gene (fragment size is about 400 bp) in transgenic plants. The reaction was performed under the following conditions: two cycles of 5 min at 94°C, 1 min at 56°C, 30 sec at 72°C, then 34 cycles of 30 sec at 94°C, 30 sec at 56°C, 30 sec at 72°C, elongation at 72°C for more 5 min, and hold at 4°C. Furthermore, genomic DNA was digested with restriction enzyme *Eco* RI, and fractionated by 1% agarose gel electrophoresis. Probe was prepared by random labeling method with digoxigenin (DIG)-dUTP.

The results of PCR and Southern blot analysis of *VrCRP* gene are presented in Table 9 and Fig. 5. Forty-six out of 55 putative transgenic tomatoes were confirmed to be transgenic. All these transgenic tomatoes were self-pollinated and T_1 progenies had been obtained and sent to plant pathology units to evaluate their anti-microbial capability.

Table 9. *PCR and Southern blot analysis of* VrCRP *gene on putative transgenic tomatoes*

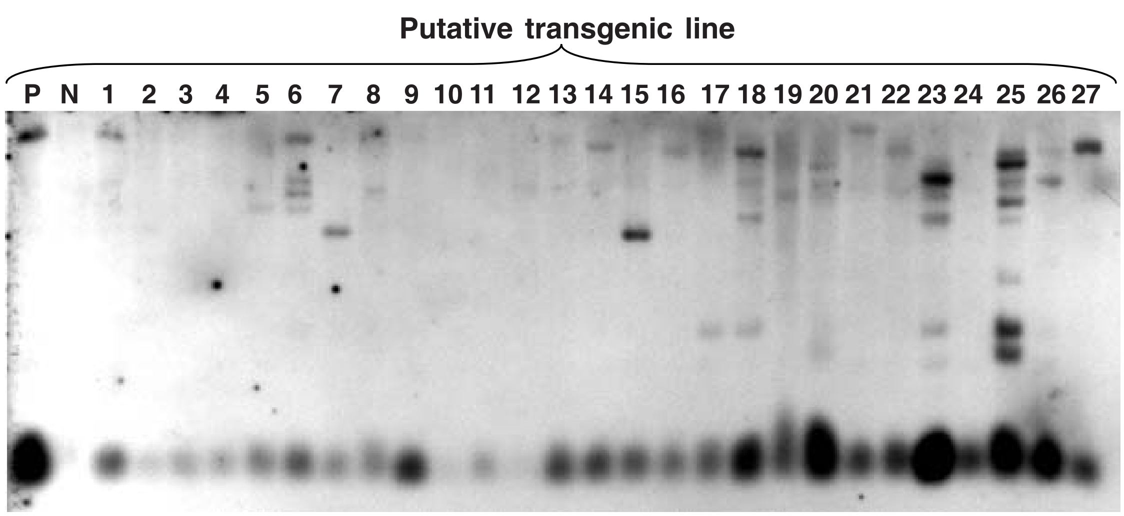
Putative transgenic tomato	PCR	Southern blot	Putative transgenic tomato	PCR	Southern blot
T_a			T_b		
2-1	+	+	1-1	+	+
3-1	+	+	3-1	-	-
4-1	+	+	4-1	+	+
5-1	+	+	4-2	+	+
6-1	+	+	5-1	+	+
7-1	+	+	6-1	-	-
7-2	-	-	7-1	+	+
8-1	+	+	8-1	-	-
9-1	+	+	9-1	+	+
9-2	+	+	9-2	+	+
9-3	+	+	9-3	+	+
9-4	+	+	9-4	+	+
10-1	+	+	10-1	+	+
11-1	-	-	10-2	+	+
12-1	+	+	11-1	+	+
14-1	+	+	11-2	-	-
15-1	+	+	12-1	-	-
16-2	-	-	13-1	+	+
17-1	+	+	13-2	+	+
18-1	+	+	14-1	+	+
18-2	+	+	15-1	+	+
19-1	-	-	19-1	+	+
20-1	+	+	20-1	+	+
20-2	+	+	21-1	+	+
20-3	+	+	22-1	+	+
21-1	+	+	23-1	+	+
23-1	+	+	Total		55
24-1	+	+			
26-1	+	+	Transgenic		46
CLN1558A	-	-	Non-transgenic		9

Tomato late blight studies

Late blight incited by *Phytophthora infestans* is the most damaging foliar and fruit disease of tomato in cool, wet environments. It is especially damaging in temperate climates and tropical highlands. The same pathogen attacks both tomato and potato, although some strains are quite specific for one crop or the other. Many physiological races have been identified in potato, but only a few have been identified in tomato, perhaps because there has been much less work on tomato late blight resistance. Physiological races in potato and tomato are unrelated.

Only a few tomato varieties are reported to possess tomato late blight resistance and they are not effective against races of the pathogen found in most locations. Therefore, AVRDC initiated a program in 1991 to identify additional sources of tomato late blight resistance in *Lycopersicon* spp., and subsequently initiated a breeding program to introgress resistance from identified sources into advanced tomato lines. Since 1991 AVRDC has been collecting isolates of *P. infestans* in Taiwan, mostly from tomato, and characterizing them by tomato race, mating type, metalaxyl sensitivity, allozyme genotype, mitochondrial haplotype, and RFLP fingerprinting (*AVRDC Report 2001*).

Early on in the AVRDC project several sources of tomato late blight resistance were identified among accessions of *L. pimpinellifolium* and *L. hirsutum.* Resistance from accession L3708 (*L. pimp.*), which confers resistance to tomato races T1 and T2, was introgressed into advanced tomato lines and



P = positive control, N = negative control

Fig. 5. *Southern blot analysis of putative transgenic plants with* VrCRP *gene*

experimental hybrids. Currently, resistance from LA1033 (*L.hirs*.), which confers resistance to tomato races T1, T2, T3, and putative T4, is being introgressed into advanced tomato lines that already carry resistance from L3708.

During the 1997–98 potato growing season, the US-11 genotype of the pathogen was detected in Taiwan for the first time (Table 11). This new genotype spread very rapidly displacing the old US-1 genotype which is thought to have been the only genotype to occur in Taiwan for many years, and perhaps since the original introduction of the pathogen. Isolates of the US-1 genotype that were obtained from tomato in Taiwan are not aggressive on potato, are sensitive to metalaxyl, and are of the A1 mating type. All 84 isolates of *P. infestans* that were collected during 2000 and 2001 are of the US-11 genotype. They are aggressive on both tomato and potato, resistant to metalaxyl, and of the A1 mating type. Evidence suggests that the US-11 genotype was introduced into Taiwan on imported 'seed' or 'table stock' potato tubers from the western part of the USA in the 1997–98 growing season. It appears to have been a single event since no other genotypes have been detected and multiple genotypes of the pathogen occur in the states from which tubers have been imported.

During 2002, 58 isolates of *P. infestans* were recovered from late blight-affected tomato and potato plants collected from numerous locations around Taiwan (Table 11). All isolates but one are of the US-11 genotype and highly resistant to metalaxyl. One of a number of isolates from tomato plants collected from the Puli area in Central Taiwan was found to be a US-1 genotype. This shows, that although the US-1 population was not detected during the previous 2 years, the US-1 genotype still exists in nature in Taiwan.

Table 11. *Numbers of US-1 and US-11 genotypes identified from 1991–2002; based on allozyme type, mtDNA haplotype, and RFLP fingerprinting*

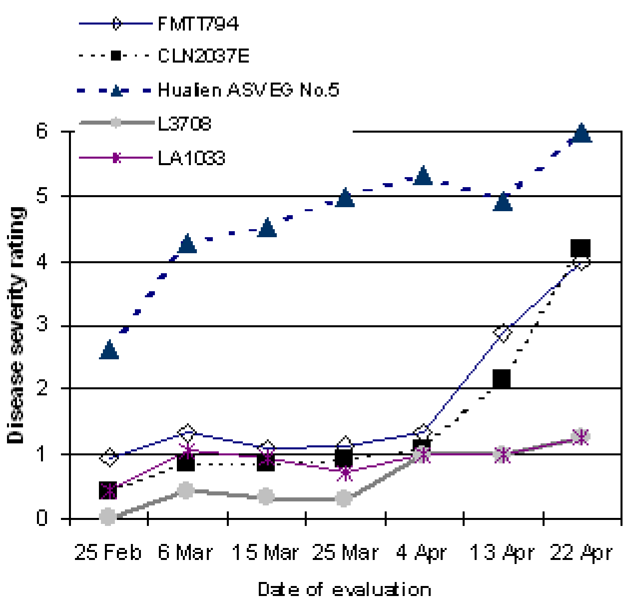
Year of isolation	Number of isolates US-1	US-11	Total
1991–97	23	0	23
1998	3	5	8
1999	1	23	24
2000	0	34	34
2001	0	50	50
2002	1	57	58

Another finding in 2002 which is of major concern was the identification of a single US-11 isolate from the Hualien area in Eastern Taiwan that produced oospores in culture. It is unclear at this time whether this is a self-fertile culture or constitutes the first record of the occurrence of an A2 mating type *P. infestans* in Taiwan. US-11 genotypes characteristically are of the A1 mating type, but there are uncomfirmed reports from other countries of the occasional occurrence of isolates that produce oospores. If the fertile culture from the Hualien area is a true A2 mating type, it is unclear whether it is the result of a recent introduction or arose spontaneously from the existing US-11 population. Of great concern is whether it is sufficiently adapted to become established in Taiwan and provide an opportunity for the pathogen to produce sexual recombinants and thereby increase the complexity of the *P. infestans* population. Considerable attention will be focused on the Hualien area during 2003 to collect a large number of isolates to determine whether self-fertile/A2 isolates can be recovered, and if so, to assess their frequency of occurrence.

Late blight-resistant accessions L3708 and LA1033 have been evaluated for their late blight reactions in the field in Taiwan each year since 1994, and similarly advanced tomato lines with resistance derived from L3708 since 1995. Resistance in these entries held up throughout the 1995 crop season and through most of the season in 1996. Toward the end of the season in 1996 a new race (T0,1,2,3) appeared that overcame L3708 and lines developed from it, but not LA1033. In 1997 this pattern was repeated, i.e., the L3708-resistance was effective until late in the season. During this period (1994–97) only US-1 genotype isolates were recovered. From 1998 to 2001, L3708, its derivatives, and LA1033 were resistant throughout the crop season. This was the period after which the US-11 genotype had been introduced and displaced the US-1 genotype in Taiwan. Thus, it was concluded that the resistant source selected against US-1 isolates was effective against the US-11 population and that its displacement of the US-1 population prevented the US-1, race T0,1,2,3 from developing in fields where it appeared previously.

During 2002 outfield plantings of L3708, advanced lines derived from L3708, and LA1033 were made in three locations—Puli area, Taichung area, and Hualien area—to monitor their late blight reactions. Resistance held up in all the resistant entries throughout the season in the Puli and Taichung areas. However, late in the season in the Hualien area, the advanced lines with resistance derived from L3708 were overcome by late blight, but not L3708 nor LA1033 (Fig. 6). The conclusion is that L3708 possesses two R genes for late blight resistance, but only one of the genes was introgressed into the advanced lines. Currently, early L3708 breeding populations are being screened to determine if any of them carry both genes for resistance.

Based on current evidence there are at least two R genes for resistance in L3708. We have revised the host genotype designation for late blight differential hosts currently being used by AVRDC for characterizing tomato races of *P. infestans* (Table 12). The change reflects the discovery of a putative *Ph*-4 gene in L3708, which changes the previous designation of the resistance gene in LA1033 from putative *Ph*-4 to putative *Ph*-5.



L3708 – resistant *L. pimp.*; LA1033 – resistant *L. hirs.*; FMTT794 and CLN2037E – F_1 and breeding line, respectively, with resistance derived from L3708; and Hualien ASVEG #5 – susceptible control.

Fig. 6. *Late blight field reactions of resistant accessions and advanced tomato lines with resistance derived from L3708*

Table 12. *Genotype designations of differential hosts used for characterization of tomato races in* Phytophthora infestans.

Host	Genotype designation	
	Previous	Current
TS 19	*Ph*+	*Ph*+
TS 33	*Ph*-1	*Ph*-1
W. Va. 700	*Ph*-1,2	*Ph*-1,2
CLN 2037	*Ph*-1,2,3	*Ph*-1,2,3
L 3708	*Ph*-1,2,3	*Ph*-1,2,3,4
LA 1033	*Ph*-1,2,3,4	*Ph*-1,2,3,4,5

Genetic diversity and population structure of *Ralstonia solanacearum* race 1 strains isolated from tomato in Thailand

North and northeast Thailand are the major tomato and hybrid tomato seed production regions of the country. Despite differences in topography, climate, elevation, and cropping systems, both regions face bacterial wilt caused by race 1 strains of *Ralstonia solanacearum* (Rs) as their major production constraint. Planting resistant varieties is an effective yet undeveloped approach in controlling tomato bacterial wilt. A good understanding on pathogen variation is a prerequisite for the successful breeding and deployment of plant resistance. Genotypic variations of Rs race 1 strains causing tomato bacterial wilt have been demonstrated in a Taiwan population. Genetic variation may be introduced into a bacterial population by mutation, recombination, and migration, and thus the pathogen population may structure in time and space to contain various genetically diverse groups.

The repetitive-polymerase chain reaction (rep-PCR) method used in this study is an efficient tool to obtain bacterial genomic fingerprints. Thus a large number of neutral markers (PCR products or bands observed in the electrophoresis) could be used for genetic analysis. In collaboration with Khon Kaen University on a project funded by BIOTECH Thailand, we examined the overall genetic diversity in the pathogen population in these two regions as well as the population structure by evaluating the differentiation degree at various geographical units. Discussions were made on the possible factors causing the observed differentiation.

A total of 257 Rs strains were isolated from wilted tomato plants in 16 fields located in north and northeast Thailand (Table 13). They were collected from the main tomato growing areas during the production seasons of 2000 and 2001. About 25 tomato plants showing typical wilting symptoms were collected randomly from each field and one strain per plant was isolated. All strains were characterized to be virulent on susceptible tomato varieties and were stored in 20% glycerol at -80°C for further studies. Biovar identities of each strain were characterized following the Hayward's method. Genomic fingerprints of each strain were obtained by rep-PCR analysis described by Louws et al. with the BOXA1R primer. Nei's index of haplotypic diversity (H) was calculated based on the formula, $H = [N/(N - 1)](1 - \Sigma f_i^2)$ with N the total number of strains and f_i the frequency of the i^{th} haplotype. To estimate genetic differentiation within the entire population, analysis of molecular variance (AMOVA) developed by Excoffier et al. was performed to test the significance on distribution of haplotypes at the different hierarchical levels.

Four types of farming systems were identified among the sampled fields, namely upland intensive mixed, lowland rice, lowland flooded, and lowland intensive (Table 13). For the lowland flooded system, fields NP2, NP3, and NK2 were located at the Mekong riverbank and may be flooded for two to four months before tomato crops are planted. Both biovar 3 and 4 strains were found in the two regions. Distribution of the two biovars seemed to be related to the farming system. Biovar 4 strains were predominant in the Mekong flooded fields and biovar 3 strains were predominant in the fields where rice or corn was the previous crop; exceptions to this were found in fields CM2 and NP3. As biovar is determined based on the utilization patterns of six carbohydrates, whether or not the distribution is related to special carbon sources present in the fields requires further studies.

A total of 48 amplified DNA fragments were scored from BOXA1R-PCR. The fragment size ranged between 250 to 4500 bp. Five DNA fragments (4300, 2800, 1300, 900, and 300 bp in size) were conserved in all strains, and 28 to 43 fragments were polymorphic when making pair-wise comparisons. Only two haplotypes were shared among the bacteria from the two regions, and one of them was predominant, encompassing 37% and 22% of the population in the north and northeast, respectively. The overall population was highly diverse genetically with an H value of 0.90 (Table 13). However, the degree of diversity varied greatly among fields. In general, the Mekong flooded fields had lower diversity, while the lowland intensive fields had higher diversity.

The results of AMOVA indicated that the Rs strains from the north and northeast regions formed a mega-population, as no significant differentiation was pointed out at the regional level (Table 14). Also, significant differentiation was observed among field (contributing 39 to 53% of the overall variation) and within field levels (contributing 40 to 59% of the overall variation) no matter whether the entire population or sub-populations of the regions or province were taken into account. This shows that micro-geographical factors like soil property and cropping system are important for shaping the pathogen population. It has been shown that soil property plays a significant role in genetic differentiation for other soil-borne bacterial species. Rs is competent for natural genetic transformation, thus genetic recombination could be important on shaping population structure. The general susceptibility of the tomato cultivars in these two regions may facilitate the maintenance of high genetic diversity of the pathogen. Among the four tomato cultivars grown in the surveyed fields, only TW4 has a degree of tolerance to bacterial wilt. However, the importance of host genotypes in the pathogen differentiation still needs to be determined.

This study provided basic information on the genetic variation of the Rs strains in the regions. However, information needs to be collected on the variation in these strains for aggressiveness and its relationship with genetic variation. Then an integrated management package can be developed with the components of host resistance and crop management.

Table 13. Information on sampled tomato fields in north and northeast Thailand and characteristics of isolated *Ralstonia solanacearum* strains including biovar, haplotype and genetic diversity index (H)

Region/Province/Field[1]	Crop sequence[2]	Tomato cultivar	Strain no.	Strain no. by biovar bv3	bv4	Haplotype no.	H[3]
All			257	150	107	37	0.90
North			83	38	45	15	0.80
Chiang Mai			46	16	30	11	0.74
CM1 (UI)	Rice-onion	Beta	13	8	5	5	0.63
CM2 (UI)	Rice	Beta	20	6	14	5	0.57
CM3 (UI)	Cabbage	Beta	13	2	11	4	0.53
Tak			37	22	15	7	0.70
TA1 (UI)	Chinese cabbage	VF134	17	2	15	5	0.66
TA2 (UI)	Corn	VF134	20	20	0	3	0.28
Northeast			174	112	62	24	0.90
Nakhon Phanom			61	22	39	6	0.56
NP1 (LR)	Rice-tobacco or tomato	Delta	20	20	0	4	0.71
NP2 (LF)	Tobacco-vegetables	Delta	15	1	14	2	0.13
NP3 (LF)	Corn	Delta	26	1	25	2	0.08
Nong Khai			41	23	18	3	0.57
NK1 (LR)	Rice	VF134	21	21	0	1	0.00
NK2 (LF)	Cucumber or hot pepper	Delta	20	2	18	3	0.48
Sakhonnakhon			72	67	5	16	0.89
SK1 (LI)	Tomato	TW4	9	9	0	4	0.69
SK2 (LI)	Corn	TW4	10	10	0	3	0.69
SK3 (LI)	Corn and papaya	TW4	12	7	5	6	0.85
SK4 (LI)	Corn	TW4	14	14	0	5	0.78
SK5 (LI)	Corn	TW4	19	19	0	3	0.20
SK6 (LI)	Cucumber	TW4	8	8	0	3	0.71

[1]UI = upland intensive mixed, LR = lowland rice, LF = lowland flooded, and LI = lowland intensive
[2]Crops before the tomato crop of each sampled field
[3]Nei's index of haplotypic diversity (H) was calculated as $H = [N/(N-1)](1 - \Sigma f_i^2)$ with N the total number of strains and f_i the frequency of the i^{th} haplotype

Table 14. Analysis of molecular variance for assessing genetic variation based on BOX-PCR DNA fingerprint of *Ralstonia solanacarum* population isolated from tomato in north and northeast Thailand

Region	Variance	CV (%)	*P*
Among region	0.01	–1.3	0.60
Among fields with region	0.24	53.1	< 0.002
Within field	0.22	48.1	< 0.002
North			
Among province	0.01	1.6	0.40
Among fields within province	0.17	39.0	< 0.0005
Within field	0.26	59.4	< 0.0005
Northeast			
Among province	0.09	17.5	0.02
Among fields within province	0.21	42.0	< 0.0005
Within field	0.20	40.5	< 0.0005
Overall population			
Among province	0.05	10.8	< 0.002
Among fields within province	0.20	42.2	< 0.002
Within field	0.22	47.0	< 0.002

Screening *Lycopersicon* species for pythium resistance

Pythium aphanidermatum is a common soil-borne plant pathogen that has a wide host range including tomato. It is very aggressive at soil temperatures above 30ºC during rainy periods or in waterlogged soils. This pathogen is a major constraint to summer-grown tomatoes causing pre- and post-emergence damping-off in the seedbed and stem and root rot of young transplants. *Pythium aphanidermatum* is often a limiting factor in hydroponics systems causing root rot and plant death. Recently, studies at AVRDC have shown that *P. aphanidermatum* plays a critical role in the well-known sudden wilt syndrome in tomato plants of all ages following flooding during summer.

Given the importance of *P. aphanidermatum* in summer tomato production and the lack of resistance in currently available tomato varieties, AVRDC initiated a project in 2002 to develop a protocol for assessing disease reactions of tomato germplasm to this pathogen in an effort to identify sources of resistance. One of the questions from the outset was whether resistance to one phase of the disease would be expressed against other phases of the disease; e.g., would resistance in the seedling stage also be expressed in older plants subjected to flooding or grown in hydroponics. Nonetheless, it was decided to begin by screening young plants of *Lycopersicon* spp. for their reactions to *P. aphanidermatum* as a first attempt to identify sources of resistance.

A total of 157 *Lycopersicon* accessions including 16 *L. cheesmanii*, 12 *L. chilense*, 16 *L. esculentum,* 25 *L. esculentum* var. *cerasiforme,* 28 *L. hirsutum*, 10 *L. parviflorum,* 25 *L. peruvianum*, and 25 *L. pimpinellifolium* were evaluated for their reactions to *P. aphanidermatum*.

A tomato isolate of *P. aphanidermatum* derived from a single zoospore was utilized to prepare inoculum for these studies. Two types of inoculum were used: zoospore suspension and infested rice grain. For zoospore production studies, *P. aphanidermatum* was grown for 24 hr on V-8 juice agar in petri plates at 28°C with continuous lighting. Agar plate cultures were diced into 0.5–1cm^2 agar blocks; sterile water was added to cover the agar blocks and the flooded plates were held at room temperature for 1 hour. Then the water was replaced and the flooded petri plates incubated for 24 hr at 30°C with continuous lighting. The floodwater was again replaced and the plates held at 20°C for 4 hr to allow zoospore formation and release. Floodwater containing zoospores was decanted and filtered through four layers of cheesecloth after which the zoospore concentration was quantified using a hemacytometer. For the infested rice grain studies, 40 cc of rice seed and 20 ml of water in 100 ml beakers were autoclaved twice. Subsequently, a 7-mm mycelial plug was transferred into each beaker and incubated at 28°C for 3 days to allow for colonization of the grain.

Tomato plants were grown, one plant per cell, in 72-cell plastic trays with 4.2 × 4.2 × 5.5cm cells filled with a commercial peat moss medium. Twenty-four plants of each accession were arranged in a RCBD with four replications of six plants each. The plants were inoculated once at the three-true leaf stage by pipeting 5 ml of 5×10^5 zoospores per ml suspension at the base of each plant. Plants surviving after 1 wk were inoculated a second time by shallow incorporation of four infested rice grains into the planting medium of each plant. Inoculated plants were held at 90–95% RH and 30ºC with a 14-hr per day light period. The planting medium was kept wet by frequent watering. Numbers of plants surviving were recorded 7 days after the second inoculation, and the percentage of surviving plants in each accession was used as the measure of resistance.

More than 75% of young plants in individual accessions of *L. hirsutum, L. peruvianum*, *L. esculentum* var. *cerasiforme, L. pimpinellifolium*, and *L. esculentum* survived inoculation with *P. aphanidermatum* (Table 15). There was a wide range of disease reactions among accessions within each species suggesting that useful sources of resistance to *P. aphanidermatum* may be available in several *Lycopersicon* spp. Twelve accessions that had >65% plant survival following inoculation are shown in Table 16. These accessions express a high level of resistance to *P. aphanidermatum* in the young plant stage, but as mentioned previously, it is not known whether plants that express resistance to one phase of the disease will be resistant to other phases. It is, however, worthy to note that accession L973B, used as the resistant control in this study, was originally identified by AVRDC as one that survives in hydroponics culture when other accessions are killed, presumably due to attack by pythium. This observation provides some encouragement that sources may be found that are resistant to more than one phase of the disease.

Table 15. *Range of reactions among accessions of* Lycopersicon *species to* Pythium aphanidermatum, *isolate Pyth4-3*

Species (subtax)[1]	No. of accessions	Plant survival (%) Min	Max	Mean
L. cheesmanii	16	0.0	48	9.5
L. chilense	12	0.0	26	8.3
L. esculentum	16	4.2	77	48.2
L. *esculentum* var. *cerasiforme*	25	4.2	85	51.3
L. hirsutum	28	0.0	96	29.7
L. parviflorum	10	0.0	21	6.3
L. peruvianum	25	0.0	88	30.2
L. pimpinellifolium	25	12.5	83	49.4

Table 16. *Tomato accessions expressing high levels of resistance in the seedling stage against* Pythium aphanidermatum, *isolate Pyth4-3*

Acc.[1]	Species (subtax)[1]	Origin[1]	Survival (%)	Expt.[2]
L1475	*L. hirsutum*	Peru	96	III
L4363	*L. hirsutum*	Ecuador	88	III
L1720	*L. peruvianum*	Peru	88	III
L3717	*L. peruvianum*	Peru	88	III
L2159	*L. esculentum* var. *cerasiforme*	Guatemala	85	I, III
L3711	*L. pimpinellifolium*	Peru	83	I
L4379	*L. hirsutum*	Peru	83	III
L3692	*L. pimpinellifolium*	Ecuador	76	I
L170	*L. esculentum* var. *cerasiforme*	Mexico	67	II
L3708	*L. pimpinellifolium*	Peru	67	II
L994	*L. esculentum* var. *cerasiforme*	Colombia	65	II
Fla MH-1	*L. esculentum* (susc ck)	USA	8 [3]	I, II, III
L973B	*L. esculentum* (resist ck)	Colombia	77 [3]	I, II, III

[1]Information and seed from AVRDC
[2]Experiments I, II, III completed on 29 August, 27 September, and 12 November 2002, respectively
[3]Average survival from three experiments

High yielding, disease-resistant chili pepper lines

The main goal of the AVRDC chili breeding program is to develop improved sources of genetic resistance to diseases, insect pests, and abiotic stresses. Advanced lines are regularly evaluated through preliminary yield trials (PYTs), which are conducted in two or more distinct growing seasons every year at AVRDC. Promising lines identified in the PYTs are evaluated more extensively through the International Chili Pepper Nursery (ICPN) trials that are conducted by cooperators around the world.

Hot pepper preliminary yield trials

In 2002, PYTs were established in spring and summer. The trials included 20 advanced lines along with two or more commercial checks and superior lines from our breeding program to keep the results in perspective. The spring trial was sown on 4 March, and transplanted into the field on 8 April 2002. Four harvests were taken at 10-day intervals during June and July. The summer planting was sown on 11 April, and transplanted into the field on 15 May 2002. Four harvests were taken at 6 to 12-day intervals from late July through August. Both trials were established using RCBD with two replications, 10 plants per plot, and the equivalent of 30,000 plants per ha density. Vegetative fresh weight data represent the total fresh weight of stems and leaves remaining following the final harvest. Assays for resistance to numerous diseases were conducted.

The warmer conditions of summer clearly reduced the productivity of all varieties (Tables 17, 18). Fruit maturity was accelerated by 7.2 ± 4.4 days (r = 0.526*), and vegetative fresh weight was only about 75% (75.4 ± 13.3%) of that produced in the spring (r = 0.764**). Summer-grown plants produced only about 90% (91.6 ± 27.0%) as many fruits as the same variety did when grown in the spring (r = 0.654**) (data not shown, as they are estimated from fruit weight and total yield data). Reduction in total fruit yield due to growing season was highly variable, but summer yields were typically 62 ± 15% of spring yields (r = 0.495*). Morphological measurements of the entries were highly correlated between the two trials: fruit length, width, and weight in the summer trial were about 75% (r = 0.947**), 80% (r = 0.918**), and 60% (r = 0.944**) of these parameters measured in the spring trial, respectively. Fruit set was the trait least affected by summer conditions, while fruit weight was reduced significantly. In some individual varieties, fruit set actually increased in the summer by 30% or more.

The most 'heat-tolerant' entry identified in this study is a selection from the Malaysian variety MC-12 (PBC308), whose summer total yield was 92% of its yield in the spring. It was the top yielding line in the summer trial, and not significantly different from the best yielder in the spring trial. While its average fruit weight declined by 33% (from 15 to 10 g) in the summer trial, the estimated number of fruit set per plant increased by 38%. This line is susceptible to anthracnose but resistant to bacterial wilt—a disease that is prominent in hot humid climates. This finding reinforces our opinion that it is possible to select for better adaptation to hot humid conditions, and that focused research and breeding under the target conditions, as are experienced in such regions as Malaysia, can be effective. This line has been used in more than fifty crosses made at AVRDC, some of which have progressed to the stage of advanced generation selections. Other lines in the 2002 Hot Pepper PYT that showed superior levels of yield stability, in that their total yields were reduced by 15% or less in the summer compared to the spring, were rated below average in yield potential.

Table 17. *Yield, plant and fruit traits, and disease reactions of inbred lines in the spring planting of the hot pepper preliminary yield trial*

Code	Name or pedigree	Total yield/ plant (g)	Days to maturity (DAS)[1]	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Vegetative fresh wt. (g/plant)	Disease resistance[2] ChiVMV (% resist. plants)	BW (% resist. plants)	Anthrac. (lesion diam)
0137-7503	Kulai/Hungarian Wax	659	114	13.2	1.7	13	856	0	100	5.9
0137-7504	Kulim/97-6880	916	110	12.8	1.6	11	1099	25	100	10.5
0137-7518	PBC971/97-6880//98-5800	905	120	10.8	1.4	8	717	0	4	9.8
0137-7522	BSS-269 F_1/ Hy Hot 3 F_1	875	117	13.6	1.8	15	1000	0	38	9.1
0137-7525	Revival F_1 selection	889	120	7.3	2.1	12	824	0	29	10.1
0137-7534	HDA832/Long Fruit*6	1140	117	14.4	2.0	17	757	0	88	9.8
0137-7535	Szechwan9/Saegochu//PP90716*5	820	116	14.6	1.4	11	608	0	71	9.4
0137-7537	HDA 248/Tit Paris*5	688	117	13.4	1.3	9	768	0	100	9.6
0137-7538	PSP-11/Jin's Delight/Kulai	880	119	11.0	2.0	14	808	8	92	–[3]
0107-7006	Friesdorfer Selex/Long Fruit	984	111	10.8	1.7	11	538	0	21	8.4
0107-7007	Jawahar 218/LongFruit	701	113	12.4	1.1	6	948	25	8	9.3
0107-7011	IR/Long Fruit	787	110	14.6	1.5	12	794	0	92	9.5
0107-7021	Kulim/HDA295//Cili Langkap*6	748	110	12.3	1.8	10	483	0	79	9.2
0107-7026	PSP-11/PBC932//Kulai	400	126	8.3	1.3	5	796	18	0	9.3
0107-7047	Szechwan9/Perennial	819	117	9.6	1.1	5	806	36	83	7.9
0107-7048	MI-2/Taiwan 83-168-1-1//MI-2	577	122	7.3	1.0	3	612	25	88	7.6
0107-7056	HDA248/CNPH703	658	122	6.1	1.2	4	918	0	8	8.4
0107-7058	Kulim/HDA248	1037	119	11.5	1.8	11	858	100	38	8.9
0107-7062	MC-12	932	114	12.6	1.8	15	474	0	79	–
9852-173 (ck)	Kulim/HDA 295 (Berke's Joy)	1170	117	9.1	1.7	9	636	0	100	5.4
9955-15 (ck)	Susan's Joy	974	114	17.5	2.4	28	830	8	4	7.5
Hy Hot F_1 (ck)	Hy Hot F_1	829	114	15.6	1.3	13	998	8	75	–
Mean		836	116	11.7	1.6	11	779			
LSD (5%)		227	5	1.2	0.2	2	220			
CV (%)		13	2	5.0	5.2	9	14			

Transplanted 8 April 2002 at AVRDC

[1]DAS: days after sowing

[2]ChiVMV = chili veinal mottle virus; BW = bacterial wilt; Anthrac. = anthracnose

[3]– = not tested

International Chili Pepper Nursery Trials

The 12th International Chili Pepper Nursery (ICPN12) was distributed to cooperating researchers in more than 15 countries during 2002. The array of 12 new entries and long-term check varieties were evaluated at AVRDC during the summer season and again in the fall/winter season. Results of the cooperator trials have not yet been received for multi-location analysis, and results of the second trial at AVRDC are likewise incomplete; both will be compiled for summary reports at a later date.

The ICPN12 trial at AVRDC was sown on 15 April 2002, transplanted 20 May, and harvested four times at 6 to12-day intervals during late July through August. This exposed the crop to the period of greatest environmental stress at our location. The trial employed a RCBD with four replications, ten plants per plot, and an equivalent of 30,000 plants per hectare density. Assays were conducted for solids, sugars, and pungency contents in fruits as well as disease reactions of plants.

Significant differences were found among trial entries in total yield, fruit weight, and capsaicin content (Table 19). Marketable yield was about 70% of total yield, a trend that produced a correlation of r = .671*. The two highest yielding lines, ICPN12#4 ('9852-173, 'Berke's Joy) and ICPN12#7 (9955-15, 'Susan's Joy'), have been reliable producers in prior ICPN trials. These lines are popular with our cooperators and are used as standard check varieties in our PYTs.

Table 18. *Yield, plant and fruit traits, and disease reactions of inbred lines in the summer planting of the hot pepper preliminary yield trial*

Code	Name or pedigree	Total yield/ plant (g)	Days to maturity[1]	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Vegetative fresh wt. (g/plant)
0137-7503	Kulai/Hungarian Wax	563	108	9.8	1.7	10	621
0137-7504	Kulim/97-6880	435	105	10.6	1.6	9	803
0137-7518	PBC971/97-6880//98-5800	312	123	8.1	1.3	6	388
0137-7522	BSS-269 F_1/ Hy Hot 3 F_1	274	109	11.1	1.7	11	606
0137-7525	Revival F_1 selection	447	115	5.6	2.0	8	806
0137-7534	HDA832/Long Fruit*6	547	111	10.1	1.9	11	544
0137-7535	Szechwan9/Saegochu//PP90716*5	527	106	12.5	1.3	8	561
0137-7537	HDA 248/Tit Paris*5	596	103	11.8	1.4	8	444
0137-7538	PSP-11/Jin's Delight/Kulai	642	115	7.9	1.8	10	730
0107-7006	Friesdorfer Selex/Long Fruit	644	108	7.8	1.5	6	415
0107-7007	Jawahar 218/LongFruit	407	108	9.7	1.1	5	624
0107-7011	IR/Long Fruit	506	108	10.8	1.5	9	634
0107-7021	Kulim/HDA295//Cili Langkap*6	463	105	8.3	1.5	6	307
0107-7026	PSP-11/PBC932//Kulai	280	111	5.2	1.2	2	633
0107-7047	Szechwan9/Perennial	514	106	7.6	1.0	3	676
0107-7048	MI-2/Taiwan 83-168-1-1//MI-2	366	109	5.7	0.9	2	451
0107-7056	HDA248/CNPH703	370	115	5.4	1.3	4	869
0107-7058	Kulim/HDA248	685	108	9.5	1.6	7	648
0107-7062	MC-12	863	111	9.1	1.9	10	468
9852-173 (ck)	Kulim/HDA 295 (Berke's Joy)	569	106	7.3	1.4	6	349
9955-15 (ck)	Susan's Joy	690	103	12.6	1.9	15	580
Hy Hot F_1 (ck)	Hy Hot F_1	588	109	12.1	1.3	9	725
Mean		513	109	9.0	1.5	8	586
LSD (5%)		216	6	0.7	0.2	1	306
CV (%)		20	3	3.9	4.9	8	25

Transplanted 15 May 2002 at AVRDC
[1]DAS: days after sowing

Most entries displayed at least partial resistance to potato virus Y (PVY) and bacterial wilt, while half of the entries showed some partial resistance to cucumber mosaic virus (CMV) and chili veinal mottle virus (ChiVMV) (Table 20). Likewise, a few lines showed some resistance to the most severe isolate of phytophthora blight, *Phytophthora capsici*, race 3. Several lines (e.g., ICPN12#7 'Susan's Joy', ICPN12#10 (Arunalu/IR), and ICPN12#11 (Bl-20/ HDA248/Szechwan) displayed some resistance to four of the six pathogens, while one line, ICPN12#2 (Szechwan10/HDA249), showed partial resistance to all screened pathogens except tomato mosaic virus (ToMV). This line is of particular interest in that it displays partial resistance to *Phytophthora capsici*, race 3. We have been screening our breeding materials with this isolate because resistance to it in seedling inoculation tests appears to signal resistance to all other stains of the pathogen.

Many assays for disease resistance resulted in intermediate percentages of plants free of symptoms, or 'resistant'. It is currently unknown whether this lack of uniformity in disease reactions represents genetic variability for factors conferring resistance, or variability in the expression of the resistance due to environmental or other non-genetic factors. Several non-symptomatic plants from the various screens have been saved, and progenies will be retested to determine if the percentage of plants resisting infection can be increased, through additional generations of targeted reselection. Evaluations for anthracnose resistance have not been completed.

Table 19. *Yield, plant and fruit traits of entries in the 12th International Chili Pepper Nursery*

Index	Entry	Name or pedigree	Total yield/ plant (g)	Mktble yield/ plant (g)	Days to maturity (DAS)[1]	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Solids (% dry matter)	Sugar (% dry wt.)	Capsaicin[2]
ICPN#1	PBC 142	Pant C-1	247	175	113	7.2	1.0	2	21.3	17.9	5.0
ICPN#2	0007-2269	Szechwan10/HDA249	439	352	108	7.7	1.3	5	15.9	30.9	0.2
ICPN#3	0007-2259	Maor/Perennial	363	259	109	6.6	1.5	6	17.8	13.5	0.1
ICPN#4	9852-173	Kulim/HDA295 (Berke's Joy)	562	534	107	8.6	1.6	8	15.3	37.5	0.3
ICPN#5	0007-2231	OP cross	389	294	104	9.5	1.7	9	15.8	26.9	1.2
ICPN#6	0007-2247	Saegochu/PBC385*5	521	330	106	11.5	1.5	8	14.9	23.6	1.8
ICPN#7	9955-15	Susan's Joy	644	461	103	12.3	2.0	15	11.9	38.9	2.8
ICPN#8	0037-7558	Tit Paris/PSP-11//2*Tit Paris	399	319	104	9.1	1.8	7	17.5	15.0	0.1
ICPN#9	0037-7544	PBC 385/HDA 248	342	280	107	8.2	1.2	5	15.5	36.2	3.3
ICPN#10	0037-7550	Arunalu/IR	488	382	106	12.6	1.1	5	20.1	27.5	0.3
ICPN#11	CCA5212	Bl-20/HDA248/Szechwan	488	255	105	8.8	1.1	4	19.5	24.4	2.6
ICPN#12	Hy Hot F_1 (ck)	Hy Hot F_1 (check)	461	117	107	12.7	1.2	8	14.7	29.1	0.8
Mean			445	313	107	9.6	1.4	7			
LSD (5%)			112	114	5	0.7	0.1	1			
CV (%)			15	22	3	4.3	4.8	12			

Transplanted 20 May 2002 at AVRDC
[1]DAS = days after sowing
[2]Capsaicin measured in mg/100 g via high performance liquid chromatography

Table 20. *Disease resistance of entries in the 12th International Chili Pepper Nursery*

			Disease resistance (% resistant plants)[1]					
Index	Entry	Name or pedigree	CMV	ChiVMV	PVY	ToMV	BW	PC3
CPN#1	PBC 142	Pant C-1	29	100	0	0	17	0
ICPN#2	0007-2269	Szechwan10/HDA249	83	17	25	0	63	38
ICPN#3	0007-2259	Maor/Perennial	8	96	100	0	25	0
ICPN#4	9852-173	Kulim/HDA295 (Berke's Joy)	0	0	100	0	100	0
ICPN#5	0007-2231	OP cross	0	0	25	0	0	0
ICPN#6	0007-2247	Saegochu/PBC385*5	0	13	100	0	96	0
ICPN#7	9955-15	Susan's Joy	58	13	100	0	46	0
ICPN#8	0037-7558	Tit Paris/PSP-11//2*Tit Paris	8	0	0	0	67	8
ICPN#9	0037-7544	PBC 385/HDA 248	0	46	0	0	92	0
ICPN#10	0037-7550	Arunalu/IR	29	0	100	0	50	8
ICPN#11	CCA5212	Bl-20/HDA248/Szechwan	92	0	100	0	88	13
ICPN#12	Hy Hot F_1 (ck)	Hy Hot F_1	87	0	100	–[2]	92	

Transplanted 20 May 2002 at AVRDC
[1]CMV = cucumber mosaic virus; ChiVMV = chili veinal mottle virus; PVY = potato virus Y; BW = bacterial wilt; PC3 = phytophthora blight, race 3
[2]– = not tested

Evaluation of solids and sugars contents reveals an inverse relationship between total solids content (measured as percentage of total fresh weight) and sugars content (measured as a percentage of dry weight), with a correlation of r = –0.633*. In pungent chilies, selection for higher dry yield by choosing individuals that have higher intrinsic dry matter content will tend to simultaneously reduce the sugars content. Thus the principal flavoring component remaining will be the capsaicin content. No significant correlation between sugars or total solids content and capsaicin content was detected in this trial set.

High yielding, disease-resistant, and heat-tolerant sweet pepper lines

The International Sweet Pepper Nursery (ISPN) trials are conducted to evaluate advanced products of the AVRDC pepper breeding program under a broad range of environments. Each of the four ISPNs have been distinct, in that approximately half of the entries have been advanced lines derived from our ongoing breeding program, and half have been accessions from diverse sources. Superior response in these ISPN trials at numerous locations identifies promising candidates for recombination in crossing blocks.

At AVRDC, we have grown each of these trials twice, under cool conditions of spring or fall and under the hot-wet conditions of the summer. Comparison of the results under contrasting conditions can serve to identify lines with above average tolerance to the more stressful conditions of the hot-wet summer and a more generally broad range of adaptation.

For several years lines have been evaluated for tolerance to heat, analyzing the whole plant performance parameters. The two major yield components affected by hot-wet conditions are the number of fruit produced and average fruit weight. Marketable yield also has a great bearing on ultimate productivity, but many non-genetic factors such as disease and pest damage influence this; consequently influences of abiotic stresses may be masked.

Fourth International Sweet Pepper Nursery

In 2002, the 4th International Sweet Pepper Nursery (ISPN4) was evaluated twice in contrasting climatic conditions. Both trials were conducted as RCBD with three replications, ten plants per plot, and an equivalent of 30,000 plants per ha. Twelve entries were used, including nine advanced lines from the AVRDC sweet pepper breeding program and three check varieties. For the spring trial, seed was sown in plug flats in a greenhouse on 4 March, and transplanted into the field on 8 April; four harvests were completed at approximately 10-day intervals, beginning on 20 June. The summer trial was similarly sown on 4 April, transplanted on 3 May, and harvested four times at approximately 12-day intervals during July and August. Fruit measurements were compiled from samples of 10 fruit taken during the first harvest that were typical of each cultivar type. Vegetative fresh weight data represent the total fresh weight of stems and leaves remaining following the final harvest. Assays for resistance to numerous diseases were conducted.

Results are presented in Tables 21–24. As has been the case in previous ISPN sets, the check cultivar Andalus F_1 presents a goal that we have not yet achieved with inbred lines. Four entries produced marketable yields statistically equivalent to Andalus, and one of them (0007-2559) was not significantly different from Andalus in marketable yield in the

Table 21. *Yield, plant and fruit traits of entries in the spring planting of the 4th International Sweet Pepper Nursery*

Index	Code	50% maturity (DAS)[1]	Marketable yield (g/plant)	Marketable fruit/ plant	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit thickness (mm)	Vegetative fresh wt. (g/plant)
ISPN4#1	9852-131	113	1088	44.1	11.7	4.1	54	4.1	648
ISPN4#2	0007-2481	114	870	13.3	10.7	7.4	149	5.1	469
ISPN4#3	0007-2530	117	745	8.1	8.5	8.6	166	5.0	561
ISPN4#4	0007-2544	116	534	9.2	8.0	7.0	105	4.9	533
ISPN4#5	0007-2559	110	1010	22.5	8.5	5.9	84	5.6	556
ISPN4#6	PBC 271	115	1014	16.7	9.2	6.9	114	5.0	711
ISPN4#7	0037-7641	117	814	27.9	14.0	4.4	64	4.0	486
ISPN4#8	0037-7655	119	1193	32.6	10.6	4.9	74	4.6	953
ISPN4#9	0037-7669	115	683	14.4	8.7	7.0	121	4.9	664
ISPN4#10	9950-5700	116	622	9.4	8.1	7.2	119	6.1	585
ISPN4#11	CCA 5081	115	952	9.8	8.3	8.3	166	6.1	717
ISPN4#12	Andalus F_1	116	1232	17.5	17.6	7.3	141	4.2	802
Mean		115	896	18.8	10.3	6.6	113	5.0	640
LSD (5%)		4	227	5.8	0.7	0.9	14	0.6	146
CV (%)		2	15	20.0	4.6	8.3	8	7.1	14

Transplanted 8 April 2002 at AVRDC

Table 22. *Yield, plant and fruit traits of entries in the summer planting of the 4th International Sweet Pepper Nursery*

Index	Code	50% maturity (DAS)[1]	Marketable yield (g/plant)	Marketable fruit/ plant	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit wall thickness (mm)	Vegetative fresh wt. (g/plant)
ISPN4#1	9852-131	102	333	20.5	8.9	3.6	33	3.0	557
ISPN4#2	0007-2481	106	206	5.2	6.5	5.7	64	3.4	252
ISPN4#3	0007-2530	105	300	6.6	6.0	7.4	96	4.0	366
ISPN4#4	0007-2544	106	302	5.9	6.8	6.9	87	4.2	243
ISPN4#5	0007-2559	100	543	15.3	6.8	5.4	54	4.1	261
ISPN4#6	PBC 271	100	411	12.5	8.1	6.9	92	4.0	446
ISPN4#7	0037-7641	106	228	8.6	11.1	4.3	47	3.3	261
ISPN4#8	0037-7655	108	304	19.4	6.6	4.1	31	3.2	524
ISPN4#9	0037-7669	106	479	9.9	7.7	5.4	99	4.3	420
ISPN4#10	9950-5700	105	351	8.2	6.8	6.5	79	3.9	141
ISPN4#11	CCA 5081	107	455	6.2	6.3	7.5	105	4.7	505
ISPN4#12	Andalus F_1	105	752	15.5	13.8	6.2	96	3.4	620
Mean		105	389	11.2	7.9	5.8	74	3.8	383
LSD (5%)		5	254	7.5	1.4	1.8	25	0.5	96
CV (%)		3	39	39.4	10.1	18.7	20	7.4	14

Transplanted 3 May 2002 at AVRDC

summer trial as well. Its average fruit size, however, is little more than one-half that of Andalus. With only one exception, experimental entries with the largest fruit size in the summer trials proved to be average or worse in marketable yield in both trials.

As in the chili pepper trials reported earlier, the more stressful conditions of summer reduced productivity of all entries in this test (Tables 21–23). Marketable yield, marketable fruit/plant, fruit size parameters, and vegetative fresh weight all declined in the summer. The time from sowing to maturity of early fruit was accelerated by an average of 10 days. The results again confirm that fruit traits are highly heritable and responsive to environmental conditions in a strongly repeatable manner, as demonstrated by the relatively small standard deviations in the entry mean values.

A comparison of results generated in two contrasting growing seasons for the same set of entries (ISPN4) illustrates our current status in selecting lines for heat tolerance. Table 23 shows the impact of the stressful summer weather on performance of the ten experimental entries in the ISPN4, relative to their performance under cooler, spring conditions. Comparisons between trials were made on a pair-wise basis for each entry, and then summarized over the entire set of entries. It is clear that our lines still lack significant levels of adaptation to compete effectively with the standard check cultivar Andalus. With regard to most of the parameters displayed, one or another trial entry performed relatively better than the check cultivar.

Table 23. *Performance of 4th International Sweet Pepper Nursery entries in summer, measured as percentage of spring performance, for yield, fruit and plant traits*

Parameter	Mean	Std. dev	Andalus F_1	Best	Worst	Correlation
Marketable yield	44.5	15.4	61.1	70.1	23.7	.439
Fruit no./plant	64.4	18.2	88.7	88.7	30.9	.830
Fruit weight	65.5	13.6	67.9	83.2	41.8	.819
Fruit length	77.4	9.1	78.3	88.5	60.9	.924
Fruit width	88.9	7.8	85.1	100.6	77.0	.918
Fruit wall thickness	77.0	7.5	81.7	87.5	64.4	.732
Vegetative fresh weight	58.6	16.2	77.3	86.0	24.1	.769

Transplanted 8 April (spring trial) and 5 May (summer trial) 2002 at AVRDC

Incorporation of disease resistance has been achieved in a few of the ISPN4 entries (Table 24). Line 0007-2530 displayed full resistance to potato virus Y (PVY), and partial resistance to race 1 of phytophthora (*Phytophthora capsici*) and several strains of bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*). Several other entries show resistance to PVY and phytophthora alone.

Sweet Pepper Preliminary Yield Trial

A similar comparison was completed in a preliminary yield trial (PYT), which included 36 entries. Two plantings of this set of materials were evaluated; each was established as a RCBD with two replications, ten plants per plot and a plant density equivalent to 30,000 plant per hectare. The spring planting was sown on 4 March, and transplanted into the field on 8 April; four harvests were taken at approximately 10-day intervals beginning on June 20. The summer trial was sown on 4 April, transplanted on 5 May, and harvested four times at 14-day intervals in July and August, the months of greatest environmental stress. About one-third of the entries in this trial were selections out of commercial hybrid bell pepper varieties, while the remainder were advanced lines from our breeding program.

Results for yield, fruit, and disease resistance traits are presented in Tables 25–28. The average number of marketable fruit per plant in summer was 16 ± 51% (ranging from –52% to 170%) higher than the same varieties grown in spring. Average fruit weights in summer declined to 55 ± 21% (ranging from 22 to 105%) of the average fruit weights in spring. Entries that showed the greatest yield stability increased the number of fruit set to compensate for losses in average fruit weight. These lines (0137-7011, 0107-7078, and 0107-7099) all produced fruit substantially smaller than the trial averages, both in spring and summer, and thus may not be immediately suitable for commercialization. In contrast, lines producing the largest fruits during the summer (e.g. 0137-7050, 0137-7040, and 0107-7094) were typically the same lines with the largest fruit in the spring trials. Of these, only 0137-7040 was able to maintain a high degree of yield stability through a dramatic increase in the number of fruit set.

Losses of economic return embodied in the reduction of total yield to marketable yield come from many sources, including fruit diseases, insect pests, sunburn, small size, and irregular shape. Yield reductions due to defects and damage amounted to 20.7 ± 7.9% in the spring trial, and 28.5 ± 9.6% in the summer trial. No varietal effect in the percentage of unmarketable fruit was discernable in this trial (r = 0.009). It was clear, however, that the plants in the summer trial were under more stress than in the spring trial. For example, a serious infestation of tomato fruitworm (*Helicoverpa armigera*) in August caused substantial damage to the summer trial.

Table 24. Disease reactions of entries of the 4th International Sweet Pepper Nursery

		Disease resistance (% resistant plants)[1]							Bacterial spot reactions[2]				
Entry	Code	CMV	ChiVMV	PVY	ToMV	BW	PC1	PC3	R1	R2	R3	R7	R8
ISPN4#1	9852-131	0	13	100	0	17	16	0	3.8	5.7	6.7	5.3	4.3
ISPN4#2	0007-2481	0	0	100	0	25	100	0	7.2	8.2	7.8	7.5	5.7
ISPN4#3	0007-2530	0	0	100	0	0	25	0	4.3	2.0	1.8	2.3	4.2
ISPN4#4	0007-2544	0	0	29	100	8	0	0	5.3	5.8	7.2	5.3	4.8
ISPN4#5	0007-2559	0	0	8	0	33	54	0	7.0	7.7	8.2	7.8	5.8
ISPN4#6	PBC 271	0	0	100	0	0	96	0	6.5	6.8	7.8	7.2	5.3
ISPN4#7	0037-7641	0	0	100	0	0	63	0	5.3	6.2	6.8	6.5	5.3
ISPN4#8	0037-7655	0	0	100	0	0	13	0	6.3	5.3	7.0	7.3	5.7
ISPN4#9	0037-7669	0	0	0	0	0	13	0	7.2	1.7	8.3	7.2	5.0
ISPN4#10	9950-5700	0	0	21	0	25	0	0	8.2	7.2	8.3	6.2	5.3
ISPN4#11	CCA 5081	0	0	0	0	21	48	0	2.0	1.5	1.7	1.7	1.5
ISPN4#12	Andalus F_1	0	0	100	0	0	32	0	8.2	8.3	8.7	8.0	5.3

[1]Screening was carried out in separate greenhouse trials using Taiwan pathogen strains; CMV = cucumber mosaic virus, ChiVMV = chili veinal mottle virus, PVY = potato virus Y; ToMV = tomato mosaic virus, BW = bacterial wilt, PC1 and PC3 = phytophthora blight, race 1 and race 3. Numbers are the percent resistant plants after inoculation.

[2]Scores are diseased leaf area according to the Barrett-Horsfall scale, and range from 0 (healthy) to 11 (100% disease). Resistant check PBC 137 scored 2.9, 1.7, 1.2, 1.0, and 1.2 for races 1,2,3,7, and 8, respectively.

Table 25. *Yield, plant and fruit traits of lines in the spring planting of the sweet pepper preliminary yield trial*

Code	50% maturity (DAS[1])	Marketable fruit/plant (g)	Marketable yield/plant (g)	Fruit length (cm)	Fruit width (cm)	Fruit wall thickness (mm)	Fruit weight (g)	Vegetative fresh wt./ plant (g)
0137-7002	122	12.6	670	8.3	5.8	4.6	77	750
0137-7004	114	10.1	624	8.9	6.4	5.4	98	653
0137-7006	113	10.6	697	7.4	6.4	4.8	98	463
0137-7011	122	10.5	547	8.0	5.6	4.0	72	516
0137-7012	116	12.8	500	6.9	6.0	3.5	64	522
0137-7013	117	8.3	760	11.1	6.4	5.4	118	724
0137-7016	114	7.8	779	18.7	5.7	4.8	151	605
0137-7017	119	16.6	834	9.7	6.0	4.1	80	786
0137-7019	120	11.6	424	6.3	5.3	4.4	54	719
0137-7021	122	11.6	648	7.3	6.0	3.6	76	534
0137-7025	120	9.8	550	9.3	5.8	4.5	86	784
0137-7032	117	10.0	732	8.8	7.1	4.7	111	472
0137-7034	116	8.0	646	7.4	7.1	5.1	100	562
0137-7040	117	7.1	769	10.6	7.4	4.8	151	759
0137-7041	113	7.0	720	8.7	7.8	5.2	140	647
0137-7042	111	8.4	798	8.7	8.1	5.0	151	680
0137-7046	114	8.9	710	8.2	7.0	5.2	107	560
0137-7048	116	9.1	643	7.5	6.5	4.4	82	524
0137-7050	117	9.4	941	8.5	7.9	5.7	141	626
0107-7077	123	16.7	546	5.1	5.1	3.2	43	476
0107-7078	116	26.0	932	7.3	5.2	3.5	49	822
0107-7085	117	18.3	642	8.0	5.2	3.5	58	572
0107-7088	117	10.8	850	17.8	6.0	4.3	121	954
0107-7094	123	6.2	498	8.0	6.7	4.2	82	483
0107-7098	110	17.8	829	8.7	5.7	5.0	71	580
0107-7099	116	16.3	543	6.2	5.4	3.0	47	473
0107-7100	123	41.1	799	7.4	3.9	3.7	33	681
0107-7104	114	14.3	736	8.3	5.7	4.8	74	561
CCA 3730-6703 (ck)	114	19.3	894	9.4	6.2	3.8	84	687
9852-131 (ck)	116	36.8	999	10.9	4.1	4.0	50	769
PBC 271 (ck)	117	16.1	980	8.7	7.1	5.7	122	848
Andalus F_1 (ck)	117	15.2	1288	17.1	6.3	4.2	142	908
Mean	117	13.9	735	9.1	6.2	4.4	92	647
LSD (5%)	5	9.4	366	0.8	0.7	0.7	21	211
CV (%)	2	33.0	24	4.3	5.4	7.2	11	16

Transplanted 8 April 2002 at AVRDC

Table 26. *Summer production as percentage of spring production in preliminary yield trials of sweet pepper*

Parameter	Mean	Std. dev	Andalus F_1	Best	Worst	Correlation
Total yield/plant	54.6	21.3	63	102.6	21.9	.412
Fruit no./plant	115.9	51	83	270	48	.753
Fruit weight	59.3	13.0	60	94.4	33.7	.776
Fruit length	74.2	8.6	76	87.6	53.6	.919
Fruit width	89.1	7.7	91	105.9	69.7	.848
Fruit wall thickness	76.3	11.0	79	105.4	56.7	.647
Vegetative fresh weight	66.0	14.4	71	111.1	66.0	.758

Spring trial transplanted on 8 April and summer trial transplanted on 5 May 2002, both at AVRDC

A comparison of the spring and summer trials is presented in Table 27. Some entries proved to be substantially superior to Andalus for one or another measure of tolerance of summer conditions, and these lines will be examined further for use in crossing blocks, ISPNs, or potential release. Tolerance to the summer conditions must, of course, be combined with superior yield potential and acceptable horticultural traits.

Progress in identifying inbred sweet pepper lines with overall performance as good as or better than Andalus has been slow, since hybrid cultivars seem to have an inherent advantage over inbreds in displaying greater stability over a range of growing conditions. Table 27 illustrates the broadly stable performance of Andalus. Although it is rarely the best performer in the trial for any single parameter, it consistently displays average or better stability across test regimes. This is an attribute that hybrids are noted for, as much as for high yield potentials.

Four lines displayed good levels of resistance to five strains of bacterial spot, and one of these (0137-7002) also showed at least partial resistance to chili veinal mottle virus and to phytophthora race 1 (Table 28). Unfortunately, it yielded no better than average in either

Table 27. *Yield, plant and fruit traits of lines in the summer planting of the sweet pepper preliminary yield trial*

Code	50% maturity (days after sowing)	Marketable fruit/plant (g)	Marketable yield/plant (g)	Fruit length (cm)	Fruit width (cm)	Fruit wall thickness (mm)	Fruit weight (g)	Vegetative fresh wt./ plant (g)
0137-7002	103	12.9	359	6.0	4.9	3.3	41	472
0137-7004	106	9.6	343	5.8	5.4	3.8	47	500
0137-7006	103	7.6	342	5.2	6.8	3.8	70	279
0137-7011	105	18.0	561	6.2	5.4	3.0	46	405
0137-7012	100	19.7	395	6.0	5.3	2.5	41	292
0137-7013	106	10.7	411	8.2	5.9	3.9	71	549
0137-7016	105	6.7	215	13.5	5.0	2.7	64	307
0137-7017	102	23.7	661	7.9	6.1	3.4	67	593
0137-7019	106	23.4	298	4.4	4.8	3.5	31	620
0137-7021	100	7.1	161	6.2	5.6	3.8	53	292
0137-7025	100	6.9	273	7.8	5.2	4.0	59	409
0137-7032	109	11.6	343	5.7	5.3	3.3	48	227
0137-7034	106	13.7	299	5.5	5.9	3.4	61	354
0137-7040	108	19.1	644	7.0	6.8	4.3	91	496
0137-7041	109	13.6	387	5.3	6.0	3.2	50	423
0137-7042	100	4.4	280	5.8	6.8	3.4	67	430
0137-7046	108	7.8	218	5.8	5.8	3.8	50	422
0137-7048	112	12.3	498	6.1	6.1	3.9	60	367
0137-7050	106	6.8	342	6.7	7.5	4.6	95	696
0107-7077	103	22.0	443	3.7	4.9	2.9	28	310
0107-7078	112	39.6	906	6.1	4.9	2.4	32	630
0107-7085	105	20.1	329	5.7	4.6	2.4	32	401
0107-7088	103	12.9	342	9.6	4.2	3.1	41	705
0107-7094	108	3.0	190	6.9	6.6	4.1	78	328
0107-7098	100	9.6	182	6.0	4.3	3.1	32	210
0107-7099	109	26.3	460	3.7	4.6	2.8	24	416
0107-7100	106	41.0	395	6.1	3.6	2.5	20	356
0107-7104	100	19.6	353	6.2	5.1	3.6	46	278
CCA 3730-6703 (ck)	100	13.6	377	6.8	5.6	2.9	48	331
9852-131 (ck)	100	24.7	308	9.2	3.8	3.0	36	457
PBC 271 (ck)	100	14.2	445	7.5	6.3	3.8	72	552
Andalus F_1 (ck)	103	12.7	806	13.1	5.7	3.3	85	641
Mean	104	15.5	393	6.7	5.5	3.4	53	430
LSD (5%)	6	12.5	314	1.4	0.9	0.6	24	191
CV (%)	3	39.0	39	10.2	8.3	8.9	22	22

Transplanted 5 May 2002 at AVRDC

trial, and was unexceptional with regard to yield stability. The remaining three lines with good resistance to bacterial spot (0137-7019, 0107-7093, and 0107-7100) carried some resistance to phytophthora, a valuable trait when grown in soils prone to flooding or waterlogging. These lines, however, produced only average yields (data on 0107-7093 were omitted due to missing plots).

Table 28. *Disease reactions and fruit traits of sweet pepper lines in preliminary yield trials grown in 2002 at AVRDC*

		Disease resistance[1] (% resistant plants)		Bacterial spot (BS) reactions[2]					Dry matter	Sugar
Entry	Name or pedigree	ChiVMV	PC1	R1	R2	R3	R7	R8	(%)	(%)
0137-7002	Boynton Bell F_1/97-7585-3	67	73	2.7	1.5	1.3	1.0	2.5	7.7	47.7
0137-7004	75-3-4-4-1-BK/BruinsmaWonder	0	0	5.8	7.7	7.5	6.8	5.7	7.5	50.7
0137-7006	75-3-4-4-1-BK/BruinsmaWonder	0	0	6.3	7.2	5.7	6.3	5.0	7.3	49.5
0137-7011	83-8022-1/97-7243-1	25	0	7.5	8.0	7.3	6.8	5.8	8.5	42.3
0137-7012	Morgold/96-9006	0	0	3.7	3.0	3.0	3.2	5.5	8.0	47.3
0137-7013	97-7515-7/BruinsmaWonder	0	0	6.7	7.8	8.8	7.8	6.2	7.1	51.1
0137-7016	Andalus F_1 selection	0	0	7.0	7.7	7.3	7.7	6.0	7.3	53.6
0137-7017	Camelot F_1 /97-7585-3//98-5143	0	0	7.0	3.6	5.2	4.8	4.3	8.1	49.7
0137-7019	Dempsey/BruinsmaWonder//98-5604	0	67	2.3	1.8	1.3	1.0	1.2	9.2	39.3
0137-7021	Jin's Gold/969006//Jin's Gold	0	0	7.5	8.0	8.0	6.7	5.3	7.5	50.4
0137-7025	HDA249/BruinsmaWonder//Jin's Gold	0	0	6.7	6.8	6.7	5.5	5.5	7.6	46.5
0137-7032	BruinsmaWonder//YoloY/34-6-7-1-1-Bk	0	0	3.7	1.8	6.8	4.3	6.0	7.6	48.6
0137-7034	BruinsmaWonder//YoloY/34-6-7-1-1-Bk	0	0	7.3	7.0	7.5	6.7	5.3	6.9	52.1
0137-7040	Commandant VIP F_1 selection	0	8	4.5	7.0	6.3	4.7	6.0	7.3	53.5
0137-7041	Golden Bell F_1 selection	0	8	5.0	4.0	4.5	3.3	5.7	7.3	56.4
0137-7042	Golden Bell F_1 selection	0	0	–[3]	–	3.6	3.2	5.5	6.3	58.0
0137-7046	Tao-Yuen Dark Red#1	0	0	7.5	7.0	8.2	6.7	5.8	7.3	55.4
0137-7048	Tao-Yuen Dark Red#1	0	0	6.8	7.0	7.8	6.5	5.8	7.7	53.5
0137-7050	Tao-Yuen Red#1	0	8	6.3	6.0	7.0	6.7	5.8	6.6	54.9
0107-7077	96-9006///T52/PBC 841//ECW-20R	0	0	6.5	6.4	8.8	6.8	5.8	9.9	40.9
0107-7078	PI201232/Line16-3///CAB/PBC840// BruinsmaWonder	0	25	6.3	–	4.5	4.6	2.8	8.6	43.0
0107-7079	PI201232/Line16-3/T52///PBC 841// BruinsmaWonder	0	0	7.0	–	9.3	7.3	5.5	9.1	37.0
0107-7084	96-9006///Jaloro/NuMexSunset// BruinsmaWonder	0	0	7.2	6.6	8.8	8.5	5.4	8.2	37.9
0107-7085	96-9006///Jaloro/NuMexSunset// BruinsmaWonder	0	0	6.3	7.4	6.8	7.0	6.2	8.9	43.9
0107-7088	Andalus F_1 selection	0	0	7.8	7.7	9.0	9.0	6.0	8.0	49.2
0107-7090	Andalus F_1 selection	0	0	7.2	7.8	8.0	7.2	6.2	8.0	52.3
0107-7093	Enterprise F_1 selection	0	25	2.2	1.5	1.7	1.2	1.0	–	–
0107-7094	Gator Belle F_1 selection	0	0	7.6	7.4	8.7	8.0	6.0	6.6	54.3
0107-7098	T52/PBC 841//ECW-20R	0	8	7.3	7.0	8.0	7.5	6.6	5.6	46.0
0107-7099	T52/PBC 841//ECW-20R	0	9	7.0	7.3	8.3	8.0	6.0	7.2	47.9
0107-7100	LongFruit/HDA201//ECW20-R	0	42	1.4	1.8	1.2	1.0	1.0	8.2	43.8
0107-7104	Red Belgian	0	0	7.2	8.7	9.3	9.2	7.0	6.0	46.4
CCA 3730-6703	97-7134-1/9852-174 (ck)	0	17	6.7	6.3	7.8	6.3	5.0	8.4	49.2
9852-131	HDA 249/Milord (ck)	0	25	6.5	6.5	7.0	6.8	5.8	6.8	47.7
PBC 271	Milord (ck)	0	92	7.8	7.7	7.5	6.8	6.0	7.5	47.7
Andalus F_1	Andalus F_1 (ck)	0	75	8.0	8.5	8.3	7.2	5.8	7.5	49.4

[1]Screening was carried out in separate greenhouse trials using Taiwan pathogen strains; ChiVMV = chili veinal mottle virus, PC1 = phytophthora blight, race 1
[2]Scores are diseased leaf area according to the Barrett-Horsfall scale, and range from 0 (healthy) to 11 (100% disease). Resistant check PBC 137 scored 2.9, 1.7, 1.2, 1.0, and 1.2 for races 1,2,3,7, and 8, respectively.
[3]– = not tested

Performance of sweet pepper hybrids in spring and summer

The production of marketable sweet peppers in the tropics is very limited due to excessive heat and numerous diseases. Heterosis within the species may be utilized to develop lines that grow vigorously, set fruit easily, develop larger fruits, and resist diseases in the tropics.

In 2002, AVRDC evaluated numerous experimental hybrids. A trial conducted in spring evaluated 95 entries and was followed by a trial in summer consisting of the 28 most promising entries of the spring trial. Two commercial hybrid varieties were included in both trials as checks. Spring trial plants were sown on 25 January and transplanted on 22 March; summer trial plants were sown on 1 April and transplanted on 3 May. Both trials were established using RCBD with two replications, 10 plants per plot, and the equivalent of 30,000 plants per ha density. Beds were covered with gray plastic mulch, and plants were staked individually. Plants were harvested three times (spring) and four times (summer) at 6 to 12-day intervals.

Summary results are presented in Table 29. In the summer planting of the experimental hybrids, all materials suffered great reductions in fruit count, yield, and fruit size when compared to the spring trial.

Combined results for yield parameters from the two trials are illustrated in Figs. 7–9. It is clear that many experimental hybrids are comparable to, or better than the check hybrids with regard to average fruit number, fruit weight, total yield, and the stability of these parameters across seasons.

The hybrid check Andalus is used in our inbred trials and consistently performs as well as or better than our advanced inbred selections. But in this evaluation of hybrids, at least eight experimental hybrids outperformed Andalus in both the spring and summer trials with regard to average fruit weight and many more were superior with regard to fruit number per plant and total yield per plant.

Correlations between the spring and summer performances in this pairing of trials are impressive (Table 30). A very strong correlation was found in average fruit weight produced by the entries grown in the two seasons. Summer-grown fruit were typically slightly less than two-thirds of the fresh weight of spring-grown fruit. This correlation suggests that lines that produce extremely large fruit under optimal conditions are likely to produce sufficiently large fruit in the hot-wet summer. Fruit count was not nearly so predictable, and the negative correlation between fruit size and fruit count (r = –.90 in the spring trial, r = –.75 in the summer trial) will constitute an ongoing constraint in progress toward improved summer productivity.

Three hybrids have been identified as particularly promising and they are receiving further evaluation and documentation for release to NARES and other partners. While matching spring performance parameters for sweet peppers during the summer has not been achieved, we are encouraged that experimental hybrids from our program compare

Table 29. *Fruit and yield characteristics of sweet pepper hybrids in two seasonal trials*

	Spring			Summer		
Hybrid	Avg fruit wt. (g)	Fruit/ plant (no.)	Total yield/ plant (g)	Avg fruit wt. (g)	Fruit/ plant (no.)	Total yield/ plant (g)
CCA4716	94	19.8	1450	83	7.3	289
CCA5002R	146	12.0	1535	136	6.5	567
CCA5040	166	15.2	1921	137	6.8	509
CCA5078	110	14.8	1450	96	6.8	446
CCA5079	80	24.4	1549	67	6.3	246
CCA5081	148	9.8	1408	154	5.1	379
CCA5081R	139	11.8	1479	170	5.3	397
CCA5089	112	19.2	1616	71	10.1	447
CCA5089R	96	18.8	1627	80	13.5	641
CCA5094	174	10.0	1333	167	6.4	479
CCA5097	108	19.3	1644	114	9.9	522
CCA5097R	115	20.8	1809	121	10.7	533
CCA5099	117	18.9	1804	83	5.6	436
CCA5117	52	39.0	1379	44	30.0	595
CCA5120	93	24.5	1660	98	11.7	485
CCA5122	108	18.1	1412	111	8.1	469
CCA5166	167	12.8	1706	124	7.0	633
CCA5171	147	17.8	1892	153	5.8	478
CCA5172	146	17.1	1876	130	8.4	588
CCA5178	84	22.3	1540	86	12.2	640
CCA5179	68	26.4	1314	65	12.6	491
CCA5180	140	18.6	1861	115	7.8	593
CCA5181	153	17.2	1830	134	8.5	700
CCA5182	120	18.2	1731	107	8.3	568
CCA5187	85	19.5	1187	71	15.7	529
CCA5188	83	22.8	1426	80	9.3	369
CCA5191	108	20.9	1593	89	20.2	599
CCA5192	72	33.3	1669	66	19.6	530
Andalus F_1 (ck)	122	15.7	1599	90	6.5	357
Veltor F_1 (ck)	132	15.5	1705	127	5.6	434
Mean	116	19.1	1600	106	9.9	498

Transplanted on 22 March (spring) and 3 May (summer) 2002 at AVRDC

Fig. 7

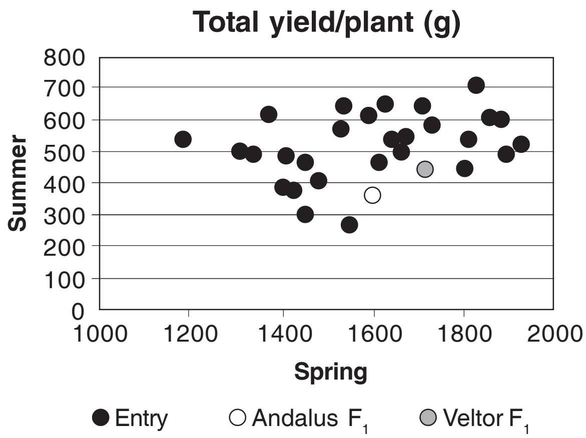


Fig. 8

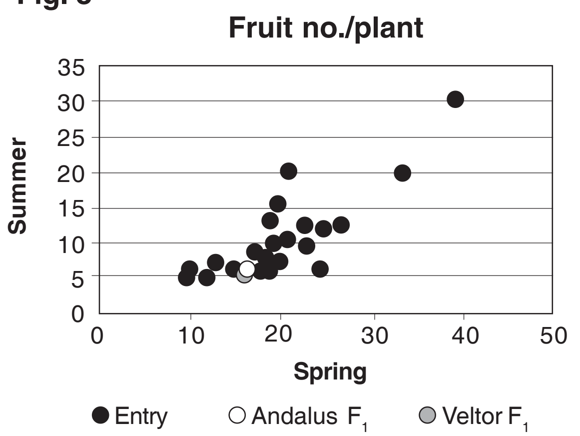
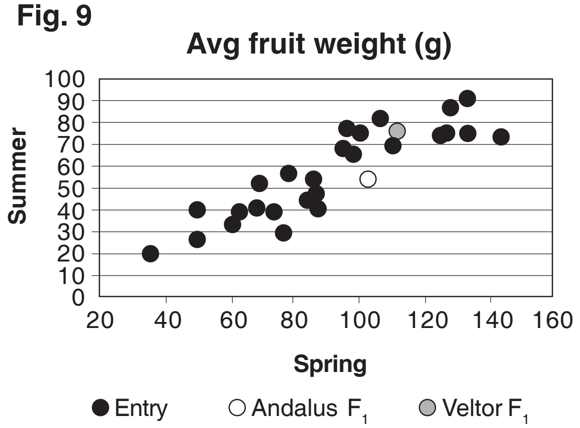


Fig. 9



Transplanted on 22 March (spring trial) and 3 May (summer trial) 2002

Figs. 7–9. *Combined results for yield parameters in spring and summer seasons for experimental hybrids and commercial hybrid checks of sweet pepper*

favorably with commercial hybrids. It remains to be seen if comparable performance can be coaxed out of advanced inbred lines, thus allowing broader and less costly dissemination of these improvements.

Table 30. *Correlations of yield parameters between spring and summer trial performances of 28 experimental and 2 commercial sweet pepper hybrids*

Parameter	Linear regression equation	Correlation coefficient
Yield/plant	Summer = Spring*0.1734 + 220.7	.31
Fruit/plant	Summer = Spring*0.7089 – 3.662	.79
Avg fruit weight	Summer = Spring*0.641 – 3.702	.89

Host resistance to pepper anthracnose

Pepper anthracnose can be incited by four species of *Colletotrichum: C. acutatum (Ca)*, *C. gloeosporiodes (Cg), C. capsic*i (Cc), and *C. coccodes*; the first three pathogens occur more frequently in warm, wet regions of the world. Although anthracnose is one of the most damaging diseases of pepper, there is no evidence that any of the current commercial pepper varieties possess resistance. For these reasons, AVRDC is engaged in identification of resistance sources, evaluation of these sources for purity of resistance, and introgression of the resistance trait into cultivated pepper (*Capsicum annuum*).

The objective of this study was to assess the scope and purity of resistance in pepper accessions, previously identified to be anthracnose-resistant, by assessing their reactions to aggressive isolates of *Ca*, *Cg*, and *Cc*. Individual plants of six accessions (*C. baccatum:* PBC81, PBC133, PBC880; and *C. chinense:* PB C932, CO4548, and CO4554) previously found to be resistant to *Ca* were selfed during 2001. Fruit from seven progeny of each line were evaluated for their reactions to *Ca*, *Cg*, and *Cc* during 2002 (sufficient fruit for the test were obtained from only two plants of accession PBC81). Up to 30 green fruit were collected from each selfed, resistant plant for inoculation. Fruit from four susceptible lines (*C. annuum:* PBC535 and C04066; and *C. chinense:* C04714 and 96085) served as susceptible checks. Up to 10 fruit from each plant were individually inoculated with *Ca*, *Cg*, and *Cc*. Inoculation was by injection of 1 µl of a 5×10^5 conidia/ml suspension into wall of each fruit using a 0.75-mm-long, 22-gauge needle. Inoculated fruit were held at

25ºC and 95–98% RH and observed for lesion development five days after inoculation. Plants were considered resistant if the average lesion size was smaller than 4 mm and susceptible if average lesion size was greater than 4 mm.

In most cases, *Ca* caused larger lesions than did *Cg* or *Cc* (Table 31). However, fruit from plants in accession C04548 developed larger lesions with *Cg* and *Cc* and fruit from two plants developed lesions more than 4 mm in diameter following inoculation with *Cg*. These data suggest that resistance to *Ca* is not in all cases indicative of resistance to *Cg* and *Cc*.

Fruit from all plants of accessions C04554, PBC880, PBC81, PBC932, and PBC133 were found to be resistant to all three pathogens (Table 31), with the exception of a single plant of C04554-8-5 which was susceptible to *Ca*. These data show that resistance in these five accessions is effective across pathogens (*Ca*, *Cg*, and *Cc*) which increases the likelihood that their resistance will be durable in the field where all three pathogens may occur. Furthermore, the data suggest that these resistance sources are not segregating for the resistance trait.

All three of the pathogen species occur on pepper in Taiwan, but Ca occurs most frequently. As stated previously, lesions caused by *Ca* on fruit of the resistant accessions were larger than those caused by *Cg* and *Cc*. Overall, *Cc* was the least aggressive pathogen on the resistant accessions as well as the controls. In fact, using the arbitrary mean lesion size of < 4 mm to separate resistance from susceptibility, the susceptible check 96085 would be considered to be resistant to *Cc*. In nature *Cc* occurs most often as a ripe fruit rot of pepper, and it is generally held that *Cc* is less aggressive than *Ca* or *Cg* on green fruit. The test reported on herein was conducted with green fruit.

Not all accessions that express resistance in the green fruit stage express resistance at the ripe fruit stage. PBC932 and PBC81 express resistance at both stages of fruit development. The AVRDC Pepper Breeding Unit has been introgressing resistance from PBC932 into advanced *C. annuum* chili lines. BC_1F_5 and BC_3F_4 lines resistant at both the green and ripe fruit stages have been identified. The BC_3F_4 lines are now being used as the resistant parent in the breeding program to: 1) develop advanced anthracnose-resistant chili and sweet pepper lines, 2) generate populations for inheritance of resistance studies, and 3) develop molecular markers for use in marker-assisted breeding for anthracnose resistance.

Table 31. *Reactions of mature green fruit from individual pepper plants to anthracnose pathogens; single plants were derived from accessions previously identified as resistant to* C. acutatum

Entry	Mean lesion diameter		
	C.acutatum	*C.gloeosporiodes*	*C.capsici*
PBC133-2-1	0.7	0.6	0.8
-2-2	2.4	2.5	2.0
-2-3	1.8	1.3	1.5
-2-4	1.6	3.0	1.5
-2-5	3.1	0.7	0.7
-2-6	2.7	1.2	1.2
-2-7	3.2	1.3	0.8
PBC880-3-1	2.4	2.1	1.2
-3-2	3.2	1.5	1.4
-3-3	2.1	2.0	2
-3-4	2.7	1.5	1.9
-3-5	2.4	1.4	2.1
-3-6	1.4	2.7	1.5
-3-7	1.3	1.3	1.1
PBC81 -7-1	1.4	1.2	0.3
-7-2	1.3	0.3	0.2
PBC932-6-1	1.7	0.2	0.2
-6-2	1.1	0.3	0.3
-6-3	1.5	0.6	0.5
-6-4	1.4	0.5	0.4
-6-5	0.8	0.3	0.2
-6-6	0.9	0.1	0.2
-6-7	1.5	0.0	0.0
CO4548-4-1	0.6	3.1	2.0
-4-2	0.9	4.2	2.2
-4-3	1.1	2.5	1.5
-4-4	1.1	3.6	3.0
-4-5	1.9	4.9	2.1
-4-6	1.4	1.7	1.5
-4-7	0.9	2.8	1.3
CO4554-8-1	1.7	0.4	0.2
-8-2	3.3	0.5	0.3
-8-3	3.4	0.7	0.5
-8-4	4.2	1.6	0.8
-8-5	2.8	0.4	0.6
-8-6	1.7	0.8	0.6
-8-7	2.3	1.0	0.5
Submean	1.9	1.5	1.0
PBC535 (*C. annu* ck)	9.5	5.8	5.5
CO4714(*C. chin* ck)	9.0	6.9	5.0
96085(*C. chin* ck)	6.1	4.2	3.0
CO4066(*C. annu* ck)	8.1	5.9	4.4
Submean	8.2	5.7	4.5
Overall mean	2.5	1.9	1.4

ChiVMV resistance identified and characterized

Chili veinal mottle virus (ChiVMV) is the most important virus of peppers (*Capsicum* spp.) grown in tropical and subtropical Asia. It is present in 10 of 11 surveyed countries in the region. Yields of infected plants may be reduced as much as 100%.

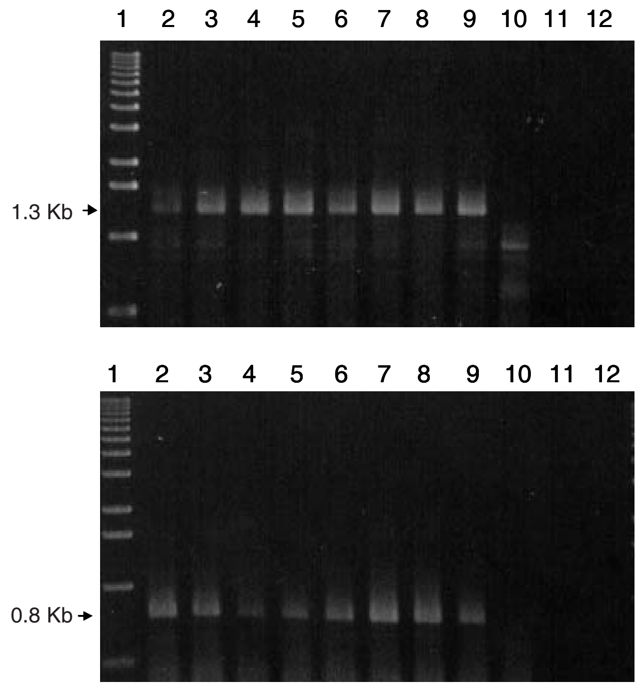
Eight ChiVMV isolates: P1037, P3380, P3389, P714, P3488, P3525, P3215, and P3384, have been obtained from peppers in Taiwan through three single local lesion transfers on *Nicotiana tabacum* var. *White Burley*. Isolates P1037, P3380 and P3389 originated from Tainan, P714 from Yunlin, P3488 and P3525 from Hualian, P3215 and P3384 from Pingtung counties. Fourteen *Capsicum* lines were selected as differential hosts for possible strain differentiation. Based on the reaction on these hosts, these ChiVMV isolates could be grouped into four strains (Table 32).

For molecular identification, the viral RNAs were extracted by Rneasy Plant Mini Kit, Qiagen, and amplified by reverse transcription-polymerase chain reaction (RT-PCR) using two previously described primer pairs: primer pair 1, Oligo(dT)/CVMV-1037Pol, which amplifies the whole ChiVMV coat protein and the 3' end nontranslated region (NTR), producing a 1.3 kb DNA fragment; and primer pair 2, Oligo(dT)/Poty3, which amplifies part of the coat protein and the 3' end NTR, producing a 0.8 kb DNA fragment (Figs. 10, 11). The amplification products of the Taiwan ChiVMV isolates are shown in Fig. 10. The RT-PCR products of five ChiVMV isolates (P3488, P3215, P3380, P3384, P714) amplified by primer pair 1 were cloned and sequenced. Sequence comparisons show that the sequences of the five ChiVMV strains were highly homologous showing >99% nucleotide sequence identities with each other. However, alignment of the five Taiwan ChiVMV sequences with ChiVMV from Thailand (GenBank Assc. No. U72193) showed only 90% nucleotide sequence homology (Fig. 12).

Table 32. *Reaction of Taiwan chili veinal mottle virus (ChiVMV) isolates on selected* Capsicum *lines*

	Isolates			
Capsicum lines	P1037, P3380	P3389	P714, P3525	P3215, P3384, P3488
VC16, VC58, VC160, VC241, VC255, C00265, PBC521	R[1]	R	R	R
VC41	R	R	R	S
PBC522, PBC524, C01664	R	R	S	S
VC232, PBC365	R	S	S	S

[1]R = resistant (0% infection: no symptoms and double antibody sandwich-enzyme-linked immunosorbent assay (DAS-ELISA) negative, and S = susceptible (80-100% infection).



Lane 1: 1 Kb ladder maker; Lane 2-9: RT-PCR products of pepper infected by P3525, P3215, P1037, P3389, P3384, P714, P3488, and P3380; Lane 10: RT-PCR products of healthy pepper; Lane 11: water control of cDNA synthesis; Lane 12: water control of PCR.

Fig 10. *Amplified RT-PCR products using Oligo(dT)/CVMV-1037pol (A), and Oligo(dT)/Poty (B) primer pairs*

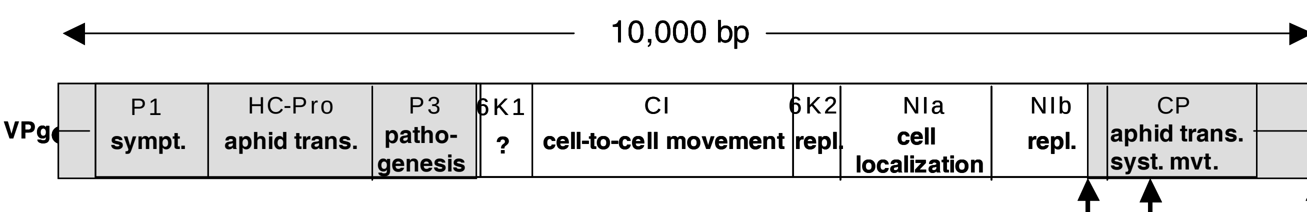


Fig. 11. *The genomic scheme of ChiVMV*

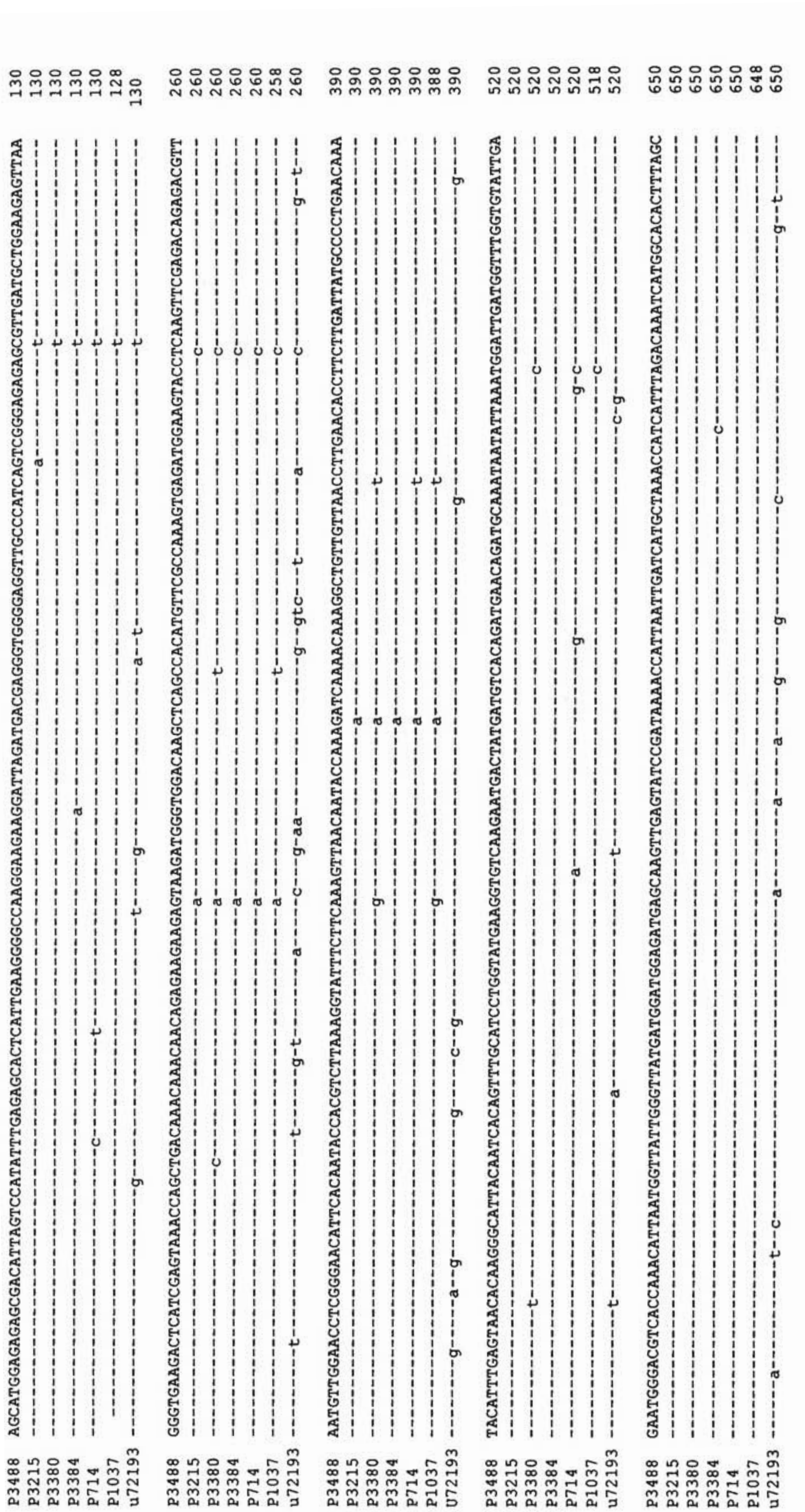


Fig. 12. *Nucleotide sequence alignments of coat protein and 3' non-translated region of five Taiwan and one Thailand (U72193) chili veinal motle virus(ChiVMV) strains*

```
P3488   AACCTTGCTGAAGCGTACATTGAGAAGCGCAACTCTGAGAAGCCATATATGCCAAGATATGGGCTTCAAAGAAACCTTACCGATATGTCATTAGCGCGATATGCTTTCGATTTCTATGAAATGACATCGA   780
P3215   ----------------------------------------------------------------------------------------------------------------------------------   780
P3380   ----------------------------------------------------------------------------------------------------------------------------------   780
P3384   ----------------------------------------------------------------------------------------------------------------------------------   780
P714    ----------------------------------------------------------------------------------------------------------------------------------   780
P1037   ----------------------------------------------------------------------------------------------------------------------------------   778
u72193  --t-----------------------------t-----------t------------------------c------------------------------------------------------------   780

P3488   AAACTCCCGTTCGAGCTCGAGAAGCACACATTCAGATGAAGGCAGCCGCATTACGTGGTGTCAACAACAGGATGTTCGGACTGGACGGTAGGGTAGGAACACAGGAGGAGGACACCGAACGCCACACAGC   910
P3215   ------------------------------------------------------------------------------------------------------------------------a---------   910
P3380   ----------------------------------------------------------------------------------------------------------------------------------   910
P3384   --------------------------------------------------------------------------------------------------g-------------------------------   910
P714    ----------------------------------------------------------------------------------------------------------------------------------   910
P1037   ----------------------------------------------------------------------------------------------------------------------------------   908
u72193  -------------------t--------------a-----a--g--t--------c----ct-g---------------------------------c--------a--------------a--t-----   910

P3488   AGAGGATGTGAATAGAAATATGCACAACTTGCTGGGTGTTCGTGGATTGTAACAT.CTTCAGCTTTTAACTAGTAATAAGTAACATATTGTAGTATATGTAACTTGGTTTATGTTGTCAATCATGCATAT   1039
P3215   -------------------------------------------------------.--------------------------------------------------------------------------   1039
P3380   -------------------------------------------------------.-----------------------------------------------------------a--g-----------   1039
P3384   -------------------------------------------------------.--------------------------------------------------------------g-----------   1039
P714    -------------------------------------------------------.--------------------------------------------------------------g-----------   1039
P1037   -------------------------------------------------------.--------------------------------------------------------------------------   1037
u72193  ---------a------------------c-------c-----g---------tccg-----a-------------g-ggac--t-------------------------------a--------------   1040

P3488   TCTTCAGTGTGGTTCCCACCATAAGTTATGTATGCTTGGTTTCATACTACTTTATATATATGTTA.TTTAGTACTCTTTATCTAGGTAACTGTGTACCCCCGCCCATTCTAGCGTGGTTCCCACC...TT   1165
P3215   -----------------------------------------------------------------.-----------------------------------------------------------...--   1165
P3380   -----------------------------------------------------------------.-----------------------------------------------------------...--   1165
P3384   -----------------------------------------------------------------.-----------------------------------------------------------...--   1165
P714    ---------------------------------------------------------g-------.-----------------------------------------------------------...--   1165
P1037   -----------------------------------------------------------------.-----------------------------------------------------------...--   1163
u72193  ---------.---------------g-----g-----------------------------a--gg------------------a---g-------t------------.-------c-t-----cct--   1168

P3488   AAT.AGAATGGAGCAACAAAGACTATTGTTATGGTTTATGGAGGTGACTCTGTGGGTCGGTAAACTGTTCAATAGTTGGCGTT   1247
P3215   ---.-------------------------------------------------------------------------------   1247
P3380   ---.-------------------------------------------------------------------------------   1247
P3384   ---.-------------------------------------------------------------------------------   1247
P714    ---.-------------------------------------------------------------------------------   1247
P1037   ---.------------------------------------------------------------------------------c   1245
u72193  -tgg-------t---------------------aacc---c------t------aa---t-gg-t-------------ca--   1250
```

Based on the above results, the CP and 3' end NTR region is not suitable to distinguish the Taiwan ChiVMV strains. However, it may be possible to distinguish the Thailand strain from Taiwan strains by specific primers, selected from the heterogeneous region (1023 to 1054 nt). Another part of the ChiVMV genome region, namely the 5' end to P3 region (plant pathogenicity) is being tested now to find greater genomic variation region among the Taiwan strains. The cloning and sequencing is in progress.

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

Knowledge of the genetic diversity of begomoviruses infecting solanaceous crops and common weeds in Asia is important for the implementation of efficient breeding programs and effective integrated pest management (IPM) strategies. This report summarizes surveys and characterization of begomoviruses infecting solanaceous crops, cucurbits, and weeds in selected countries in Asia.

Fresh leaf samples from plants showing symptoms typical of begomovirus infection (e.g., vein clearing, yellowing, curling, and blistering of leaves and upright terminal shoots, and general plant stunting) were collected, squashed on nylon membranes and tested by nucleic acid hybridization (NAH) using digoxigenin-labeled probes of approximately 1.4-kb length. Some fresh and dried leaf samples were also processed by polymerase chain reaction (PCR) using the begomovirus-specific degenerate primer pair PAL1v1978/PAR1c715, which amplifies the top part (approximately 1.4 kb) of DNA-A of whitefly-transmitted begomoviruses. A 1.4-kb band following electrophoresis was evidence that the sample contained a begomovirus. For molecular characterization, specific primers were designed based on the sequences of the 1.4-kb DNA products in order to obtain the bottom parts of DNA-A. For the detection of DNA-B, two degenerate primer pairs were used, namely DNABLC1/DNABLV2 and DNABLC2/DNABLV2.

A Basic Local Alignment Search Tool (BLAST) analysis was conducted with sequences of all begomoviruses available in the GenBank database of the U.S. National Center for Biotechnology Information (NCBI). Further sequence comparisons were performed individually by using DNAMAN software.

The results confirm that tomato is infected by begomoviruses in many countries of Asia and in the Dominican Republic (Table 33). Peppers in Cambodia and Vietnam, as well as *Ageratum* sp. in Vietnam were also found infected by begomoviruses.

Sixteen begomoviruses were cloned and sequenced in 2002 (Table 34), including begomoviruses infecting tomatoes, pumpkin, eggplant and cucurbits from Asian countries. Begomoviruses are considered distinct and new if their sequences have less than 90% identity with any other geminivirus.

The virus associated with tomato leaf curl disease from Bangalore, Karnataka state, India had 97% sequence identity with *Croton yellow vein India virus* (AJ50777) and should be considered the same virus species. Viruses from the weed species *Croton* sp. and *Parthenium* sp. from the same area had sequence identities of 94% and 90% respectively with *Tomato leaf curl Karnataka virus* (U38239), suggesting that they may be strains of the latter. However, another begomovirus from Karnataka infecting the *Euphorbia*

Table 33. *Geminivirus survey of major solanaceous crops and weeds using NAH and/or PCR, 2002*

Country	Host	Method	No. samples tested	Positive no. (%)
Bangladesh	Tomato	N_1[1]	129	44 (34)
Cambodia	Tomato	P	9	3 (33)
	Pepper	P	6	5 (83)
Dominican Rep	Tomato	N_2	44	28 (64)
	Pepper	N_2	84	0 (0)
Indonesia	Tomato	P	20	1 (5)
Laos	Tomato	P	2	2 (100)
Myanmar	Tomato	P	1	1 (100)
	Weed[2]	P	2	0 (0)
Philippines	Tomato	P	6	6 (100)
Taiwan	Tomato	P	80	80 (100)
	Eggplant	P	1	0 (0)
	Weed[3]	P	14	0 0)
Vietnam	Tomato	P	11	5 (45)
	Pepper	P	5	3 (60)
	Weed[4]	P	4	1 (25)
Total	Tomato		302	167 (55)
	Pepper		95	8 (8)
	Weed		20	1 (5)

[1]NAH (N) = Nucleic acid hybridization; N_1 = 1.4 kb probe derived from Tomato leaf curl Bangladesh virus; N_2 = 1.4 kb probe derived from Tomato yellow leaf curl virus–[Egypt]; PCR (P) = polymerase chain reaction using the degenerate primer pair PAL1v1978/PAR1c715

[2]*Ageratum conyzoides, Heliotropium indicum*

[3]*Solanum nigrum, Euphorbia hirta, Bidens pilosa*

[4]*Ageratum* sp., *Bidens pilosa*

weed species had only 88% sequence identity with the *Tomato leaf curl Karnataka virus* and is most likely a distinct geminivirus species.

The two tomato leaf curl virus isolates from Islamabad (AF448059, AY150304) and Dargai (AF448058, AY150305) in Pakistan had 96% sequence identity in their DNA-A and 88% in their DNA-B. Both isolates had 95% or higher DNA-A sequence identity with *Tomato leaf curl New Delhi virus*-[Severe] (U15015) from northern India, suggesting they are very closely related strains of the same virus. However, these two Pakistan tomato begomovirus isolates were unrelated to the Pakistan chili leaf curl virus (AF336806), with which they share less than 75% sequence identity.

The viruses associated with eggplant yellow mosaic disease in Thailand (AF511530, AF511527) and tomato yellow leaf curl disease in Thailand (AF511529, AF511528) have high sequence identities of 99% in their DNA-A and of 98% in their DNA-B. Based on the high sequence identities in both DNA-A and DNA-B, these two virus isolates are most certainly one and the same species.

Based on sequence comparisons of begomovirus available in the GenBank database, three distinct begomoviruses were identified, including one from tomato in Laos and two from weeds, i.e., *Euphorbia* sp. from India and *Ageratum* sp. from Taiwan.

It is interesting to note that the bipartite begomoviruses in tomato samples from Islamabad and Vietnam and the begomovirus in a cucurbit sample from Vietnam all have more than 90% DNA-A sequence identities with other begomoviruses, namely *Tomato leaf curl New Delhi Virus*-[Severe], *Tomato yellow leaf curl Thailand virus*, and *Squash leaf curl China virus*, respectively; however, their DNA-B components have less than 90% sequence identity with the respective viruses. The reason for that is not yet understood.

The results of this year's research further confirm the great genetic diversity of begomovirus in solanaceous crops, other crops, and weeds in Asia.

Table 34. *DNA sequence BLAST analysis of begomoviruses of crops and weeds cloned and sequenced in 2002 at AVRDC*

Country / location	Crop	Clone	DNA type	GenBank accession	Virus with highest sequence similarity (GenBank accession)	Seq. sim. (%)
India (Bangalore, Karnataka)	Tomato	I9	A		*Croton yellow vein India virus* (AJ50777)	97
India (Hebbal, Karnataka)	*Croton* sp.	IMCb	A		*Tomato leaf curl Karnataka virus (*U38239)	94
India (Hebbal, Karnataka)	*Euphorbia* sp.	IMEg	A		*Tomato leaf curl Karnataka virus* (U38239)	88
India (Hebbal, Karnataka)	*Parthenium* sp.	IMPh	A		*Tomato leaf curl Karnataka virus* (U38239)	90
Laos (Savannakhet)	*Ageratum* sp.	L24	A		*Ageratum yellow vein China virus* (AJ495813)	91
Laos (Savannakhet)	Tomato	L17-1	A		*Ageratum yellow vein China virus* (AJ495813)	84
Pakistan (Dargai)	Tomato	PKT5	A	AF448058	*Tomato leaf curl New Delhi virus*-[Severe] (U15015)	95
	Tomato	PKT5	B	AY150305	*Tomato leaf curl New Delhi virus*-[Severe] (U15015)	90
Pakistan (Islamabad)	Tomato	PKT1	A	AF448059	*Tomato leaf curl New Delhi virus*-[Severe] (U15015)	97
	Tomato	PKT1	B	AY150304	*Tomato leaf curl New Delhi virus*-[Severe] (U15015)	89
Taiwan (Hualien)	*Ageratum* sp.	A2	A		*Ageratum yellow vein Singapore virus* (X74516)	88
Taiwan (Hualien)	*Ageratum* sp.	A4	A		A2	95
Taiwan (Taoyuan DAIS)	*Ageratum* sp.	TA3	A		*Ageratum yellow vein Singapore virus* (X74516)	96
Taiwan (Tainan)	*Ageratum* sp.	AgSL	A		*Ageratum yellow vein Taiwan virus* (AF307861)	99
Taiwan (AVRDC)	Pumpkin	PA1	A		*Squash leaf curl China virus* (AB027465)	93
Thailand (Kanchanaburi)	Eggplant	TE02	A	AF511530	*Tomato yellow leaf curl Thailand virus* (AF511529)	99
	Eggplant	TE02	B	AF511527	*Tomato yellow leaf curl Thailand virus* (AF511528)	98
Vietnam (My Tho)	Tomato	V30	A		*Tomato yellow leaf curl Thailand virus* (AF511529)	94
	Tomato	V30	B		*Tomato yellow leaf curl Thailand virus* (AF511528)	88
Vietnam (My Tho)	Cucurbit	V34	A		*Squash leaf curl China virus* (AB027465)	94
	Cucurbit	V34	B		*Tomato leaf curl New Delhi virus*-[Severe] (U15015)	82

The growing partnership between AVRDC and private seed industry

High-yielding vegetable cultivars adapted to the tropics are critically needed to boost the productivity of Asian farmers. The tomato and pepper breeding programs at the Asian Vegetable Research and Development Center (AVRDC) develop genetically improved lines with characters essential for tropical adaptation, including high temperature fruit set and yield, multiple disease resistance, and good fruit qualities. AVRDC's improved genetic materials, primarily inbred lines, are freely available to public and private institutions conditional on compliance with its Material Transfer Agreement. AVRDC has a strong tradition of working with national agriculture research systems, contributing to the release of 325 lines in 52 countries. In recent years, the rapid growth of the private seed industry in Asia has opened new opportunities for partnership.

A strong and dynamic seed industry benefits farmers. AVRDC actively supports the private seed sector by: 1) providing improved inbred lines that accelerate cultivar development; 2) sharing its disease screening protocols; 3) training persons in genetic improvement and seed production; 4) and sharing of information. About one-third of AVRDC tomato and pepper seed shipments go to the private companies, yet we know little about the fate of these materials and their impact. In 2001, we designed a survey to assess the impact of AVRDC tomato, sweet pepper, and chili pepper lines in the private seed sector and to obtain feedback on future AVRDC breeding goals. The following is a summary of the report, focusing on feedback from companies based in Asia.

The survey was sent to 85 seed companies that had received seed of AVRDC tomato, sweet pepper, or chili pepper lines anytime during 1996–2001. We received complete or partial responses from 42, of which 29 are Asian-based and 19 are members of APSA. Of the responding companies, 62% were domestically owned, 26% were subsidiaries of multinational corporations, and 12% were domestic/foreign joint ventures. Forty-four percent of the companies were established before 1980, 34% were founded between 1981 and 1990, and 22% were established in 1991 or later. Out of the 29 companies located in Asia, nine employ less than seven permanent research staff, and ten each employ 7–12 or more than 12 permanent research staff.

The survey revealed that the top reason for requesting AVRDC lines was desirable genes (cited by 36% of respondents), followed by free availability (29%), and uniformity (20%). When asked what were the most desirable genes in AVRDC material, the leading response was disease resistance (33%), followed by heat tolerance (20%), wide adaptation (17%), good fruit quality (15%), and high yield (14%).

From 1996–2001, the 29 Asian-based companies released 228 new tomato cultivars, 157 new chili pepper cultivars, and 39 new sweet pepper cultivars (Table 35). The share of releases containing AVRDC material was small, ranging from 0% in sweet pepper to 8% for tomato. This could be due to the lag time required to evaluate and incorporate AVRDC lines into new cultivars, unsuitability of AVRDC lines for direct use, the lack of research and development capacity of some seed companies, and the fact that the private sector was not a primary target of AVRDC in the past.

Very striking is the increase in cultivars with AVRDC genetic background being released by surveyed companies during 2002–2003 (Table 35). For example, about one-third of the tomato cultivars to be released by 20 surveyed Asian-based companies will contain some AVRDC genetic background. Substantial increases in the number of chili and sweet pepper cultivars containing AVRDC genetic background are also projected.

Younger companies employing relatively fewer permanent research staff will release the lion's share

Table 35. *Characterization of past and recent releases of tomato and pepper lines by Asian-based seed companies*

	1996–2001				2002–2003			
	Total	With AVRDC material		Companies using	Total	With AVRDC material		Companies using
	releases	releases	(% of total)	AVRDC materal	releases	releases	(% of total)	AVRDC material
Tomato	228	19	8.3	5	121	41	33.9	20
Chili pepper	157	8	5.1	4	84	13	15.5	11
Sweet pepper	39	0	0.0	0	47	6	12.8	5
Total	424	27	6.4	7	252	60	23.8	21

of cultivars containing AVRDC genetic background compared to older companies or those with more research staff (Fig. 13). For example with tomato, AVRDC genetic material will be in about 50% of cultivar releases of companies that are young (started after 1990) or small (less than seven permanent research staff). In contrast, AVRDC material will be in only about 27% of cultivar releases of companies that are older (started before1981) or large (more than 12 permanent research staff). Clearly, AVRDC assists young and small companies by providing adapted inbred lines that hasten development of new cultivars.

Survey participants were asked for their input in determining priorities for future AVRDC plant breeding research by indicating the three most important objectives for each crop (Table 36). Disease resistance remains a high priority for all crops, especially bacterial wilt, geminiviruses and late blight for tomato, and anthracnose and virus complexes for chili pepper and sweet pepper.

Improved fruit qualities were frequently mentioned for the three crops. Specifically for tomato, seed companies were looking for long shelf life, firmness, high lycopene and solids content, and resistance to fruit cracking and other fruit defects. For chili pepper, most desired traits were suitable pungency, good drying quality, smooth and shiny skin, and long shelf life. For sweet pepper, companies were seeking lines with superior fruit shape and size, long shelf life, superior flesh quality and flavor, as well as high vitamin and solids contents.

Surprisingly, yield was not specified as a high priority although heat tolerance is important, especially for sweet pepper. Insect resistance was not given much importance even though significant insect problems exist on all three crops; this low priority reflects the difficulties and low chances of success in breeding for insect resistance.

Table 36. *Priorities for future AVRDC research, as requested by surveyed Asian-based seed companies*

Category/trait	Tomato	Chili pepper	Sweet pepper
	(% of responses)		
Viral diseases	30	24	26
Fruit qualities	22	20	21
Bacterial diseases	22	10	10
Fungal diseases	14	26	15
Abiotic stresses	10	8	15
Yield/plant characters	2	4	10
Insects/nematode resistance	0	8	3

In conclusion, private seed companies in Asia have clearly benefited from AVRDC plant breeding research. We expect the private sector to become an even greater user of AVRDC improved genetic material in the future. Nearly all (98%) survey respondents stated that they will request AVRDC material in the future.

More than one-third of the respondents (37%) were prepared to engage with AVRDC in collaborative research. Many of these companies were small in size and felt that this collaboration would provide a window of opportunity for them, particularly if they could influence the choice of lines to be tested in trials. Nearly all companies stated that they would consider collaborative research, but security and confidentiality were often expressed as concerns.

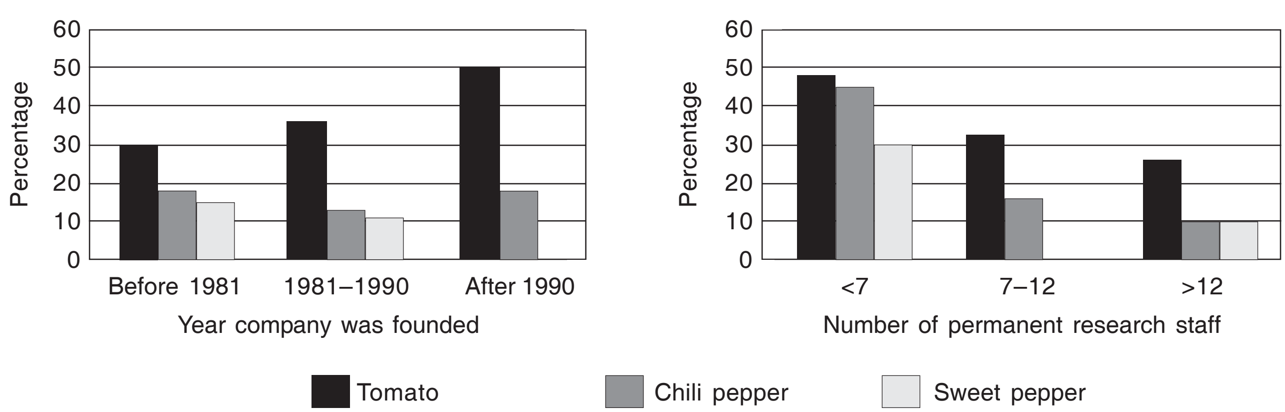


Fig. 13. *Share of releases during 2001–2003 containing AVRDC genetic material by company age and number of permanent research staff*

As funds for international agricultural research declines, AVRDC must be able to document its impact and generate funds from new sources. In this regard, more feedback from private seed companies on performance and use of AVRDC genetic material is required. Better communication between AVRDC and the private seed sector, especially through regional organizations such as Asia & Pacific Seed Association (APSA), will help direct AVRDC plant breeding research to complement and strengthen that of the private seed sector. We have no doubt that APSA members will become more involved in the work of AVRDC research, as clients and collaborators, and perhaps as financial supporters.

Genetic diversity in *Solanum nigrum* complex and its relationship with nontuberous *Solanum* species

Solanaceae is one of the most important plant families considering its great size and widespread use. The genus *Solanum* is the biggest in this family with between 1000 and 1400 species described under more than 3000 names. It consists of about 200 tuberous species and between 800 and 1200 nontuberous species. Tomato, potato, eggplant and pepper are widely grown crops, but there are a number of "not as popular but also economically important" species that belong to this genus. An example is the *Solanum nigrum* complex, popularly used as fruit and leafy vegetable in Southeast Asia and the Americas.

The section *Solanum* is one of the largest, most widespread and variable species groups of the genus *Solanum*. It is usually known as the section *Morella* and centers around the species known as the black, common or garden nightshade, *Solanum nigrum*. This weed of disturbed habitats is the type species of both the section and the genus. The species group is often referred to as the "*Solanum nigrum complex*", which has yet to be classified. Some related research has been done for species found in the Americas, Europe, India, and Australia but none so far for Southeast Asia.

Solanum nigrum is a good example of polyploid complex based on x = 12 chromosomes (Beg and Khan, 1989). In India and Australia, the '*nigrum*' complex is considered as consisting of three species: *S. americanum* (2n = 2x = 24, inflorescence umbellate; fruit shiny purplish-black with reflexed sepals); *S. nigrum* (2n = 6x = 72, inflorescence racemiform; fruit dull purplish-black with sepals adhering to the fruit); and *S. villosum* (2n = 4x = 48, fruit elliptical, very distinctive orange, orange-brown or reddish-orange fruit). It is hypothesized that the complex in Southeast Asia contains the same elements.

Taxonomically, the members of the *S. nigrum* complex are generally confusing because of their species similarity, phenotypic plasticity (change in plant form which can be caused by mowing, application of herbicides, grazing and various insect infestations), and genetic variability. Furthermore, polyploidy is frequent in the complex.

Besides the '*nigrum*' complex, several other nontuberous species are included for analysis. For instance, *S. aethiopicum and S. macrocarpon* are widely grown in the tropics of Africa, Southeast Asia and South America; *S. incanum* is an important vegetable in tropical Africa and Asia; and *S. torvum* is grown in South, Southeast, and East Asia; and *S. sisymbrifolium* is grown in South America.

The objectives of this study are to establish molecular phylogenetic relationships and genetic diversity data among seven *Solanum* species with special focus on the '*nigrum*' complex collected by AVRDC, and to eliminate duplicate collections.

Thirty-two accessions, consisting of seven *Solanum* species collected from Southeast Asia and some other countries were used for this study (Table 37). The CTAB (hexadecyltrimethyl ammonium bromide) method was followed to extract genomic DNA from young leaves of *Solanum* plants grown in greenhouse. A total of 852 10-mer random primers consisting of 548 UBC (Univ. of British Columbia) and 304 Operon (Operon Technologies, Alameda, Cal.) primers were screened for random amplified polymorphic DNA (RAPD) analysis. RAPD reactions were carried out in 25 µl volume containing 1 X buffer (10 mM Tris-HCl, pH 8.3; 50mM KCl), 3 mM MgCl2, 100 µM dNTPs, 0.2 µM primer, 1 unit *Taq* DNA polymerase and 25 ng plant genomic DNA. Amplification was performed in an Eppendorf Thermocycler (Mastercycler gradient). The thermal cycle program was five minutes at 94°C, followed by 30 seconds at 94°C, 30 seconds at 40°C, and one minute at 72°C for 40 cycles, and then further extended at 72°C for 10 minutes. RAPD products were fractionated in 1.5% agarose gel by electrophoresis at 100 V for 2 hr, and then stained with ethidium bromide. The images were then recorded by the AlphaImager 2000 (Alpha

Table 37. *Accession information of seven* Solanum *species collection in AVRDC's Genetic Resources and Seed Unit (GRSU)*

Species	Origin[1]	No.	Accessions (GRSU code)
S. americanum	Philippines (PH)	11	S00260, S00261, S00262, S00263, S00264, S00265, S00268, S00269, S00270, S00271, S00272
	Japan (JP)	2	S00861, S00862
	Tanzania (TZ)	1	S00859
	Vietnam (VN)	2	S00864, S00865
S. villosum	Bangladesh (BD)	1	S00810
	Japan	2	S00860, S00863
	Tanzania	1	S00854
S. aethiopicum	Senegal (SN)	1	S00197
	Taiwan (TW)	1	S00830
	Tanzania	1	S00831
S. incanum	Malaysia (MY)	1	S00011
	Thailand	1	S00458
	Taiwan	1	S00834
S. macrocarpon	Malaysia	1	S00052
	Philippine	1	S00274
	Tanzania	1	S00846
S. sisymbrifolium	United Kingdom (UK)	1	S00199
S. torvum	Malaysia	1	S00012
	Vietnam	1	S00852

[1] Parentheses show the designated abbreviation of countries used by GRSU

Innotech). RAPD bands were scored with 0/1 scoring method (0 as absent and 1 as present). The data matrix was employed by NTSYS-pc system and analyzed using the method SIMQUAL (similarity for qualitative data) with Jaccard's similarity coefficient. The dendrogram was constructed by UPGMA (unweighted pair-group method using arithmetic average) with the SAHN (sequential agglomerative hierarchical non-overlapping) routine to measure the genetic similarity among the tested entries.

For further understanding the representation of single plant for genetic diversity analysis, intra-accession diversity in *Solanum* species was investigated in this study. At least two plants per accession were analyzed to determine any variability within an accession. The accessions listed in Table 38 were studied using the following eight 10-mer random primers: OP-AX6, OP-AX9, OP-S11, OP-V6, OP-Y4, OP-Y20, UBC-333 and UBC-428. Besides S00262 (*S. americanum* collected from Philippines), data showed there were no polymorphic bands or few minor bands were polymorphic among individuals within the selected accession of the seven species. RAPD patterns of DNA sample of S00262 were distinctly different from those of other samples of S00262, as shown in Fig. 14. This suggested that the seeds of this accession were contaminated with other accessions. The morphological data investigated by GRSU also suggested that this sample could be S00810 (*S. villosum* collected from Bangladesh) (data not shown). The breeding system of *Solanum* is primarily autogamous with occasional outcrossing. This intra-accession study confirms the homogeneity in these crops and also indicates the representativeness of individual plant from each accession for further genetic diversity analysis. Furthermore, the RAPD marker is a useful tool for the seed purity test and certification of the seedling.

Table 38. *Accessions used in the intra-accession diversity analysis*

Species	Accession (GRSU code)	Origin	Sample no.
S. aethiopicum	S00197	Senegal	10
S. americanum	S00262	Philippines	7
	S00859	Tanzania	6
	S00861	Japan	2
S. incanum	S00458	Thailand	10
S. macrocarpon	S00052	Malaysia	10
S. sisymbrifolium	S00199	United Kingdom	10
S. torvum	S00852	Vietnam	5
S. villosum	S00863	Japan	5
	S00810	Bangladesh	2

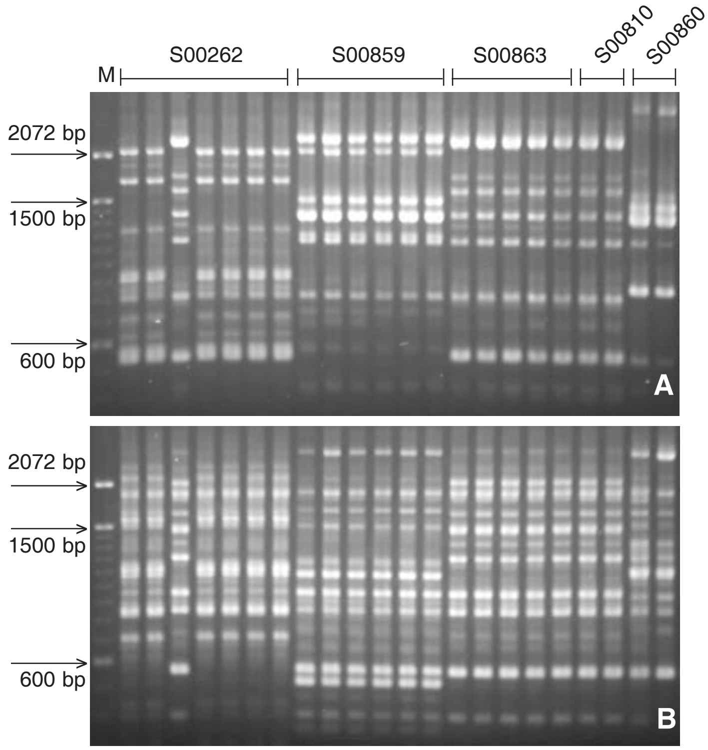
After primer screening, 42 primers producing polymorphic and scorable bands with good reproducibility were chosen for further amplification of DNA from all accessions (Table 39). Figure 14 shows the list of scorable RAPD bands generated by each primer.

A total of 616 RAPD bands were scored. The size of scorable band ranged from 330 to 3500 bp. The number of bands generated by each primer varied from 5 to 28 with an average of 14.7. Among the 616 bands, only one band was common in all seven species. The extremely high polymorphism (99.84%) scored from all 32 accessions indicates the distinct difference among these species. When *S. americanum* Miller and *S. villosum* Miller of the '*nigrum*' complex were

Table 39. *List of scorable random amplified polymorphic DNA (RAPD) bands generated by each primer*

Primer no.	Sequence (5' to 3')	GC %	Bands within '*nigrum*'			
			All[1]	Total[2]	Poly-[3]	Mono-[4]
UBC-137	GGTCTCTCCC	70	9	7	7	0
UBC-150	GAAGGCTCTG	60	10	7	5	2
UBC-186	GTGCGTCGCT	70	8	7	7	0
UBC-331	GCCTAGTCAC	60	8	7	6	1
UBC-333	GAATGCGACG	60	9	9	9	0
UBC-338	CTGTGGCGGT	70	8	7	7	0
UBC-428	GGCTGCGGTA	70	17	12	11	1
UBC-550	GTCGCCTGAG	70	28	17	15	2
OP-I4	CCGCCTAGTC	70	9	6	6	0
OP-I18	TGCCCAGCCT	70	24	12	10	2
OP-S1	CTACTGCGCT	60	17	8	8	0
OP-S11	AGTCGGGTGG	70	13	10	10	0
OP-T4	CACAGAGGGA	60	23	8	6	2
OP-T6	CAAGGGCAGA	60	19	8	6	2
OP-T18	GATGCCAGAC	60	17	11	10	1
OP-U3	CTATGCCGAC	60	5	4	4	0
OP-U10	ACCTCGGCAC	70	17	12	12	0
OP-V6	ACGCCCAGGT	70	14	11	11	0
OP-V14	AGATCCCGCC	70	13*	9	8	1
OP-W4	CAGAAGCGGA	60	14	10	10	0
OP-W8	GACTGCCTCT	60	9	9	9	0
OP-W16	CAGCCTACCA	60	13	9	8	1
OP-X7	GAGCGAGGCT	70	19	12	12	0
OP-X14	ACAGGTGCTG	60	15	10	8	2
OP-X15	CAGACAAGCC	60	21	15	14	1
OP-Y2	CATCGCCGCA	70	20	13	12	1
OP-Y4	GGCTGCAATG	60	17	12	11	1
OP-Y5	GGCTGCGACA	70	16	11	10	1
OP-Y10	CAAACGTGGG	60	12	11	11	0
OP-Y15	AGTCGCCCTT	60	10	8	5	3
OP-Y20	AGCCGTGGAA	60	18	13	13	0
OP-Z15	CAGGGCTTTC	60	15	7	6	1
OP-AE4	CCAGCACTTC	60	15	12	12	0
OP-AE17	GGCAGGTTCA	60	24	16	16	0
OP-AE18	CTGGTGCTGA	60	13	7	5	2
OP-AE19	GACAGTCCCT	60	6	4	3	1
OP-AN12	AACGGCGGTC	70	18	13	13	0
OP-AN17	TCAGCACAGG	60	21	12	11	1
OP-AX6	AGGCATCGTG	60	13	10	9	1
OP-AX7	ACGCGACAGA	60	12	10	9	1
OP-AX9	GGAAGTCCTG	60	12	9	9	0
OP-AX19	CCCTGTCGCA	70	15	7	5	2
Total			616	412	379	33
(%)				100	91.99	8.01

[1]Number of total bands/per primer within all 32 accessions
[2]Number of total bands/per primer within the *S. nigrum* complex
[3]Number of polymorphic bands/per primer within the *S. nigrum* complex
[4]Number of monomorphic bands/per primer within the *S. nigrum* complex
*The only one common band generated by this primer within all 32 accessions



M = 100 bp DNA ladder marker

Fig. 14. *RAPD patterns of the intra-accession diversity study in the 'nigrum' complex generated by primer OP-AX9 (A) and OP-Y4 (B)*

analyzed, a total of 412 RAPD bands were scored. Among the 412 bands, 379 bands (91.99%) were polymorphic and there were only 8.01% common bands.

Low similarity was found among these seven species with the Jaccard's similarity coefficient of 0.14 (Fig. 15). Similarity levels between the *S. americanum* Miller and *S. villosum* Miller accessions ranged from 0.28 to 1.00. This suggested that the '*nigrum*' complex have a wide genetic background.

Based on the cluster analysis with the 616 RAPD bands, the resulting dendrogram shows two major groups at Jaccard's similarity coefficient of 0.14. *S. americanum* and *S. villosum* are clustered as the first major group. The second major group includes *S. aethiopicum*, *S. incanum*, *S. macrocarpon*, *S. sisymbrifolium* and *S. torvum*. As a whole, all 32 accessions could be separated into ten clusters. The first major group is further divided into four clusters, while the second major group is further divided into six clusters (Fig. 15). The grouping pattern is approximately in accord with the delimitation of species, since accessions within a species have higher similarity when compared with other species. For instance, in the second major group, accessions of *S. aethiopicum* are grouped in cluster V with high similarity level ranged from 0.92 to 0.96. *S. macrocarpon* are in cluster VII with extremely high similarity level ranged from 0.99 to 1.00. *S. torvum* are grouped in cluster X with similarity level of 0.99. However, *S. incanum* is the species that shows high genetic diversity in the second major group, since the three accessions are distributed in clusters VI and VIII with the similarity level ranged from 0.16 to 0.34.

Among these seven *Solanum* species, *S. americanum* and *S. villosum* show closer relationship with each other than with other five species. This is the evidence that these two species are part of the '*nigrum*' complex. However, in this major group, it is further divided into four clusters. The 16 accessions of *S. americanum* are distributed in cluster I, II, III, and IV. The accessions collected from Philippines in cluster I with high similarity level ranged from 0.99 to 1.00. The four *S. villosum* accessions are distributed in cluster I and IV.

Traditionally, the most important characters by which the three species of the '*nigrum*' complex can be distinguished from each other are the chromosome number and the appearance of berry. In *S. villosum* the berries are orange-red, the berries of *S. americanum* are shiny purplish black with reflexed sepals, and the berries of *S. nigrum* are dull purplish black with sepals adhering to the fruit.

Based on the morphological characteristics by GRSU, few accessions should be reclassified. For example, accession S00262 (*S. americanum* from Philippines) should be reclassified into *S. villosum*, since the fruit color is scarlet red. Accession S00861 (*S. americanum* from Japan) should be reclassified into *S. nigrum*, since the fruit color is black. Accession S00863 (*S. villosum* from Japan) should be reclassified into *S. americanum*, since the fruit color is purple black. Lastly, the fruit color of accession S00810 (*S. villosum* from Bangladesh) is purplish black, not orange or red, and it should be further investigated (data not shown).

According to the RAPD data, accessions S00810 and S00863 show high similarity level of 0.95 with each other, and are grouped with 11 *S. americanum* accessions at Jaccard's similarity coefficient of 0.93 in cluster I. It is clear that these two accessions have closer relationship with the *S. americanum* accessions collected from Philippines than with *S. villosum*. Besides, accession S00262 is grouped with two *S. villosum* accessions at 0.58 in cluster IV. Accession S00861 is in cluster III alone, which is grouped with cluster I and II with similarity level of 0.41. DNA marker analysis confirms that these few accessions should be reclassified as suggested by GRSU's morphological investigation.

It is clear that the grouping pattern of these three species of the '*nigrum*' complex is also approximately in accord with the delimitation of species. That is, *S. americanum* (except accession S00862) is located in cluster I and II, *S. villosum* is grouped in cluster IV, while *S. nigrum* is in cluster III. Secondly, the intra-species genetic diversity is different among species. *S. americanum*, *S. villosum* and *S. incanum* have apparently higher genetic diversity than other nontuberous *Solanum* species such as *S. aethiopicum*, *S. macrocarpon* and *S. torvum*. Thirdly, the *S. americanum* accessions in GRSU's collection has three distinct subgroups, which indicates the genetic diversity among these collections. And the dendrogram shows that the genetic diversity of *S. americanum* has correlation with geographical origin. Fourthly, based on RAPD analysis, *S. nigrum* seems to be more closely related with *S. americanum* than with *S. villosum*. Lastly, however, since chromosome number is one of the most important characters that can distinguish the three species of the '*nigrum*' complex, it is suggested that polyploid number should be further investigated to confirm the genetic relationship between the *S. nigrum* accession (S00861), the *S. americanum* accessions (S00810 and S00863) and the *S. villosum* accession (S00262).

These results show that RAPD analysis is a useful tool for *Solanum* germplasm diversity analysis and genotypic identification, and can provide baseline information on genetic relationships among these *Solanum* accessions. For recognizing the *S. nigrum* complex, chromosome number and the appearance of the berries are known to be the most important characters for distinguishing the three species. In this study, the results based on RAPD data provide good evidence for the morphological identification, and it is believed that RAPD analysis can be a great method for germplasm management in the '*nigrum*' complex.

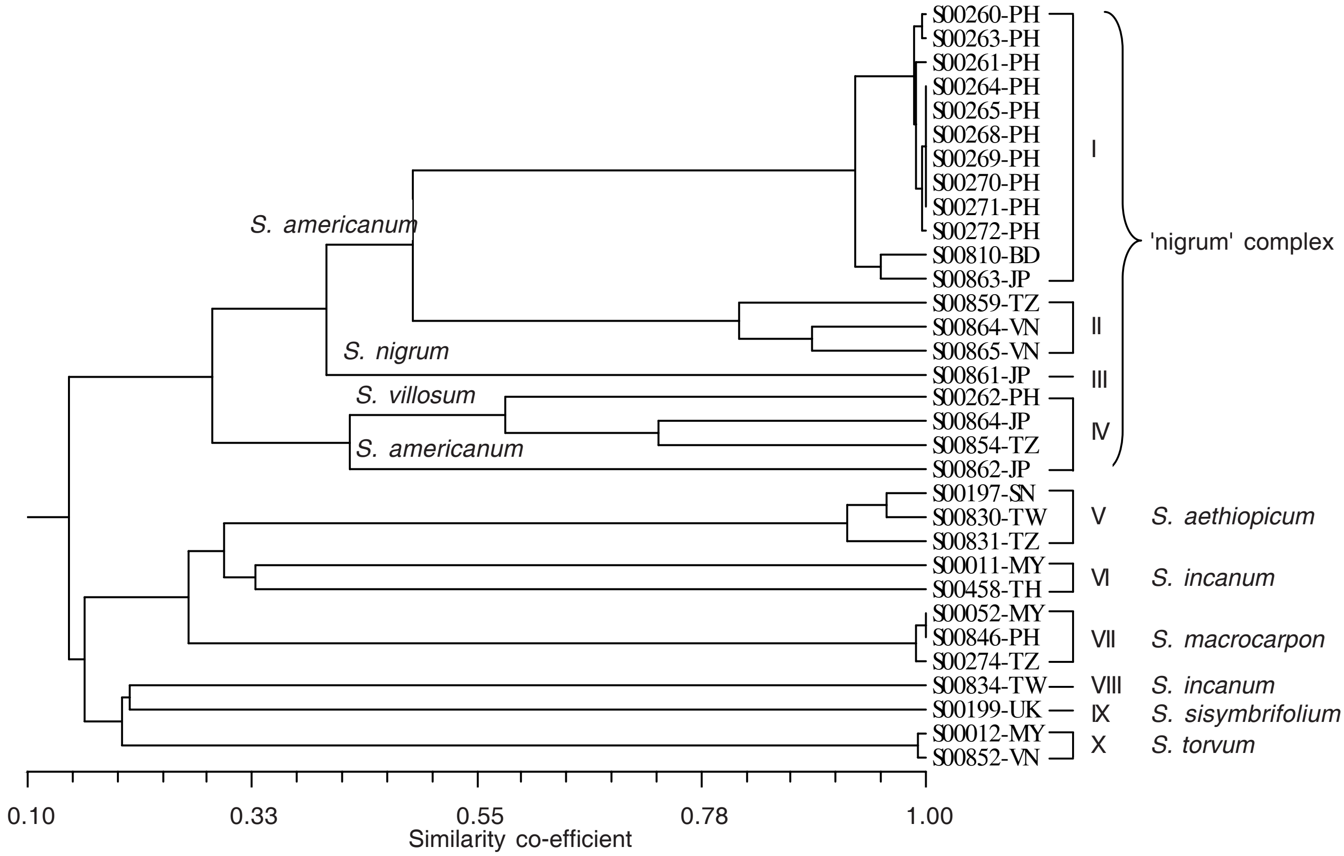


Fig. 15. *Cluster analysis of 32* Solanum *accessions. The scale on the bottom of the dendogram is the Jaccard's similarity co-efficient based on 616 random amplified polymorphic DNA (RAPD) bands, Roman numerals on the right indicate* Solanum *clusters.*

Project 2. Bulb alliums

Project 2 focuses on AVRDC's research on bulb alliums. Its objectives are to increase yield, improve storability, and eliminate diseases of onion, garlic, and shallot.

Project Coordinator: P Gniffke

Early maturing, high-yielding onion for the tropics

The average yield of onions in the tropics is about 12 to 15 t/ha, only half the yield of temperate areas. The development of high yielding, early maturing lines for short-day tropical conditions is a key objective of our breeding program, and this report summarizes our current progress.

Forty-seven elite lines were evaluated for maturity and yield characteristics. They were evaluated in three groups: 8 early maturing yellow bulb lines (with two checks), 14 high yielding yellow bulb lines (with four checks), and 23 high yielding red bulb lines (with three checks). The experiment used completely randomized designs with two replications and 60 plants per plot. Lines were evaluated for yield and bulb quality characteristics. A preliminary yield observation trial was also evaluated, including unreplicated plots of 14 white, 158 yellow, and 27 red bulb lines.

Seeds were sown in plug flats (128 cells/flat) on 17 September 2001. On 21 November, the seedlings were transplanted in three rows with 15 cm and 10 cm between rows and plants respectively; beds were 1 m wide. The date of crop maturity was recorded when 50% of plants in each plot had fallen tops.

Superior lines from earlier evaluations were recombined, and unreplicated evaluation plots including 27 F_1, 6 F_2, 201 F_3 and 103 F_4 families were sown on 6 September 2001 and transplanted on 7 November. At maturity, large bulbs were selected for high yield potential and/or early maturity.

No significant differences on days to maturity were found between lines in the group targeting early maturity, or between the test lines and the early check cultivar Superex. However, the average days to maturity of this group (120.5 days) is less than the other high yield groups (126.6 and 130.4 days for yellow and red groups, respectively). Three lines produced yields equivalent to the check cultivars California 606 and Superex (Table 40). Two lines, AC709(C)-C and TA1010(A)-AST-C, matured early (110 days each) but showed very low yield potential (28.3 and 15.3 t/ha) (data not shown). AC836(C)ST-C is most promising among this group of lines and seed multiplication is in progress. Hybrids OC422 F_1 (AC572 × TA358) and OC424 F_1 (TA1002 × AC572) were earliest at 104 days after transplanting with average bulb weights of 243 and 178 g, respectively; bulbs of these lines have been vernalized and planted for F_2 seed production.

Four yellow lines and two red lines have been selected for advancement due to their high marketable yields (Tables 41, 42). In general, the average bulb

Table 40. *Performance of selected early maturing yellow bulb onion lines*

Entry	Marketable yield (t/ha)	Bulb weight (g)	Marketable bulbs (%)
AC836(C)ST-C	94.3 a[1]	348 a	94.0 a
TA998(E)ST-C	78.3 ab	268 b	90.0 a
AC715(B)ST-C	69.0 b	268 b	92.5 a
California 606 (ck)	89.8 a	329 ab	91.5 a
Superex (ck)	61.5 b	240 c	87.5 a
Mean of 8 lines	59.9	237.8	82.9
CV (%)	13.1	13.8	11.0

Transplanted 21 November 2001 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$

Table 41. *Performance of selected high-yielding yellow onion lines*

Entry	Marketable yield (t/ha)	Bulb weight (g)	Marketable bulbs (%)	Days to maturity
AC835(Y)ST-N	73.8 abc[1]	268 ab	95.0 a	123 a
TA481(1)-A-N	68.0 abc	262 ab	89.5 ab	128 a
TA504(A)-A-N	60.0 bc	283 a	81.5 b	128 a
AC136-1-A-C	52.5 c	200 b	89.5 ab	128 a
Granex 429 (ck)	73.5 abc	317 a	87.0 ab	128 a
Texas Grano 502 (ck)	85.0 a	332 a	79.0 b	123 a
Mean of 14 lines	45.7	193.7	74.6	126.6
CV (%)	21.0	16.4	11.4	2.7

Transplanted 21 November 2001 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$

Table 42. *Performance of selected high-yielding red onion lines*

Entry	Marketable yield (t/ha)	Bulb weight (g)	Marketable bulbs (%)	Days to maturity
AC521(A)-A-C	57.0 b	226 c	85.5 ab	128 bc
AC461(E)-C	55.0 b	242 bc	84.5 ab	128 bc
California 606 (ck)	93.8 a	386 a	94.0 a	118 d
Red Creole (ck)	12.5 c	123 d	36.0 c	143 a
Texas Grano 502 (ck)	60.8 b	267 b	74 b	123 cd
Mean of 23 lines	31.2	157.8	65.1	130
CV (%)	19.9	10.9	15.1	3.0

Transplanted 21 November 2001 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$

weight of the red onion lines evaluated (158 g) was less than the average bulb weight of the yellow onion lines evaluated (194 g).

For quality evaluation, the 45 lines discussed above along with four check varieties were analyzed for dry matter, total soluble solids (TSS), and pyruvic acid. Highly pungent (pyruvic acid > 9µmole/g), red-bulb lines are shown in Table 43. A high correlation between dry matter and TSS in these materials was confirmed (r = 0.95). High levels of pungency and TSS on lines AC119-C-AST-AST-C and AC707(B)-A-C suggest they have better flavor.

Two lines from the preliminary yield observation trial, TA741(B)-C and TA1007(A)-C, were selected for improved yield potential in red onion. Because inbreeding depression occurs in onion, these selected lines have been sib-multiplied to maintain yield performance.

Early generation breeding materials are showing substantial improvements over earlier cycles of selection (data not shown). Out of 19 new crosses targeting high yield, three displayed larger bulb weights than California 606 (250 g). They are OC347 (AC715 × CAL606), OC406 (TA471 × AC506) and OC414 (TA377 × TA1001) with average bulb weights of 261, 338 and 318 g, respectively. A total of 111 bulbs of F_2 population (15.4%) and 130 lines from F_3 families (51.2%) were selected for large bulb size (> 8 cm diameter).

Uniformity was improved in the F_4 generation families; lines with high percentages of marketable bulbs are shown in Table 44. Seed multiplication is in progress for further evaluation and selection for yield.

Table 43. *Dry matter, total soluble solids and pungency of selected onion lines*

Entry	Bulb color	Dry matter (%)	Total sol. solids (°Brix)	Pyruvic acid (µmole/g fwt[1])
AC461(E)-C	Red	11.4	12.2	9.56
AC119-C-AST-AST-C	Red	16.9	16.1	9.51
AC319(A)ST-C	Red	13.9	14.4	9.31
AC707(B)-A-C	Red	15.9	13.5	9.93
TA119-1-A-N	Red	11.3	11.7	10.48
TA176-B-A-N	Red	12.4	11.3	9.47
TA364ST-D-AST-C	Red	12.1	11.2	10.02
California 606 (ck)	Yellow	6.6	7.2	6.48
Red Creole (ck)	Red	17.5	17.6	10.48
Texas Grano 502 (ck)	Yellow	6.9	7.4	5.33
Mean of 49 lines		13.1	12.7	7.24
Range		5.4–18.6	6.4–17.6	3.11–10.48

Transplanted 21 November 2001 at AVRDC
[1]fwt = fresh weight

Table 44. *Performance of selected F_4 onion lines*

Entry	Pedigree	Bulb color	Market. yield (t/ha)	Bulb wt (g)	Market. bulbs (%)
OC186-B-A-N	TA382× AC325	Wht	81.8	273	100.0
OC172-C-A-C	TA377× AC49	Yel	66.2	245	90.0
OC20-7-E-C	AC50×TG502	Yel	61.8	216	95.9
OC175(LR)-C-B-N	TA377×TA358	Yel	51.3	189	90.6
Texas Grano 502 (ck)		Yel	46.8	243	64.3
Granex 429 (ck)		Yel	49.0	315	51.9
Red Creole (ck)		Red	11.1	153	24.1
Mean of 103 lines			32.0	161	64.3
Range			5.1–90	74–311	15–100

Transplanted 7 November 2001 at AVRDC

Development of onions with good yield and storability traits

To increase stability of onion supplies in the tropics, AVRDC works to improve the storability of cultivars adapted to the cool-dry season. Both red and yellow onions are included in our efforts to combine high yield potential with improved storability under low cost, ambient storage conditions. While short-day red onions generally show superiority for storability in our trials, some long-day yellow onions grown in other conditions are known to have good storability.

Thirty-nine elite lines from the AVRDC breeding program were evaluated for yield performance and storability, using a randomized complete block design (RCBD) with two replications and 60 plants for each plot. Eighteen additional lines were evaluated without replication. The red onion cultivar Red Creole was used as a check for storage ability, while yellow onion cultivars Texas Grano 505 and California 606 served as checks for yield. Seeds were sown and transplanted to the field on the same day and in the same manner as other yield trials discussed here (see previous report). Yield data were recorded after full ripening.

Marketable bulbs were kept in nylon net bags for storability testing. Bags were placed on shelves in a well-ventilated storage room under ambient conditions (28°C, 75% RH) for four months, beginning 9 May 2002. Forty-nine lines along with three check cultivars were replicated two to four times with 40 bulbs per replication, and arranged randomly on storage shelves. In addition to 78 sib-mated lines, 15 F_1, 35 F_2, 312 F_3 and 5 BC_1F_1 lines were screened for storability in a non-replicated trial. Bags were inspected each month, and numbers and weights of disease-free bulbs were recorded.

While data were collected over a storage period of four months, results on storage loss percentages after three months are presented here, in order to conform to presentation on this topic in earlier annual reports. Storage losses were due mainly to diseases (e.g., black mold caused by *Aspergillus niger* and soft rot caused by *Erwinia carotovora* pv. *carotovora*), mite infestation, sprouting, rooting and physiological weight loss; records were not kept of the relative contribution of each problem. Out of 49 lines tested for storability, 16 have yellow bulbs and 33 have red bulbs. The top four lines of each color for storability are shown in Table 45. The average storage loss of the yellow onion entries is 62.4%, higher than the average 28.4% loss of red bulb entries. A negative correlation was found between bulb weight and storability (r = –0.44 and –0.43 for red and yellow bulb lines, respectively; r = –0.53 combined).

Table 45. *Storability and yield characteristics for promising red and yellow onion lines*

Entry	Storage loss (%)	Marketable yield (t/ha)	Bulb weight (g)	Marketable bulbs (%)	Days to maturity
Red					
AC473-CST-AST-BST-N	1.8 a[1]	19.5 de	82 e	78.0 bc	128.0 cde
AC431-S-PB-AST-C	10.0 ab	10.0 e	98 de	33.0 e	146.0 a
AC119-C-AST-BST-N	12.7 bc	33.5 bc	130 cd	73.5 bc	131.5 bcd
AC319-C-GST-C	25.2 bcd	32.5 c	126 cde	86.0 b	128.0 cde
Red Creole (ck)	42.0 d	17.0 de	139 cd	40.0 e	140.5 ab
Yellow					
Yellow Granex-C-D-AST-C	45.5 d	30.0 cd	146 cd	63.5 c	118.0 e
TA386(F)-CST-B-AST-C	46.7 d	29.0 cd	133 cd	81.0 bc	123.0 de
AC450-C-CST-C	51.8 d	26.3 cde	124 cde	73.0 bc	128.0 cde
TA377-CST-AST-AST-C	52.7 d	36.3 bc	172 c	73.5 bc	131.5 bcd
California 606 (ck)	91.7 e	90.0 a	325 a	96.0 a	118.0 e
Texas Grano 502 (ck)	89.8 e	50.5 b	221 b	79.0 bc	128.0 cde
Mean	47.9	28.2	138.1	69.2	132.3
CV (%)	29.6	18.7	14.1	14.1	3.6

Transplanted 21 November 2001 and stored for three months of ambient room conditions beginning 9 May 2002 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test, $P \leq 0.05$

Only three red bulb lines displayed significantly better storability than Red Creole. The line AC473-CST-AST-BST-N lost only 8.6% of its initial fresh weight after storage for four months and minimal bulbs spoiled.

Among the 42 lines which had no significant difference from Red Creole in storability, only four had larger bulb weights, namely TA1003(A)ST-1-0, AC319(A)ST-C, AC731(B)ST-C, and AC691(C)ST-C, which averaged 177, 205, 193 and 213 g per bulb, respectively, at the end of storage. One red onion line, AC727(A)-BST-N, with 52.1% storage loss, had a bulb weight (252 g) similar to Texas Grano 502. All of these lines were smaller than California 606.

Although average storage losses in yellow bulb lines were higher than in red bulb lines, the relative advance over standard checks is superior. Of the 16 yellow bulb lines tested, eight displayed significantly less storage loss than Texas Grano 502 and California 606. This improvement was gained at the expense of bulb size and marketable yield.

The average storage loss of 15 new cross combinations is 42%, while check cultivars California 606 and Red Creole recorded 82.3 and 64.7% losses, respectively. Top performers OC242 (AC119 × AC319) and OC398 (TA386 × Yellow Granex) each had average bulb weights greater than 150 g and the best storability (35.9 and 39.5%) among red and yellow onions, respectively.

After three months storage, 311 bulbs of F_2 populations and 87 lines from F_3 families remained and were selected for further evaluation and improvement. This constitutes a 6.5% and 27.9% selection rate for storability in the F_2 and F_3 generations, respectively. All lines mentioned in this report are part of our on-going research and breeding activities, and are not yet available for distribution.

Evaluation of *A. cepa* × *A. fistulosum* lines to develop Stemphylium leaf blight-resistant onion

Stemphylium leaf blight (SLB) caused by *Stemphylium vesicarium* is a major disease affecting alliums in the tropics. Crosses between common onion, *Allium cepa,* and Welsh onion, *A. fistulosum* were made to introgress resistance genes into the former species. However, the sterility and poor seed set of interspecific progeny limit their use in onion improvement. Evidence that some shallot varieties may have originated from spontaneous crosses between *A. cepa* and *A. fistulosum*, which were then multiplied vegetatively, suggests there is a possibility that SLB-resistant shallot lines may be selected as individual plants from interspecies populations.

In Winter 2000–01, 95 single plant selections with reduced SLB symptoms and shallot-type bulbs were taken from interspecific populations, and then multiplied for evaluation. Individual bulblets of these lines were planted in two rows on 0.75-m-wide beds and evaluated with four check cultivars (three shallots and one Welsh onion) without replication on 14 May 2001. The spaces between rows and plants in-rows were 20 and 15 cm, respectively. Disease symptoms for SLB, anthracnose (*Colletotrichum gloeosporioides*), and purple blotch (*Alternaria porri*), and bulbing response to summer conditions were evaluated on 4 June 2001. Bulbs were harvested on 4 July and 15 August and kept in refrigerated storage (7°C) until replanting. On 18 October 2001, they were replanted in a manner similar to the Summer 2001 season, for multiplication and further selection. Self-pollinated seed from individual lines was harvested in Spring 2002.

Out of 95 lines evaluated in Summer 2001, 44 (3 F_5, 6 F_6, 12 BC_1F_2, 19 BC_1F_3 and 4 BC_1F_4) produced bulbs and were replanted for the winter trial. Most of these lines came from progenies of the combinations CF1 (AC4 × AF468), CF19 (AC50 × TA198), FC46 (TA198 × AC50) and CF16 (AC15 × TA198). The average plant weight and bulblet number per plant was 0.37 kg and 9.3, respectively.

Disease ratings were recorded for major diseases of *A. cepa*, since the *A. fistulosum* parent not only has durable resistance on SLB but also partial resistance to anthracnose and purple blotch. Disease symptoms were generally more severe in summer than in winter, producing particularly weakened plants due to heat stress and low levels of resistance to anthracnose.

Typical problems of interspecific progenies, such as thickened neck and reduced bulbing, were improved in summer compared to winter, but bulblet count (ranging from two to six bulblets per plant) and size were reduced in summer relative to winter. Even though they had been selected for bigger bulblets in 2000, all lines selected after the summer trial had problems with early bolting, reduced bulbing, and thickened neck when planted in October 2001, and they produced poorer quality bulbs compared to check varieties. This may have been due to the vernalizing effects of cold storage (7°C) of the bulbs before replanting. Except for four lines of intermediate type, the flower morphology resembled the *A. cepa* parent, and pollen fertility ranged from 61.3 to 99.0%. Lines having fewer disease symptoms and good bulbing behavior were selected for good pollen fertility. They are listed in Table 46. The line 11299-12 had pollen fertility of 74.7% and the best performance during 2001 growing seasons. Artificial inoculation tests to confirm SLB resistance in these lines are in progress.

Yield and storability of virus-free shallot lines

Most of the shallots produced in the tropics are grown using vegetative bulblets for propagation. Viruses may be transmitted through bulblets and significant reduce yields. AVRDC has produced several virus-free shallot lines through meristem culture. This trial evaluated these lines for yield and storability characteristics.

Ten AVRDC lines, two storage check lines, and two general check lines were planted at AVRDC on 18 October 2001. Plants were set in four rows on 0.75-m-wide beds with rows spaced 20 cm apart and plants spaced 15 cm apart within rows. A RCBD with 30 plants per plot and three replications was used. Yield data were recorded after full ripening, and bulbs were stored in nylon net bags for testing. Bags were hung in well-ventilated conditions at ambient temperatures for seven months, beginning 29 March 2002.

VFS95 3-5 was the top performer. It had significantly higher yields and stored better than all other lines tested (Table 47). It matured early and produced many red bulblets, which are favored by consumers in

Table 46. *Characterization of shallot type lines selected from interspecies progenies for less disease symptoms*

Entry	Pedigree	Generation	Plant type[1]	Disease rating[2] summer	Disease rating[2] winter	Plant wt. (kg)	Bulblet no./plant	Summer bulb size[3]	Summer bulb no.	Flower type[4]	Flower rate[5]	Pollen fertility (%)[6]
11295-1	AC4/AF468//AC319	BC_1F_2	On	1	2	0.36	9	L	4–6	AC	1	71.0
11297-6	AC4/AF468//AC319	BC_1F_2	On	1	2	0.50	10	L	2–4	-[7]	0	-
11299-1	AC4/AF468//AC319	BC_1F_2	On	1	2	0.40	9	M-L	2–4	AC	2	63.4
11299-12	AC4/AF468//AC319	BC_1F_2	On	1	1	0.36	5	L	4	AC	2	74.7
11390-1	AC50/TA198//AC50	BC_1F_3	On	1	2	0.50	9	L	2–3	AC	3	98.3
11390-9	AC50/TA198//AC50	BC_1F_3	On	3	0	0.56	13	M	1	CF	1	70.9
11413-11	TA198/AC50//AC119	BC_1F_3	On	2	2	0.60	16	L	2	AC	1	79.3
11413-15	TA198/AC50//AC119	BC_1F_3	On	2	1	0.36	11	M	3	AC	2	74.3
11415-4	TA198/AC50//AC119	BC_1F_3	On	2	1	0.32	9	M	4–5	AC	2	84.0
11458-1	AC15/TA198//AC325	BC_1F_3	Sh	2	1	0.32	8	L	2–3	AC	3	63.9
S25	*A. cepa* var. *ascaloniicum*	Check	Sh	3	3	-	-	SS	4–8	AC	3	-
S28	*A. cepa* var. *ascaloniicum*	Check	Sh	2	2	-	-	S	4–5	-	0	-
TA198	*A. fistulosum*	Check	Af	1	0	-	-	0	-	AF	3	-
Mean of 44 lines						0.37	9.3					79.6
Range						0.10–0.72	3–25					61.3–99.4

Transplanted 4 June 2001 (summer) and 21 January 2002 (winter) at AVRDC
[1] On = onion, Sh = shallot, Af = Welsh onion
[2] 0 = no symptoms, 1 = < 1–5% infection, 2 = 6–25% infection, 3 = 26–50% infection, 4 = > 50% infection
[3] L = large, M = medium, S = small; SS = very small, 0 = no bulbing
[4] AC = onion type, CF = intermediate type, AF = Welsh onion type
[5] Percentage of plants bolting: 0 = no bolting, 1 = 1–5%, 2 = 6–30%, 3 = 31–50%, 4 = >50%
[6] Percentage of pollen stained in acetocarmine observed under microscope
[7] No data

Table 47. *Yield and storability characteristics of selected shallot lines*

Entry	Origin	Yield (t/ha)	Storage loss (%)	Days to maturity	Avg bulblets/ plant	Bolting behavior[1]
VFS95 3-5	Philippines	29.6 a[2]	43 a	107 bc	27 b	3
VFS101m4	Thailand	22.9 ab	57 abc	103 c	10 c	2
VFS92 3-5	Philippines	21.0 b	69 bcd	101 c	10 c	1
VFS99m1	Thailand	20.1 b	70 bcd	101 c	9 c	1
VFTA169m4	Thailand	17.3 bc	81 de	107 bc	11 c	2
VFS96m2	Indonesia	16.8 bc	67 bcd	107 bc	19 b	3
VFS41m9	Indonesia	16.2 bc	95 e	147 a	23 b	0
VFS100m4	Thailand	16.2 bc	82 de	105 bc	10 c	1
VFS70-5	Taiwan	14.7 bc	87de	138 a	20 b	0
VFTA329m4	Thailand	11.4 c	58 abc	103 c	10 c	2
S25 (ck)[3]	Indonesia	20.5 b	77 cde	101 c	21 b	1
S28 (ck)[3]	Taiwan	14.0 bc	69 bcd	147 a	36 a	0
S31V(9)HT (ck)[4]	Philippines	19.4 bc	52 ab	120 b	25 b	1
S44V(9) (ck)[4]	Thailand	20.4 b	55 abc	101 c	27 b	1
Avg of 14 lines		18.6	69	113	19	
CV (%)		24.3	40	7.5	24	

Transplanted 18 October 2001 at AVRDC
[1] Measured as percentage of plants bolting: 0 = no bolting, 1 = 1–5%, 2 = 6–30%, 3 = 31–50%, 4 = >50%
[2] Mean separation in columns by Duncan's multiple range test, $P \geq 0.05$
[3,4] Good storage check, and general production check lines, respectively

the tropics. The line bolts easily and may be suitable for development as a true seed shallot. Five other lines stored better or similar to the check lines while four lines stored very poorly (data not shown).

Production and economic analysis of using virus-free planting materials for garlic

Virus-free planting materials have been shown to increase yields of garlic but these materials are expensive to growers. Technologies need to be developed that produce and maintain virus-free materials at lower costs. This study evaluated yield trends, rates of re-infection, and economic returns when virus-free lines are grown and propagated under low-cost, unprotected conditions.

Meristem-derived bulbs of four garlic cultivars (G176, G180, G29, and G54) with different cumulative generations of open field propagation were planted in the fall seasons of 2000 and 2001. Plantings were established using RCBD with three replications; each 5-m plot consisted of 100 plants in two rows, with 10 cm between plants and 15 cm between rows, on a 0.75-m-wide raised bed. Trials were planted on 24 October 2000 and 16 October 2001, and harvested on 6 April 2001 and 4 April 2002, respectively. Leaves from each plot were sampled and assayed for leek yellow stripe virus (LYSV) and onion yellow dwarf virus (OYDV) prior to harvest. Yield data for the experiments of 2000 and 2001 were compared to give a more precise impression of the yield improvement and stability possible through the use of meristem-derived materials.

Combined analysis of variance (ANOVA) indicated that the factors of year, variety, and generation of propagation all had significant and interacting influences on bulb yield. The yield of G180 was significantly increased from 37 to 74% for the meristem-derived stocks compared to its original, virus-infected, stock (Table 48). The only atypical pattern occurred with the line G176 in the 2001 trial, when yield of the virus-infected original line was equivalent to all generations of virus-freed plants.

All of the garlic plantings displayed a rapid re-infection with the two viruses assayed. Nevertheless, virtually all of the meristem-derived materials displayed substantially higher yield than their original checks. Their re-infection rates were low in original virus-free (VF0) stocks when first exposed to the open field but virus accumulation increased in the stocks as they were planted in unprotected field conditions for more than two consecutive years. It is possible that natural, as compared to manual, re-infection introduces low titers of the virus, which test positive in enzyme-linked immunosorbent assay (ELISA) tests, but may have limited effect on productivity. Impact was measured on vegetative growth. Results showed that the meristem-derived plants had significantly higher plant, longer pseudostems, higher green garlic yield, and improved quality compared to their original checks.

An economic analysis was conducted using recently published data from the Taiwan Council of Agriculture. Based on 0.1 ha of nethouse production for meristem-derived bulbs, the production cost for one kg was estimated at US$2.72 (scale-up could reduce unit costs). This cost is higher than the US$1.16 per kg production cost for a typical local variety with unknown virus-infection status.

Planting one ha of garlic requires 1250 kg of seed bulb. Overall costs of garlic production in Taiwan is quite high at US$8319 per ha, mainly due to high labor cost. Conventional planting materials amount to only about 17% of total production costs. If we assume a yield increase of 30% by using meristem-derived material (using average yields across four lines in Table 48), the net enhancement of returns is at least US$1522 per ha. Therefore, it is economically feasible to increase yield of garlic through the use of meristem-derived material. Moreover, farmers can maintain meristem-derived material themselves for more than two generations in the open field and still receive a substantial yield advantage without the recurring cost of purchasing virus-free planting stock.

Table 48. *Bulb yield and virus infection rate of different generations and lines of meristem-derived garlic*

		2000				2001			
		Yield	Yield	Incidence (%)		Yield	Yield	Incidence (%)	
Entry	Generation	(t/ha)	index[1]	LYSV[2]	OYDV[2]	(t/ha)	index	LYSV	OYDV
G176	Original	9.0 c[3]	100	86.7	80.0	13.0 a	100	100.0	100.0
	VF0	14.0 a	156	80.0	73.3	13.3 a	103	23.3	3.3
	VF1	11.0 b	123	73.3	46.7	13.2 a	102	86.7	73.3
	VF2	13.1 a	146	20.0	33.3	11.8 a	91	80.0	40.0
	VF3	14.3 a	159	73.3	13.3	12.3 a	95	76.7	60.0
	Mean	12.3				12.7			
G180	Original	10.6 c	100	93.3	100.0	10.5 b	100	100.0	86.7
	VF0	16.9 a	159	80.0	40.0	15.2 a	145	23.3	3.3
	VF1	15.5 ab	146	93.3	66.7	18.3 a	174	96.7	40.0
	VF2	14.6 b	137	93.3	73.3	14.4 a	136	100.0	90.0
	VF3	17.3 a	163	93.3	46.7	15.8 a	149	86.7	90.0
	Mean	15.0				14.8			
G29	Original	7.9 b	100	100.0	100.0	10.2 bc	100	100.0	100.0
	VF0	5.8 c	73	100.0	100.0	11.7 b	115	20.0	3.3
	VF1	12.7 a	161	80.0	66.7	8.8 c	86	100.0	100.0
	VF2	12.6 a	159	80.0	46.7	14.5 a	142	100.0	100.0
	Mean	9.8				11.3			
G54	Original	7.2 c	100	86.7	86.7	6.5 b	100	100.0	90.0
	VF0	11.4 a	159	80.0	26.7	8.3 a	127	3.3	0.0
	VF1	10.1 ab	140	80.0	60.0	8.3 a	127	46.7	50.0
	VF2	7.8 bc	109	66.7	46.7	9.0 a	139	93.3	86.7
	Mean	9.1				8.0			

Transplanted in fall seasons of 2000 and 2001 at AVRDC

[1] Yield divided by its original yield × 100

[2] LYSV = leek yellow stripe virus, OYDV = onion yellow dwarf virus

[3] Mean separation in columns for each line by Duncan's multiple range test, $P \leq 0.05$

Project 3. Legumes for crop diversification

Project 3 at AVRDC focuses on soybeans and mungbeans. It has three major purposes:

- Evaluate and promote the use of short duration mungbeans and soybeans in cereal-based cropping systems for crop diversification.
- Promote legumes in cereal-based diets to improve protein and iron nutrition.
- Improve soil sustainability through inclusion of legumes in cereal-based systems.

Legumes are commonly referred to as pulses in South Asia. They are rich in protein and iron and their carbohydrate is easily digestible. Lentils, chickpeas and pigeon peas are adapted to cool weather and require a long growing season. Mungbean and blackgram are adapted to hot weather and mature quickly.

South Asia has more than 50% of the world's area and production of mungbean. However, the average yield of mungbean in South Asia is only around 400 kg/ha. The major yield constraint is mungbean yellow mosaic virus (MYMV). Low yields lead to low incomes for farmers and high prices for consumers. Increasing yields will improve access of this nutritious pulse to the rural and urban poor.

Soybean is a multi-purpose crop used in human diets, animal fodder, and industrial purposes. At AVRDC, soybean research focuses on its use as a early maturing, nutritious vegetable that can be grown year-round to generate income, improve nutrition of the poor, and sustain soil productivity through crop diversification. Since it is a new crop to most countries, there is a need to aggressively promote its production, processing, marketing, and utilization.

Project Coordinator: S Shanmugasundaram

Incorporation of mungbean in cereal-fallows in the Indo-Gangetic Plains of South Asia

Introduction

In the Indo-Gangetic plains of Bangladesh, India and Nepal, the major cropping system is rice-wheat. In India alone about 10.5 million ha is under rice-wheat cropping systems (RWCS). Continuous cultivation of cereals results in deteriorating soils, declining water tables, increasing insect pest and disease populations, and other environmental problems. After the harvest of wheat and before the planting of rice, the land remains fallow for 65 to 70 days (late March/April to early July). Early maturing (55 to 65 day) mungbean varieties can fit well between wheat and rice. The mungbean crop will increase the income of farmers, improve their nutrition, and sustain soil productivity.

Under the umbrella of South Asia Vegetable Research Network (SAVERNET), the mungbean subnetwork initiated a project, "Improving the income and nutrition by incorporating mungbean in cereal fallows in the Indo-Gangetic Plains of South Asia, specifically Bangladesh, India and Nepal." The project was supported by the Department for International Development (DFID) of the United Kingdom. A planning workshop was organized at the International Crops Research Institute for the Semiarid Tropics (ICRISAT) from 23 to 25 May 2002 in which 21 delegates from Bangladesh, India, ICRISAT, and AVRDC participated. They developed a blueprint for implementing the project activities.

Variety releases

Based on multi-location and multi-season data collected from the evaluation of different mungbean lines, numerous lines were released using AVRDC material. In Bangladesh, Bangladesh Agricultural Research Institute (BARI) released BARIMUNG-5 (NM-92) and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) released BU-Mug 1 (VC 6372[45-8-1]) and BU-Mug 2 (VC 6372[30-65]). In India, Punjab Agricultural University (PAU), Indian Agricultural Research Institute (IARI), and GB Pant University of Science and Technology released SML 668 (NM-94), Pusa Vishal (NM-92) and Pant Mung 5

(VC 6368), respectively. In Bhutan, VC 2778A was released (this line was earlier released in Thailand as KPS 2).

Agronomic trials

A number of agronomic trials evaluating practices involving sowing dates, seed rates, seed priming, plant population density, tillage versus no tillage, weed control, soil nutrient status, irrigation requirements, and incidences of diseases were conducted at Bangladesh and India.

Trials in Bangladesh

Date of sowing

In Bangladesh, four mungbean varieties, BARIMUNG 2, BARIMUNG 5, BU-Mug 1, and BU-Mug 2 were planted at 15-day intervals beginning 15 March 2002 in Jessore (southern Bangladesh). In Dinajpur (northern Bangladesh), the four cultivars were planted in 10-day intervals beginning 30 March 2002. A split plot design with three replications was used at each site.

At Jessore, the earliest planting date was best for all cultivars (data for this trial is not presented). Similarly, the earliest planting date was best for BARIMUNG 5, BUMug-1 and BUMug-2 in Dinajpur. Planting time did not influence the time to maturity; however, cultivars differed significantly for time to maturity. In Jessore, BU-Mug 1 and BUMug 2 were four days earlier maturing compared to BARIMUNG 2. In Dinajpur, BU-Mug 2 was two days and six days earlier maturing than BARIMUNG 5 and BARIMUNG 2, respectively. At either site, BU-Mug 1 and BU-Mug 2 could yield about 800 to 900 kg/ha even if planted as late as 9 April in rice-wheat systems.

Seed rate and spacing

Since farmers are not familiar with sowing mungbean in rows, a field experiment was conducted in Jessore and in Dinajpur to determine the optimum seed rate and spacing with two cultivars, BARIMUNG 5 and BU-Mug 2. Four spacing arrangements were used. Three treatments used plots consisting of three 6-m-long rows. Spacings between and within the rows were 30 cm × 5cm, 30 cm × 10 cm, and 20 cm × 10 cm. The fourth treatment was broadcast sowing with 30 kg/ha seed rate. A split plot design with three replications was used. The experiment was planted on 15 March at Jessore and 1 April in Dinajpur.

The results showed that Jessore is a significantly high yielding location (690 kg/ha) compared to Dinajpur (603 kg/ha). The Jessore planting was irrigated whereas the Dinajpur planting was rainfed. Combining data from both locations showed that row planting (mean of 711 kg/ha for three treatments) was significantly and consistently higher yielding than broadcast sowing (450 kg/ha). Row plantings also required less seed for planting, thereby reducing costs to farmers.

Trials in India

Date of sowing and seed rate

At Punjab Agricultural University (PAU), date of sowing and seed rate experiments were conducted. The newly released cultivar SML 668 was planted on 26 March and 19 April 2002 at PAU farm in India. Seed rates of 20, 30, 35, 37.5, and 40 kg/ha were used. A split plot design with date of sowing as the main plot and seed rate as subplot was used with four replications.

The differences in yield between sowing dates and between seed rates were significant (Table 49). However, the interaction between sowing dates and seed rates was nonsignificant. The results showed that the yield will significantly decrease (31%) as the planting date is delayed. The optimum seed rate for maximum yield for SML 668 is 35 kg/ha regardless of the planting date (Table 49). For the local small-seeded cultivar, the recommended seed rate is 25 kg/ha.

Table 49. *The response of SML 668 to different dates and rates of sowing in a split-plot experiment sown at Punjab Agricultural University, India*

Treatment	Yield (kg/ha)
Sowing dates	
26 March	2069
19 April	1432
CD (5%)	292
Seed rates (kg/ha)	
25	1541
30	1659
37.5	1881
40	1900
CD (5%)	195

Irrigation and mulching

To determine the effect of irrigation and mulching on productivity of SML 668, a split plot experiment was conducted. Three levels of irrigation (2, 3, and 4 irrigations) were used as the main plot and two mulching treatments (4 t/ha wheat straw mulch and no mulch) were the subplots. Three replications were used. The trial was sown on 27 March 2002 at PAU farm in India. The differences in yield between irrigations were nonsignificant. However, the mulching produced significantly higher yield, 2,301 kg/ha, compared to no mulching, 2,012 kg/ha.

Tillage practices

Since the fallow period after wheat harvest and before the rice planting is short (about 65 days) efficient use of the time is essential to harvest a successful additional crop. An experiment was conducted to compare no tillage with tillage and tillage plus straw incorporation. The subplots were 2% urea spray and no spray (control). SML 668 was used with four replications. The trial was sown on 23 April 2002 at PAU farm in India.

Results showed that the differences in yield between tillage and no tillage in yield were nonsignificant. However, both treatments were significantly better than straw incorporation. Urea spray did not improve the yield. It is concluded that no tillage produces similar yields as tillage; furthermore, it saves valuable time and resources and reduces cost of production.

Irrigation and fertilization

An experiment was conducted to determine the number of irrigations and levels of N and P fertilizer required for maximum yield. Four levels of irrigation (2, 3, 4, and 5 irrigations) served as main plots. Three levels of N and P served as subplots: control treatment of 0N–0P–0K kg/ha, recommended rate of 12.5N–17.2P–0K kg/ha, and a 50% higher P rate of 12.5N–25.8P–0K kg/ha. The RCB factorial trial had three replications, used SML 668 as the cultivar, and was sown on 24 April 2002 in a sandy loam soil.

The differences in yield between irrigation number and between fertilizer levels were significant (Table 50). However, the interaction between these two factors was nonsignificant. Under these field conditions, four irrigations (at 15, 25, 35, and 45 days after sowing) gave significantly higher yield than other irrigation treatments. The recommended N and P fertilizer rate produced the highest yields.

Table 50. *The response of SML 668 to different levels of irrigation and fertilization*

Treatment	Yield (kg/ha)
Irrigation (no.)	
2	1161
3	1251
4	1610
5	1664
CD (5%)	95
Fertilizer rate (kg/ha)	
0N–0P–0K	1274
12.5N–17.2P–0K	1468
12.5N–25.8P–0K	1521
CD (5%)	111

Split plot experiment sown on 24 April 2002 at Punjab Ag. Univ., India

Plant density

Since the improved cultivars are larger seeded than most traditional lines, it is important to determine the optimum plant population density for maximum yield. Four cultivars (Pusa Vishal, UPM 98-1, Pusa 9531 and SML 668) were planted in three plant population densities (330,000 [30 × 10 cm spacing], 400,000 [25 × 10 cm] and 500,000 [20 × 10 cm] plants/ha) using a split plot design with three replications at PAU farm.

The differences in yield between cultivars and between plant population densities were significant. The interaction between cultivars and plant population densities was nonsignificant. Three cultivars matured earlier and produced significantly higher yields than UPM-98-1 (Table 51). The plant population density of 500,000 plants per ha produced significantly higher yields than the density of 300,000 plants per ha.

Table 51. *Responses of cultivars and plant populations*

Treatment	Days to maturity	Yield (kg/ha)
Cultivar		
Pusa 9531	69	2376
Pusa Vishal	69	2366
SML 668	65	2424
UPM 98-1	70	1844
CD (5%)		390
Population (plants/ha)		
330,000 (30 × 10 cm)		2144
400,000 (25 × 10 cm)		2305
500,000 (20 × 10 cm)		2339
CD (5%)		178

Split plot experiment sown on 24 April 2002 at Punjab Ag. Univ., India

Field sprouting

During the rainy season, seeds in mature pods may germinate inside the pod when there is continuous rain. In order to study the differences between cultivars SML 134 and SML 668, 10 mature pods from each cultivar were placed in three petri dishes with moistened filter paper underneath the pods. The filter paper was kept moist by sprinkling water three times daily. The results are presented in Table 52.

The results showed that it took more time for sprouts to emerge from SML 668 compared to SML 134. This may be due to SML 668 having a thicker pod than SML 134, thus protecting the seeds better from moisture. SML 668 also had a larger seed diameter than SML 134, 4.64 mm compared to 3.87 mm. In the field it is expected that SML 668 will be less prone to sprouting since its pods are formed above the plant canopy and rain can easily drain off the pods.

Table 52. *Emergence of seedlings from pods of two mungbean cultivars in response to moisture*

Days	Emergence of seedlings in pods	
	SML 668	SML 134
1	Pods swollen	Pods swollen
2	No emergence	3 seedlings in 1 pod
3	5 seedlings in 2 pods	21 seedlings in 6 pods
4	9 seedlings in 3 pods	35 seedlings in 11 pods
5	20 seedlings in 6 pods	60 seedlings in 18 pods
6	35 seedlings in 13 pods	97 seedlings in 24 pods

Hardseededness

In a related study, a replicated trial was conducted to determine the degree of hardseededness in different cultivars harvested and stored for different durations. Four cultivars were used: BARIMUNG-2, BARIMUNG-5; VC 3890A (a selection from AVRDC); and KPS 1 (an improved selection of VC 1973A released by Kasetsart University in Thailand). The seed sizes of the four cultivars were 20, 40, 50, and 60 mg respectively. The seeds were harvested during autumn seasons of 1999, 2000, and 2001 and the spring season of 2002. Temperatures and humidities were recorded during the harvest periods. Maximum temperatures in the three autumns ranged from 25.2 to 27.6°C; minimum temperatures ranged from 16.1 to 23.7°C. In spring of 2002, the maximum and minimum temperatures were 31.8 and 23.7°C, respectively. The maximum and minimum RH in autumn ranged from 86 to 94% and 47 to 60%, respectively; the maximum and minimum RH for the spring of 2002 were 99 and 62% respectively. There was almost no rainfall during the harvest in the three autumns (0.2 mm total) while in the spring 12.4 mm of rain fell. Hardseededness was determined using the standard germination test as described above. After 96 hours the number of hard, rotten, and germinated seeds were recorded. Arcsine transformation was used before analyzing the data. A RCB factorial design with four genotypes and four storage durations and four replications were used.

There were significant differences for hardseededness and percent germination between cultivars and between years. Cultivar × year (season) interactions were also significant (Table 53). BARIMUNG-2 produced the lowest percent hard seed (1%) in 2001 and the highest (12%) in 1999. BARIMUNG-5 had the lowest percent hard seeds (0.75%) in 2002 and the highest (19.75%) in 2001 (Table 54). Such variability in hardseededness of BARIMUNG-2 and BARIMUNG-5 might be the effect of field weathering. The negative relationship between seed size and hard seeds in different years confirmed the effect of field weathering in differentiating hard seeds development in mungbean as it was significant in 1999 ($r = -0.836^{**}$) and in 2002 ($r = -0.730^{**}$) but not in other two growing years. The relationship between seed size and hardseededness was nonsignificant ($r = 0.368$).

From the results, it may be concluded that hard seeds of mungbean are more in the genotypes within the seed size of 40 mg or less and varies widely over growing seasons. Therefore, if such seeds are used for planting or sprouting, care should be taken to assess their germination in advance.

Table 53. *Analysis of variance for hardseededness in mungbean cultivars*

Sources	DF	SS	MSS	F
Treatments	15	3991	266	26.47**
Cultivar (C)	3	2284	761	75.76**
Year (Y)	3	361	120	11.96**
C x Y	9	1346	150	14.88**
Error	48	482	10	

** Significant at $P \leq 0.01$ level

Table 54. *Cultivar and year interaction for percentage of hardseededness in mungbean*

	Cultivars				
Year	BARI-MUNG-2	BARI-MUNG-5	VC 3890A	KPS 1	Mean
1999	12.00 Aa[1]	6.50 Bb	1.00 Cc	0.50 Cc	5.00 a
2000	2.50 Aa	0.75 Bb	0.25 Cc	0.25 Cc	0.94 c
2001	1.00 Ab	19.75 Aa	0.25 Cc	0.25 Cc	5.31 a
2002	1.75 Bb	12.00 Aa	0.25 Cc	0.00 Cc	3.50 b
Mean	4.31 B	9.75 A	0.44 C	0.25 C	

[1]Means in rows (capital letter) and in column (small letter) are not significantly different at $P \leq 0.05$ using Duncan's multiple range test

Seed production

In summer and kharif seasons, a total of 1,101 t of seeds of SML 668 and Pusa Vishal has been multiplied by more than 10 agencies in Punjab, India (Table 55). The seed is sufficient to plant 25,133 ha of SML 668 and 4,232 ha of Pusa Vishal. Similarly, a total of 3,993 t of seeds of six mungbean cultivars were produced by eight agencies in Bangladesh (Table 56). This amount is sufficient to plant 114,000 ha in 2003.

Table 55. *Seed production (t) of mungbean cultivars by farmers and agencies in Punjab, India during 2002*

	Season		
Seed farm/agency[1]	Summer	Kharif	Total
Pusa Vishal			
Development agencies	107.5[2]	-	107.5
IARI, New Delhi	1.5	-	1.5
IARI, Karnal	0.7	-	0.7
IARI, Pusa Bihar	9.0	-	9.0
Progressive farmers	20.0	-	20.0
Seed farm	20.0	-	20.0
Subtotal	158.7	-	158.7
SML 668			
PAU	210.0[2]	50.0	260.0
PSSC	45.0	330.0[2]	375.0
NSC	6.0	15.0	21.0
Private agencies	20.0	30.0	50.0
FLDs by Pulses section	8.0	1.0	9.0
FLDs by DEE	10.0	7.5	17.5
Progressive farmers	40.0	170.0	60.0
Subtotal	339.0	603.5	942.5
Total	**497.7**	**603.5**	**1,101.2**

[1]PAU, PSSC, NSC, FLD, DEE, IARI = Punjab Agricultural University, Punjab State Seed Corporation, National Seed Corporation, Front Line Demonstrations, Directorate of Extension Education, and Indian Agricultural Research Institute, respectively

[2]Includes seeds distributed to farmers

Table 56. *Seed production (t) of mungbean varieties by farmers and agencies in Bangladesh during 2002*

	Season			
Farmers/ Agency[1]	Late Rabi	Kharif I	Kharif II	Total
BARIMUNG-2				
Farmers of Jessore	-	1500	300	1800
Farmers of Natore	-	100	-	100
Farmers of Barisal	600	-	-	600
BADC	-	-	100	100
BARI	10	10	-	20
Private companies/ NGOs	-	20	5	25
Subtotal (tons)	610	1630	405	2645
BARIMUNG-5 (NM 92)				
Farmers of Jessore	-	500	25	525
Farmers of Natore	-	50	-	50
Farmers of Barisal	200	-	-	200
BADC	-	-	50	50
BARI	30	10	-	40
Private companies/ NGOs	-	5	-	5
Subtotal	230	565	75	870
BINA MUNG-2				
Farmers of Jessore	-	50	-	50
Farmers of Barisal	100	-	-	100
BADC	-	10	-	10
Subtotal (tons)	100	60	-	160
BINA MUNG-5				
Farmers of Jessore	-	50	-	50
Farmers of Barisal	200	-	-	200
BADC	-	50	-	50
BINA	-	10	-	10
Subtotal (tons)	200	110	-	310
BU-Mug 1 [VC 6372-(45-8-1)]				
Farmers of Barisal	5	-	-	5
BADC	1	1	-	2
BSMRAU	-	1	-	1
Subtotal (tons)	6	2	-	8
BU-Mug 2				
BSMRAU	-	0.1	0.2	0.3
Subtotal (tons)	-	0.1	0.2	0.3
Total	**1146**	**2367.1**	**480.2**	**3993.3**

[1]BADC, BARI, BINA, BSMRAU = Bangladesh Agriculture Development Corporation, Bangladesh Agricultural Research Institute, Bangladesh Institute of NuclearAgriculture, and Bangabandhu Sheikh Mujibur Rahman Agricultural University, respectively

Inheritance studies for pod aroma and flower color of vegetable soybean

The major objective of vegetable soybean improvement at AVRDC is to increase its yield potential while maintaining the high quality required for the special export market. A recent initiative is to develop aromatic soybeans with diverse seed colors so as to expand consumer choices.

A group of vegetable soybeans called *Dadachamame* have a unique taro or jasmine aroma similar to aromatic rice. It is reported that the aroma is due to the chemical 2-acetyl-1-pyrrolin, similar to the chemical found in aromatic rice. In Spring 2002, 300 seeds of a cross between Dadacha 2000 (aromatic) and GC 92005-77-2-1 (non-aromatic) were planted in clay pots in the screen house. At full seed development stage (R_6), four to eight pods per plant were harvested. The pods were boiled in 4.0 m sodium chloride solution for 1.5 min to prevent enzyme degradation. Pods were cooled in ice-cold water and each pod was individually and instantly quick-frozen at –40°C. Frozen pods were saved in plastic bags and kept in the freezer at –20°C. Each sample was boiled for 3 min in boiling water individually. To avoid overwhelming panel members' senses, no more than 50 samples were evaluated for aroma in a single session. Observed F_2 segregation ratios for aromatic and non-aromatic types as well as white and purple flower phenotypes were compared with expected ratios for a single gene model using chi-square analysis.

The results showed that the F_1 plants from the cross between Dadacha 2000 and GC 92005-77-2-1 produced pods that were without aroma, thereby indicating that aroma is likely governed by a recessive allele. The observed and expected data on segregation of the F_2 for both aroma and flower color are shown in Table 59. The observed ratio fitted well with the expected ratio for single gene inheritance for both traits (Table 59). Chi-square analysis indicated no linkage between these traits' genes (Table 60).

The aromatic segregants were selected and advanced to the F_3 where seed size and seed coat color were found quite variable. The seed coat color of the parents was brown and green. Among the F_2 segregants with aroma, 7 were brown, 1 coffee-colored, 2 greenish-brown, 8 greenish-yellow, 2 yellow, and the remaining 31 entries segregated for seed coat color. Three lines had uniformly large seeds, 7 had medium-size seeds, 5 had small-size seeds, and the remaining 36 lines segregated for seed size. Future selection will focus on large seed size and diverse seed coat colors.

Table 59. *Observed segregation ratios and χ^2 values for goodness of fit to monogenic inheritance model for F_2 population derived from crosses between aromatic and non-aromatic lines*

Characters	Aroma		Flower color	
	With	Without	White	Purple
Observed α: β[1]	58	178	70	176
Observed ratios	1.0 : 3.0		1.0 : 3.0	
Expected ratios	1.0 : 3.1		1.0 : 2.5	
χ^2 for single gene model	0.02 NS[2]		1.5 NS	

[1]α = aromatic, white flower; β = non-aromatic, purple flower
[2]Difference between observed and expected ratios is nonsignificant

Table 60. *Combined characterization of aroma and flower color ratio and χ^2 values for goodness of fit to measure linkage of the genes*

Character[1]	PN	PY	WN	WY
Number of plants	126	32	38	19
Observed ratio	6.6	1.7	2.0	1
Expected ratio	9.0	3.0	3.0	1
χ^2 for non-linkage model		4.36 NS[2]		

[1]PN, PY, WN, and WY = purple flower without pod aroma, purple flower with pod aroma, white flower without pod aroma, and white flower with pod aroma, respectively
[2]Difference between observed and expected ratios is nonsignificant

Molecular markers for bruchid and MYMV resistance in mungbean

Infestations of bruchids and MYMV may create severe damage to mungbean crops. Since MYMV is endemic only in South Asia, a breeding program to incorporate MYMV resistance in mungbean would rely on material selection processed in this region where the disease is prevalent. Development of molecular markers for MYMV would be useful to facilitate this breeding process. To apply marker assisted selection in mungbean breeding, a set of recombinant inbred lines (RILs) had been generated to complement this approach. These RILs (F_{11}), deriving from NM92 (MYMV-resistant) and TC1966 (bruchid-resistant), expressed a random combination of various traits inherited from both parents. The homozygousity within each individual line makes permanent maintenance of the population possible. The population can thus be used as permanent mapping population and allow screening for various traits at various locations.

Markers for bruchid

Though bruchid resistance in TC1966 has been reported to involve a single dominant gene (Kitamura et al., 1988), data from other reported papers as well as our own previous investigations indicate more than one gene is involved. The expected segregation ratio for a single gene-inherited trait in a recombinant inbred population is 1:1; however, preliminary tests among the 200 RILs revealed 44 lines with 0% damage, and damaged lines increased steadily from 0 to 100% damage (Fig. 16). This result conflicts with the single gene hypothesis for bruchid resistance.

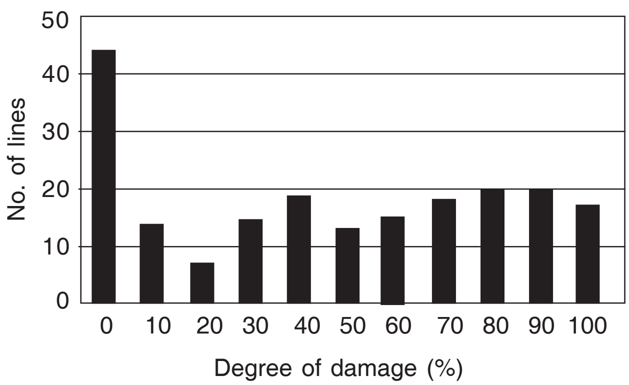
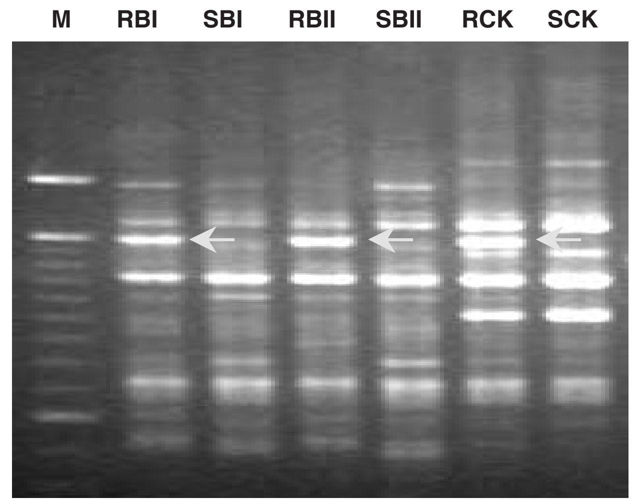


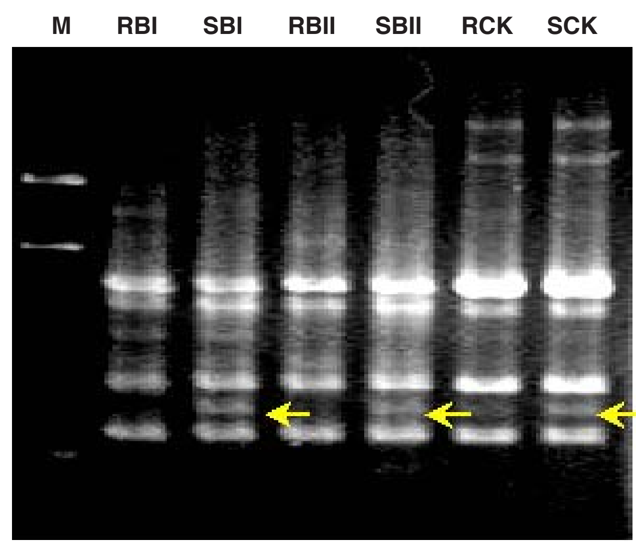
Fig. 16. *Bruchid damage for 200 recombinant inbred lines*

For generation of molecular markers for bruchids, DNA from both extreme tails was separately bulked for RAPD analysis. Two resistant bulks (0% damage) and two susceptible bulks (80–100% damage) were prepared. More than 600 primers were pre-tested for effective amplification in mungbean. A total of 360 primers were selected and RAPD-tested with four bulked samples and two parents. Eight out of 360 primers produced polymorphic banding between R and S bulks but not between R and S parents. Only one primer (OPV02) produced a unique band in two R bulks and TC1966 (R parent) (Fig. 17), and the other primer (UBC223) produced a unique band in two S bulks and NM92 (S parent) (Fig. 18). Most of the RAPDs (8 out of 10) were detected in R bulks, while two detected in S bulks. These RAPDs will be further screened and studied by linkage analysis to explore its correlation with bruchid reaction.



Lanes from left to right: molecular weight marker (M), resistant bulk I (RBI), susceptible bulk I (SBI), RBII, SBII, resistant check (RCK) and susceptible check (SCK)

Fig. 17. *RAPD analysis for bruchid resistant and susceptible bulk DNA samples with primer OPV02*



Lanes from left to right: molecular weight marker, resistant bulk I (RBI), susceptible bulk I (SBI), RBII, SBII, resistant CK and susceptible CK

Fig. 18. *RAPD analysis for bruchid resistant and susceptible bulk DNA samples with primer UBC223*

Markers for MYMV

A single recessive gene is believed to control resistance to MYMV. A cooperative project with Punjab Agriculture University was initiated to screen these RILs. Strategies for marker generation will be proposed based on the screening results.

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 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 socio-economic and nutritional aspects of vegetables; and
- develop improved decision-making tools for national agricultural research and extension systems to increase the effectiveness and efficiency of vegetable research and development efforts.

Program Director: LL Black

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

Vegetable production in the tropics and subtropics is challenged by high temperatures, flooding, and diseases, limiting yield of high value vegetables such a tomato and sweet peppers. The following research projects are aimed to develop sustainable productin practices that enhance yields of these vegetables during the off-season, thereby leading to increased profits for farmers.

Contact: R Lada

Hybrid tomato lines for grafting

Tomato production during the hot-wet season provides opportunity for enhanced productivity and profits; however, yields during this season are limited by numerous environmental factors. Heat-tolerant tomato lines and grafting technologies have been developed for combating heat, flooding, and bacterial wilt (BW), but the increasing prevalence of tomato leaf curl virus (ToLCV) continue to challenge production. The goal of this study is to identify ToLCV-resistant hybrids that can serve as scions for grafted plants that can be used in the hot-wet season.

The study involved nine tomato hybrids (Avinash, CLN2026D, CHT501, FM847, FM848, PT4723, TLCV1, TLCV2, and TLCV15) and two grafting levels (grafted using eggplant rootstock EG203 and nongrafted). Eggplant seeds were sown on 26 April 2002 and tomato seeds were sown on 29 April. Grafting was done on 15 and 16 May and the grafted plants were transplanted to the field on 29 May. The experimental design was a randomized complete block design (RCBD) with three replications. Plot size was 4.0 × 1.5 m, which allowed 16 plants in each plot. Standard management practices as prescribed by AVRDC were adopted. The previous crop grown in the field was tomato. Data were collected and analyzed on yield and incidences of ToLCV and BW.

Tomato scions differed significantly in their resistance to ToLCV (Table 61). The lowest incidence of ToLCV was observed with FM847 (4.2%), although this response was not statistically different than the responses of P4723, FM848, TLCV1, TLCV2, TLCV15. Hybrids C2026D, Avinash, and CHT501 were most sensitive. Grafting significantly reduced the incidence of BW. The response of scions grafted onto EG203 varied from 0 (TLCV2) to 39% (CLN2026D) incidence of BW.

Yield differed significantly among the hybrids, irrespective of whether it was grafted or not. In general, grafted plants recorded higher yields compared to non-grafted plants. The highest yield of 35.5t/ha was obtained with grafted TLCV2, which was comparable with other top performers, grafted TLCV15 and grafted FM847. Avinash and CLN2026D, whether grafted or not, registered the lowest yields due to their susceptibilities to ToLCV.

Table 61. *Performance of tomato hybrids grafted onto EG203 rootstocks*

Hybrid	ToLCV incidence (%)[1] Grafted	ToLCV incidence (%)[1] Non-grafted	BW incidence (%)[1] Grafted	BW incidence (%)[1] Non-grafted	Yield (t/ha) Grafted	Yield (t/ha) Non-grafted
Avinash	89.6 ab[2]	97.9 ab	21.0 def	64.4 abc	0.8 i	2.0 hi
CLN2026D	97.9 ab	100.0 a	39.0 cde	50.0 bcd	6.0 f-i	6.4 f-i
CHT501	64.6 b	93.8 ab	2.1 f	80.4 abc	18.8 cde	12.7 d-g
FM847	4.2 cd	18.8 cd	6.3 f	79.2 ab	30.6 ab	8.5 f-i
FM848	6.3 cd	35.4 c	18.8 def	68.8 abc	25.2 bc	11.3 egh
P4723	22.9 cd	6.3 cd	19.4 def	91.7 a	15.1def	3.8 ghi
TLCV1	6.3 cd	4.2 cd	10.4 ef	88.1 a	15.3 def	11.0 e-h
TLCV2	8.3 cd	12.5 cd	0.0 f	56.8 bcd	35.5 a	22.6 bcd
TLCV15	6.3 cd	0.0 d	6.3 f	83.2 ab	31.6 ab	19.4 cde
Mean	34.0	41.0	13.7	73.6	19.9	10.8

Transplanted 29 May 2002 at AVRDC

[1]Observation for tomato leaf curl virus as of July 2002 and for bacterial wilt as of October 22

[2]For each parameter, mean separation within a row and/or column by Duncan's multiple range test at $P \leq 0.05$

In vivo evaluation of eggplant and tomato lines for bacterial wilt resistance

Bacterial wilt (BW) caused by *Ralstonia solanacearum* (Rs) is the most severe disease of tomato crops grown during the hot-wet season. The soil-borne disease consists of numerous strains that differ widely from region to region. It is essential to identify lines with a broad base of tolerance and the objective of this study was to evaluate eggplant and tomato lines for resistance to different strains of Rs in vivo.

The trial consisted of eggplant and tomato lines that have shown resistance to Rs in previous studies, tomato F_1 hybrids of parental lines that have shown resistance in previous research, a wild species of eggplant (*Solanum sysimbrifolium*), and susceptible checks. Plants were grown in containers and inoculated with strains of either Rs 4, 186, or 190 using standard protocols. Plant mortality and wilting symptoms were measured four weeks after inoculation.

Significant variation in mortality among the eggplant and tomato entries was observed for the various Rs strains. Rs 190 was the most virulent strain in this study, causing death to 34.9% of plants inoculated with the strain (Table 62).

Among eggplant accessions, TS3, TS69, EG192, EG195, EG203, and EG219 consistently showed the highest levels of resistance for the three Rs strains. EG195 appeared to be most resistant as less than 5% of its plants showed wilting symptoms. In contrast, the susceptible check EG048 suffered near 100% mortality for all strains. The wild species *S. sysimbrifolium* was highly resistant to Rs 190, but was moderately sensitive to other strains.

The tomato accessions varied in their resistance to different Rs strains (Table 62). For example, H7996 was the most resistant of all tomato entries to Rs 4, resisted Rs 186, but was susceptible to Rs 190. The F_1 derived from crossing H7996 and CRA 66 was most resistant to Rs 186, and showed the least amount of wilting symptoms overall among the tomato entries. Resistance among the hybrid progeny of H7996, BF Okitsu 101, and CRA 66 were relatively similar. The heat-resistant hybrid CHT501 showed intermediate levels of tolerance to Rs 4 and 186, but was susceptible to Rs 190. The susceptible check, L390, suffered near 100% mortality for all strains.

In conclusion, eggplant line EG195, tomato line BF Okitsu 101 and the hybrid produced from crossing tomato lines H7996 and CRA 66 show comprehensive resistance to multiple strains of *Ralstonia solanacearum.*

Table 62. *Sensitivity of eggplant and tomato rootstocks inoculated with strains of* Ralstonia solanacearum

Rootstocks	Plant mortality (%)[1] Rs 4	Rs 186	Rs 190	Wilting symptoms (%)
Eggplant				
EG192	8.5 ef	4.5 cd[2]	22.0 c-f	29.3 cd
EG195	2.0 f	3.5 cd	9.0 d-g	4.8 f
EG203	7.0 f	2.0 cd	19.0 c-f	15.0 def
EG219	2.5 f	4.5 cd	9.5 efg	6.7 f
TS3	3.0 f	1.0 cd	15.0 c-f	11.7 ef
TS56B	31.0 bcd	14.5 bc	49.0 b	42.5 c
TS69	6.5 f	7.5 cd	5.0 fg	10.0 ef
S. sysimbrifolium	28.0 bcd	24.5 b	1.0 g	40.0 c
EG048 (ck)	100.0 a	96.5 a	100.0 a	99.2 a
Tomato				
BF-Okitsu 101	11.0 def	3.5 cd	18.0 c-f	25.8 cde
CRA-66	24.0 b-e	2.0 cd	38.0 bc	40.8 c
H7996	3.5 f	2.0 cd	48.0 b	35.8 c
CRA-66*BF-Okitsu 101	12.5 c-f	4.5 cd	20.0 cde	33.3 c
H7996*BF-Okitsu 101	4.5 f	3.5 cd	24.0 cd	17.5 def
H7996*CRA-66	5.0 f	0.5 d	19.5 c-f	14.2 def
CHT501 (F_1)	43.5 b	11.5 bc	96.5 a	57.5 b
L390 (ck)	100.0 a	95.0 a	100.0 a	99.2 a
Mean	23.1	16.5	34.9	34.3

[1]Measured four weeks after inoculation
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.01$

Effects of chili pepper rootstock on the performance of sweet pepper entries during the hot-wet season

Sweet pepper plants are weak-rooted and extremely sensitive to the heat and flooding characteristic of the hot-wet season. Chili pepper has a more extensive root system and is more tolerant of these stresses. It is hypothesized that grafting sweet pepper scions onto chili pepper rootstocks will increase yields of sweet pepper in the hot-wet season. The objective of this study was to evaluate chili rootstocks for their future use as rootstocks in sweet pepper production in the hot-wet season.

Four chili pepper accessions (97-7195-1, 9852-54, CM334, and Toom) were used as rootstocks for scions

(Blue Star, Andalus, 9852-131, PBC438, and PBC843). The grafted plants were transplanted on 18 June 2002. The experimental design involved 5 (scions) × 5 (4 rootstocks + non-grafted control) set to a factorial experiment using a randomized complete block design (RCBD) with three replications. The grafted and non-grafted plants were transplanted onto 30-cm raised beds at a spacing of 60 cm between rows and 50 cm between plants within a row. Plots were 1.5 x 4.0 m, with 16 plants per plot. Standard cultural practices of AVRDC were followed. Plots were flooded for 48 h at the peak flowering stage (60 days after transplanting).

Non-grafted plants registered the lowest yields irrespective of cultivar (Table 63). Among non-grafted plants, Blue Star produced the highest yields, 24.0 t/ha, while accessions PBC 438 and PBC 843 produced only 4.8 and 3.4 t/ha, respectively.

Grafting significantly increased yields for all accessions except in the case of 9852-131. Irrespective of scions, plants grafted onto rootstock 9852-54 produced the highest yields. The relative advantage for plants grafted onto this rootstock, compared to non-grafted controls, was 127% for Blue Star, 218% for Andalus, 68% for 9852-131, 529% for PBC438, and 841% for PBC843.

Plant survival after 48 hr of flooding also demonstrated the superiority of grafted plants (Table 64). In this test of flooding tolerance, rootstock 9852-54 again showed its superiority. The relative advantage of plant survival due to grafting using 9852-54 ranged from 31% for PBC843, 56% for 9852-131, 74% for Andalus, 105% for Blue Star, and 140% for PBC438. In conclusion, these studies found rootstock 9852-54 to be superior in terms of plant survival and yields after flooding.

Table 63. *Yield (t/ha) of sweet pepper scions grafted onto chili pepper rootstocks*

	Scions					
Rootstocks	9852-131	Andalus	Blue Star	PBC438	PBC843	Mean
97-7195-1	21.5	37.2 b	34.3 bc[1]	14.1 c	22.6 ab	25.9
9852-54	22.7	57.3 a	54.6 a	30.2 a	32.0 a	39.4
CM334	16.0	35.4 b	33.6 bc	15.7 bc	20.4 b	24.2
Toom	22.5	43.6 b	44.8 ab	21.7 b	30.3 ab	32.6
Non-grafted	13.5	18.0 c	24.0 c	4.8 d	3.4 c	12.7
Mean	19.2	38.3	38.3	17.3	21.7	

Transplanted 18 June 2002 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.01$

Table 64. *Effect of chili rootstocks on survival of grafted sweet peppers after 48 hr flooding during the hot-wet season*

	Scions					
Rootstocks	9852-131	Andalus	Blue Star	PBC438	PBC843	Mean
97-7195-1	45.8 a-e[1]	45.8 a-e	62.5 a-c	56.3 a-d	47.9 a-e	51.7
9852-54	39.6 a-e	72.9 a	72.9 a	64.6 ab	60.4 a-c	62.1
CM334	12.5 e	29.2 b-e	56.3 a-d	35.4 a-e	27.1 b-e	32.1
Toom	52.1 a-d	70.8 a	66.7 ab	50.0 a-d	43.8 a-e	56.7
Non-grafted	25.0 cde	41.7 a-e	35.4 a-e	20.8 de	45.8 a-d	33.8
Mean	35.0	52.1	58.8	45.4	45.0	

Transplanted 18 June 2002 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.01$

Effects of grafting and shelters on sweet peppers grown in the hot-wet season

Sweet pepper yields are very low in the hot-wet season. The weak-rooted plants are susceptible to damage from bacterial wilt, flooding, and the impact of heavy rains. The objective of this study was to assess the effects of grafting and rain shelters on productivity of sweet pepper during the hot-wet season.

The experiment involved a split-split plot design with 2 × 2 × 3 factorial combination of shelter (shelter and no shelter) as main plot, and rootstocks (Toom, 9852-54, non-grafted) and scions (Andalus and Blue Star) as subplot treatments. There were four replications. The plot size was 1.5 × 6 m. Plants were transplanted on a 30-cm raised bed and set in double rows on each bed spaced at 60 cm between rows and 50 cm between plants within the row. This allowed a population density of 24 plants/plot (16,667 plant/ha). Standard cultural practices of AVRDC were followed. Observations on yield and incidences of blossom end rot (BER) and bacterial wilt (BW) were collected.

The interaction between shelter, rootstock, and scion were not significant for yield and incidence of BW. Rain shelters did not affect yield or BW significantly, but did cause significantly more (70%) BER (Table 65). The summer of 2002 was relatively dry and potential benefits from the rain shelter may not have been expressed.

Table 65. *Main effects of rain shelter on total yield, blossom end rot (BER) damage, and incidence of bacterial wilt (BW) for grafted sweet pepper*

Shelter	Total yield (t/ha)	BER damage (t/ha)	BW (%)
Yes	29.4	7.5 a[1]	27.4
No	33.2	4.4 b	29.9

Grown in Summer 2002 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.01$

The interaction between rootstock and scion however was significant. Grafted plants produced significantly higher yields and suffered lower incidences of BW compared to non-grafted plants. Among rootstocks, 9852-54 extended a significant level of protection against BW and significantly enhanced the yields of both Andalus and Blue Star, by 110% and 221%, respectively (Table 66). Although grafted plants of both cultivars suffered from less incidence of BW, they suffered from higher incidences of BER. Scions grafted onto Toom were most susceptible to BER.

In conclusion, grafting using 9852-54 provided protection against BW and greatly enhanced the total yield of commercial sweet pepper cultivars. Although grafted plants suffered more BER, the overall yield benefits of grafting were impressive. There were no significant advantages detected for rain shelters in the relatively dry summer of 2002.

Table 66. *Performance of sweet pepper scion/chili pepper rootstock combinations for total yield and incidences of blossom end rot (BER) and bacterial wilt (BW)*

Scions	Rootstocks	Total yield (t/ha)	BER damage (t/ha)	BW incidence (%)
Andalus	9852-54	43.4 a[1]	10.8 b	14.6 b
Andalus	Toom	36.2 ab	11.0 a	29.2 b
Andalus	Non-grafted	13.5 c	5.0 bc	62.0 a
Blue Star	9852-54	42.4 a	3.9 bc	6.8 b
Blue Star	Toom	36.2 b	11.0 a	29.7 b
Blue Star	Non-grafted	20.1 c	1.6 c	27.1 b

Grown in Summer 2002 at AVRDC
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.01$

Evaluation of *Capsicum* species for flooding resistance

Grafting sweet pepper onto chili rootstocks may enhance yields during the hot-season. The chili rootstock may provide a degree of tolerance to flooding, a limiting factor in production during the season. This study examined the hypothesis that tolerances to flooding differ among *Capsicum* species.

Eighty-five accessions belonging to six species of *Capsicum* (*C. annuum, C. baccatum, C. chacoense, C. chinense, C. frutescens, C.* and *pubescens*) were raised and transplanted onto a 30-cm raised bed. The bed size was 1.5 × 6 m. Plants were set at two rows spaced at 60 cm apart with 40 cm between plants; plant density was 20 plants/plot. Plots were transplanted on 16 July 2002. The field was under a tomato-rice cropping system.

Matured plants were flooded under a constant water level for 48 hr in the field. Soil temperatures were 29–31°C from 10:15 AM to 3:00 PM during the days of flooding. Plant survival was recorded two weeks after the floodwater was removed.

Among the six species, the plant survival percentage was highest with accessions of *C. frutescens* and *C. baccatum* (Table 67). Cultivated pepper (*C. annuum*) accessions were moderately sensitive. A total of 48 ecotypes, mostly from *C. frutescens*, *C. chacoense* and *C. baccatum*, were selected for future evaluation.

Table 67. *Plant survival of* Capsicum *species subject to 48 hr of flooding under field conditions*

Species	Lines evaluated	Plant survival (%)	Ecotypes selected
C. annuum	15	20.6	6
C. baccatum	16	45.0	9
C. chacoense	15	30.9	11
C. chinense	19	29.7	9
C. frutescens	17	46.3	13
C. pubescens	3	0	0
Total	85	28.8	48

Transplanted 16 July 2002

Mini-cabbage for hot-wet season production in tropical lowlands

Common cabbage production in the tropics is concentrated in the highlands in order to take advantage of the lower temperatures. However, in order to reduce seasonality during the hot-wet season and to enhance productivity of the lowlands, it is essential to develop technologies for their production in the summer. Seed companies have developed heat-tolerant hybrids with potential for lowland production. In previous trials at AVRDC some small-headed cultivars were identified with good heading potential, early maturity, and uniformity in heading. The purpose of this study was to evaluate the performance of the selected mini-cabbage cultivars for hot-wet season production in tropical lowlands and to evaluate various protective production systems.

Two mini-cabbage cultivars, Golden Cross and Miniball, were compared with two regular-size cultivars, Shiafong #1 and KY Cross, for earliness and yield. The trial was arranged in a split plot design with three replications. Treatments consisted of three different environments: nethouse with nylon netting, greenhouse (nethouse with roof of clear polyethylene), and open field. The cultivars were randomly arranged inside each of structures. The houses were made of a galvanized pipe frame structure that was 20-m-long, 5-m-wide, and 2.8-m-high with an arched top. Material used to enclose the houses was 32-mesh nylon net. Mini-cabbage plots consisted of three 3.6 × 1.0 m, 30-cm-high beds with 72 plants in a double row with 30 cm in-row spacing (66,666 plants/ha). Regular cabbage plots consisted of two 3.5 × 1.5 m, 30-cm-high beds with 28 plants in a double row with 50 cm in-row spacing (26,666 plants/ha).

The first trial was sown on 8 May and transplanted on 6 June 2002. Unusually hot-dry weather during June seriously retarded growth of all entries and plants grown under various protective structures were severely affected. The interaction between cultivar and environment was highly significant. Heavy rain on 1, 11, and 17 July (364 mm total) seriously damaged regular cultivars. The early maturing mini-cabbages escaped from damage by early harvest. Golden Cross showed most stability under different environments and yielded an acceptable 17 t/ha on average, which is equivalent to a daily yield of 425 kg/ha/day.

The second trial was sown on 18 July and transplanted on 15 August 2002. Except for a heavy rain on 11 September (60 mm), there was hardly any precipitation. The unusually warm mean temperatures of 29.0°C in September and 27.6°C October resulted in adverse effects to all entries (Table 68).

The interaction between cultivars and structures for maturity and yield was significant for the early summer planted mini-cabbages (Table 69). Golden Cross matured earliest under structures and in the open field. Planting mini-cabbage under open field conditions provided higher yields irrespective of any cultivar compared to protective structures. In the open field, Golden Cross was the highest yielder and significantly higher than Shiafong #1 and KY Cross. Golden Cross provided the highest daily yield (425 kg/ha/day).

In the late summer plantings, there was no significant interaction for maturity between cultivars and structures (Table 68). Again, Golden Cross matured earliest among the cultivars. There was no significant advantage of structures on earliness in maturity. The highest yield (35.1 t/ha) was observed with Miniball grown under open field conditions. As with the early summer planting, higher yields were generally obtained in the open field rather than under structures. Miniball registered the highest daily yield (576 kg/ha/day).

In conclusion, mini-cabbages performed better under open field conditions than under structures during the summer season. Golden Cross is recommended for early summer and Miniball for late summer production.

Table 68. *Response of cabbage cultivars under different growing environments*[1]

Cultivar	Maturity (DAT[2]) GH	NH	OF	Mean	Yield (t/ha) GH	NH	OF	Mean	Daily yield (kg/ha/day)
Shiafong #1	66 ax[3]	58 ay	60 ay	61	4.9 by	10.0 bx	5.6 cxy	6.9	113
KY Cross	63 ax	61 axy	57 ay	62	0.6 cy	8.0 bx	12.0 bx	6.9	111
Golden Cross	43 cx	41 bx	36 cy	40	9.5 ay	19.5 ax	21.8 ax	17.0	425
Miniball	55 bx	43 by	44 by	47	3.4 bcy	16.9 ax	20.5 ax	13.6	289
Mean	57	51	49		4.6	13.6	15.0		

Transplanted 6 June 2002 at AVRDC
[1] GH = nethouse with clear polyethylene roof; NH = nethouse; OF = open field
[2] DAT = days after transplanting
[3] Mean separation in columns (a,b,c) compares cultivars, and in rows (x,y) compares environments using LSD at $P \leq .05$

Table 69. *Response of cabbage cultivars under three different environments*[1]

Cultivar	Maturity (DAT[2]) GH	NH	OF	Mean	Yield (t/ha) GH	NH	OF	Mean	Daily yield (kg/ha/day)
Shiafong #1	60	61	57	59 a[3]	22.9 ay	25.1 bxy	28.5 bx	25.5	432
KY Cross	58	60	58	59 a	24.3 ay	27.3 bxy	28.6 bx	26.7	453
Golden Cross	47	48	47	48 c	18.2 by	22.1 cx	23.6 cx	21.3	444
Miniball	56	53	52	54 b	24.5 ay	33.6 axy	35.1 ax	31.1	576
Mean	55 x	56 x	54 x		22.5	27.0	29.0		

Transplanted 15 August 2002 at AVRDC
[1] GH = nethouse with clear polyethylene roof; NH = nethouse; OF = open field
[2] DAT = days after transplanting
[3] Mean separation in columns (a,b,c) compares cultivars, and in rows (x,y) compares environments using LSD at $P \leq .05$

Response of warm season vegetables grown during the cool-dry season under protective structures

Enhancing productivity and profitability of vegetables will reduce poverty and malnutrition. Producing good yields of vegetables in the off-season when market prices are highest will enhance profitability. Protective structures may enhance warm-season vegetable production in the lowland tropics during the hot-wet season. These structures can also be used to produce warm-season vegetables during the cold-dry season since these structures can act as thermal curtains, providing required heat. Further, it would also pay back the costs of the structures. The objective of this study is to evaluate the growth of warm-season vegetables during the cool-dry season under different types of structures.

The trial was established in a field previously planted with summer tomato and was arranged in RCBD with four replications. Treatments consisted of three levels of structures (rain shelter with side netting [RS+Net], rain shelter with open sides [RS], and open field [OF]). There was a single bed (2.0 m wide and 5.0 m long) under each of the shelters. The rain shelters were made of galvanized pipe frame structure: 5.0 m long, 2.4 m wide, 2.4 m high, and topped with UV-resistant clear polyethylene. Sixty-mesh nylon net was used to enclose the sides of RS+Net structure.

Bitter gourd, cucumber, okra, and yardlong bean were transplanted 15 November 2001 in two rows per bed. Cucumber, okra, and yardlong bean were planted with 50 cm within rows and 80 cm between rows. Bitter gourd was planted at a wider spacing with 2.5 m within row and between plants. Insect pests and diseases were managed by weekly spraying of insecticide/fungicide mixtures. The average maximum air temperature in the RS+Net treatment was about 3–4°C (during the winter) and 5–6°C (during the spring season) higher than the RS and OF treatments. Average minimum temperature was about 1°C higher in the RS+Net treatment than the RS and OF treatments throughout the growing season. Bitter gourd, cucumber,

Table 70. *Marketable fruits and yield of selected warm-season vegetables grown under different protective environments*

	Bitter gourd		Cucumber		Okra		Yardlong bean	
Shelter[1]	Markatble fruits[2]	Yield (t/ha)	Markatble fruits[2]	Yield (t/ha)	Marktable pods[2]	Yield (t/ha)	Marktable pods[2]	Yield (t/ha)
RS+N	109 a	59.7 a	590 a	57.9 a	121 a	21.5 a	1026 a	33.3 a
RS	105 a[3]	46.3 a	200 b	15.4 b	54 a	8.1 a	861 a	27.1 b
OF	61 b	25.4 b	199 b	14.8 b	52 a	7.2 a	874 a	27.8 b
Mean	91	43.8	329	29.4	76	12.3	920	29.4

Transplanted 15 November 2001 at AVRDC

[1] RS+N = rain shelter + netting along sides; RS = rain shelter alone; OF = open field

[2] Data presented on 10 m^2 basis

[3] Mean separation in columns by Duncan's multiple range test, $P \leq .05$

okra, and yardlong bean were harvested 24 January to 15 April 2002, 19 December 2001 to 11 March 2002, 18 February to 25 March 2002, and 8 February to 15 April 2002, respectively.

Marketable fruit number and total yield of bitter gourd were significantly higher under RS+Net than under the OF (Table 70). Although yields were enhanced under RS+Net, this environment was not significantly better than the rain shelter without netting. With respect to cucumber and yardlong bean, both marketable fruit number and total yield were enhanced significantly under RS+Net, accounting for 291% and 199% increases compared to the OF. Although the total yield of okra was enhanced under RS+Net, by nearly twofold, it was not significantly different than other treatments due to vast variations among different replications.

Planting density effects on yield of leafy vegetables

Yield of leafy vegetables varies with plant population density. Yield response to planting density also differs from one species to another. The objectives of this study were: 1) to evaluate the effect of plant spacing on growth and productivity of selected leafy vegetables, and 2) to determine optimum planting density for maximum biomass and edible yield.

Leafy vegetables evaluated were amaranth (*Amaranthus cruentus*), Jute mallow (*Corchorus olitorius*), kangkong (*Ipomoea repens*), and pak-choi (*Brassica chinensis*). Vegetables were planted at three row spacings (10, 20, and 30 cm). For each row spacing, three within row plant spacings were used (5, 10, and 15 cm). The nine plant spacing combinations and the number of rows per bed are shown in Table 71. All plots followed the standard bed size of 1 m wide and 2 m long (1 × 2 m). The experiment was laid out using a split plot design with four replications. The main plots were assigned to between row spacing while the subplots were assigned to within row spacing. All vegetables were direct-seeded on 25–26 October 2002 and thinned down to one seedling per stand after developing two to three true leaves. Management practices such as fertilizer application, irrigation and drainage, and pest management followed the AVRDC recommendations for leafy vegetable cultivation. Once-over harvest at the prime market stage was followed for all vegetables.

Data were collected on days from sowing to harvest, biomass, plant height, number of leaves, leaf width and length including petiole, and leaf area index (LAI). In this report only data on plant weight and plant yield are presented. Statistical differences in yield response to planting density were determined using orthogonal contrast and regression analysis.

Table 71. *Plant spacing combinations for leafy vegetables*

Row spacing (cm)	In-row spacing (cm) 5	10	15	No. of rows/bed
10	5 × 10	10 × 10	15 × 10	4
20	5 × 20	10 × 20	15 × 20	3
30	5 × 30	10 × 20	15 × 30	2

Sown 25–26 October 2000 at AVRDC

Amaranth

The effect of planting density was significant on plant weight and yield (Table 72). Plant weight and yield increased with increasing plant density. Orthogonal contrasts indicated that plant weight and yield from the 200 plants m^2 population were higher than those in the

50 and 22 plants m^2 population density. Plant weight and yield did not differ significantly when plants were spaced differently but with similar plant density (Table 72). For instance, plant weight and yield at the 5 × 20 cm and 10 × 10 cm spacings (both with 100 plants m^2) were similar. Likewise, the difference in plant weight and yield between the 5 × 30 cm and 15 × 10 cm (67 plants m^2) were not significant (Table 72). The yield response of amaranth to planting density was quadratic and significant (R^2 = 0.97)**. Maximum yield was attained at plant density of 200 m^2.

Table 72. *Plant weight and yield of amaranth as influenced by plant density*

Treatment	Spacing (cm)	Population (plant/m^2)	Plant weight (g)	Yield (kg/m^2)
1	5 × 10	200	51.5	10.4
2	5 × 20	100	53.4	5.3
3	5 × 30	67	49.9	3.3
4	10 × 10	100	56.4	5.6
5	10 × 20	50	43.3	2.2
6	10 × 30	30	45.4	1.5
7	15 × 10	67	43.4	2.9
8	15 × 20	33	34.2	1.6
9	15 × 30	22	31.1	2.5
Contrasts				
G1 (P200 vs. P50 vs. P22)		*	**	
G2 (P100 vs P67 vs. P33)		*	**	
P100 (T2 vs. T4)		NS	NS	
P67 (T3 vs. T7)		NS	NS	
P33 (T6 vs T8)		NS	NS	
G1 vs. G2	NS	*		

Sown 25–26 October 2002 at AVRDC
NS,*, ** Nonsignificant or significant at $P \leq 0.05$, or 0.01, respectively

Jute mallow

Orthogonal contrasts indicated no significant differences in plant weight among plant densities (Table 73). However, significant differences in yield were observed between plant densities. Plants grown at high density yielded greater than plants at low density. Highest yield was obtained from density of 200 plants m^2. Differences in yield were not significant when plants were spaced differently but with similar density (Table 73). The yield response of jute mallow to planting density was similar to amaranth which followed a quadratic pattern and significant (R^2 = 0.98). This data indicate that jute mallow can be planted at closer spacing (5 × 10 cm) for maximum yield.

Table 73. *Plant weight and yield of jute mallow as influenced by plant density*

Treatment	Spacing (cm)	Population (plant/m^2)	Plant weight (g)	Yield (kg/m^2)
1	5 × 10	200	13.9	2.20
2	5 × 20	100	14.1	0.95
3	5 × 30	67	15.3	0.92
4	10 × 10	100	12.6	0.91
5	10 × 20	50	13.4	0.47
6	10 × 30	30	10.8	0.29
7	15 × 10	67	10.5	0.66
8	15 × 20	33	10.1	0.27
9	15 × 30	22	12.7	0.26
Contrasts				
G1 (P200 vs. P50 vs. P22)		NS	**	
G2 (P100 vs. P67 vs. P33)		NS	**	
P100 (T2 vs. T4)		NS	NS	
P67 (T3 vs. T7)		NS	NS	
P33 (T6 vs. T8)		NS	NS	
G1 vs. G2	NS	**		

Sown 25–26 October 2002 at AVRDC
NS,*, ** Nonsignificant or significant at $P \leq 0.05$, or 0.01, respectively

Kangkong

Although plant density did not significantly influence kangkong plant weight, yield increased significantly with increasing plant density (Table 74). The response was similar to that of jute mallow. Highest yield was obtained at density of 200 plants m^2. Spacings of 5 × 10 cm, 5 × 20 cm, and 10 × 10 cm resulted in significantly higher yield than spacings of 5 × 30 cm, 10 × 20 cm, 10 × 30 cm, 15 × 10 cm, 15 × 20 cm, and 15 × 30 cm. Within the same density but with different plant spacing, differences in yield were not significant (Table 74). Yield increased linearly as plant density increased (Y = 0.37 + 0.004X, r = 0.94**). This data that suggest kangkong can be planted at higher density for top yield.

Pak-choi

Both the plant weight and yield of pak-choi was significantly influenced by planting density. As shown in Table 75, plant weight tended to decrease when plants were spaced closer or at higher density. Except for spacing at 5 × 20 cm (100 plants m^2), plant weight of pak-choi at lower densities was higher than those obtained from the highest density of 200 plants m^2. The yield response of pak-choi to planting density followed a linear pattern. Yield increased linearly as plant density increased (Y = 2.44 + 0.03X, r = 0.194**).

The data indicate that wider spacing (lower plant density) produced larger plant size but lower total yield compared to closer spacing or higher plant density.

Table 74. *Plant weight and yield of kangkong as influenced by plant density*

Treatment	Spacing (cm)	Population (plant/m²)	Plant weight (g)	Yield (kg/m²)
1	5 × 10	200	10.0	1.10
2	5 × 20	100	13.5	0.76
3	5 × 30	67	12.2	0.63
4	10 × 10	100	9.4	0.79
5	10 × 20	50	10.9	0.53
6	10 × 30	30	13.2	0.28
7	15 × 10	67	17.6	0.41
8	15 × 20	33	13.3	0.39
9	15 × 30	22	13.5	0.29
Contrasts				
G1 (P200 vs. P50 vs. P22)		NS	**	
G2 (P100 vs. P67 vs. P33)		NS	*	
P100 (T2 vs. T4)		NS	NS	
P67 (T3 vs. T7)		NS	NS	
P33 (T6 vs. T8)		NS	NS	
G1 vs. G2	NS	NS		

Sown 25–26 October 2002 at AVRDC
NS,*, ** Nonsignificant or significant at $P \leq 0.05$, or 0.01, respectively

Table 75. *Plant weight and yield of pak-choi as influenced by plant density*

Treatment	Spacing (cm)	Population (plt/m²)	Plant weight (g)	Yield (kg/m²)
1	5 × 10	200	69.3	9.1
2	5 × 20	100	108.2	7.1
3	5 × 30	67	111.2	6.2
4	10 × 10	100	74.6	4.7
5	10 × 20	50	118.2	4.3
6	10 × 30	30	114.2	3.2
7	15 × 10	67	95.5	6.4
8	15 × 20	33	120.0	3.5
9	15 × 30	22	126.7	2.3
Contrasts				
G1 (P200 vs. P50 vs P22)		**	**	
G2 (P100 vs P67 vs. P33)		**	**	
P100 (T2 vs. T4)		**	*	
P67 (T3 vs. T7)		NS	NS	
P33 (T6 vs T8)		NS	NS	
G1 vs. G2	NS	NS		

Sown 25–26 October 2002 at AVRDC
NS,*, ** Nonsignificant or significant at $P \leq 0.05$, or 0.01, respectively

Cell size for production of leafy vegetable transplants

Transplant production constitutes one of the major costs in the production of leafy vegetables. The cost of producing transplants can be reduced by using optimum container (cell) size; however, appropriate container size depends on leafy vegetable species and varieties. Larger transplants require larger container or cell size, whereas, smaller transplants require smaller cell size. There is no one size that fits all varieties or species. The objective of this study was to determine the optimum cell size of plastic trays for producing the highest yields of leafy vegetables.

Treatments consisted of four different cell-sizes of plastic trays: A = 128-cell; B = 100-cell; C = 72-cell; and D = 50-cell. The corresponding dimension (top diameter × depth × bottom diameter) in cm for each cell were A = 3.0 × 3.2 × 1.9; B = 4.0 × 2.6 × 4.2; C = 4.5 × 2.5 × 4.5; and D = 6.0 × 4.5 × 5.0. Thus, the larger the cell size, the lower the number of cells per tray. Seeds of eight leafy vegetables: 1) non-heading Chinese cabbage, 2) pak-choi, 3) choysum, 4) Chinese kale, 5) amaranth, 6) celosia, 7) jute mallow, and 8) kangkong were sown in all four containers. Seedlings were thinned to one per cell five to seven days after germination. Seedlings were grown in the greenhouse for 15 days before transplanting into the field. All treatments were transplanted in the field on the same day regardless of transplant size.

Transplants were planted on 30-cm-high raised beds with 60-cm-wide bed tops. Bed size was 1 m × 2 m or 2 m². Each bed had four rows spaced at 10 cm between rows. Transplants were spaced 15 cm within rows. For each species, plots were arranged in RCBD with four replications. Two middle rows were sampled at harvest; data on plant height, plant weight and yield were determined from harvested samples.

Non-heading Chinese cabbage

The effect of cell size on plant height, weight and yield was significant (Table 76). Larger and taller plants were produced from the 50-cell tray compared to trays of other cell sizes. Highest yield was also produced from the 50-cell tray and was significantly different from other treatments. The recommended container for this crop is a 50-cell tray.

Pak-choi

Transplants grown in the 50-cell tray resulted in higher plant weight and yield as compared with other cell size treatments (Table 76). Plant weight in the 50-cell tray was significantly higher than all other treatments, but the yield from the 50-cell tray was similar to that in the 100-cell tray. For pak-choi, optimum container sizes for transplant production would be 50- or 100-cell trays.

Table 76. *Plant height, weight, and yield of leafy vegetables as influenced by transplant container size*

Container size (cells/tray)	Transplant Plant height (cm)	Plant weight (g)	Plant yield (kg/m²)
Non heading Chinese cabbage			
50	31.5 a[1]	78.8 a	4.52 a
72	28.7 bc	60.4 b	3.35 b
100	29.5 b	58.3 b	3.38 b
128	28.3 c	50.6 c	3.11 b
Pak-choi			
50	22.8 a	85.6 a	5.30 a
72	22.1 ab	76.9 b	4.50 b
100	21.6 b	79.6 b	5.10 a
128	20.9 b	67.8 c	4.1 0 c
Choysum			
50	31.5 b	38.0 c	1.99 b
72	36.8 a	50.6 a	3.14 a
100	36.5 a	48.1 ab	2.93 a
128	33.3 b	43.9 b	2.23 b
Chinese kale			
50	34.0 ab	45.0 b	2.52 b
72	35.6 a	54.9 a	3.25 a
100	34.9 ab	52.9 a	3.24 a
128	33.9 b	47.2 b	3.15 a
Amaranth			
50	24.5 ab	24.3 a	1.33 b
72	25.0 a	25.8 a	1.81 a
100	24.0 b	24.2 a	1.69 a
128	20.5 c	21.4 b	1.13 c
Celosia			
50	40.3 a	43.0 a	2.99 a
72	37.0 b	42.2 a	2.52 b
100	37.2 b	43.2 a	2.80 a
128	33.5 c	33.1 b	1.87 c
Kangkong			
50	39.5 a	27.9 a	1.46 a
72	35.9 bc	18.8 c	1.04 bc
100	36.7 b	22.0 b	1.22 b
128	33.8 c	18.3 c	0.94 c

Sown December 2001 at AVRDC

[1] Mean separation in columns for each vegetable by Duncan's Multiple Range Test at $P \leq 0.5$

Choysum

The effect of cell size on plant weight, height and yield of choysum was significant (Table 76). Highest plant weight was produced in the 72-cell tray and was significantly different from the 50- and 128-cell trays. Lowest plant weight and yield was obtained from the 50-cell tray. Both the 72- and 100-cell trays produced similar yields and were significantly higher than the 50- and 128-cell trays. The recommended container sizes for choysum are 72- or 100-cell trays.

Chinese kale

Higher plant weight for Chinese kale was obtained from 72- and 100-cell trays (Table 76). Plant weight from these treatments was significantly higher than the 50- and 128-cell trays. However, yields from these treatments were not different from the 128-cell tray. The recommended container sizes for choysum are 72- or 100-cell trays.

Amaranth

The response of amaranth to cell size was significant (Table 76). Plant weight and yield in the 128-cell tray were significantly lower than for the other cell size treatments. There were no significant differences in plant weight between the 50-, 72- and 100-cell size treatments, but in terms of yield, the 72- and 100-cell trays produced significantly higher yields than the 50- and 128-cell size treatments. For amaranth, the optimum containers are 72- or 100-cell trays.

Celosia

The response of celosia to cell size was similar to that of amaranth (Table 76). Plant weight and yield in the 128-cell tray were significantly lower than for the other treatments. Plant weight was similar for the 50-, 72- and 100-cell treatments. This trend was also similar for plant yield, except that yield in the 72-cell tray was significantly lower than the 50- and 100-cell trays. For celosia, recommended containers are 50- or 100 cell trays.

Kangkong

The effect of cell size on plant weight, height, and yield of kangkong was significant (Table 76). Transplants grown in the 50-cell tray resulted in significantly higher plant weight, height, and yield than other cell size treatments. This indicates that kangkong is favored by larger cell size (50-cell trays).

Jute mallow

There were no data for jute mallow since low temperatures stunted field establishment and growth of this species during the season (December to February).

Conclusions

This study indicates that optimum cell size for transplant production varies with species of leafy vegetables. Optimum container size for non-heading Chinese cabbage, pak-choi and kangkong was the 50-cell per tray. For Chinese kale, amaranth, and celosia, container sizes of 50-, 72-, and 100-cell trays did not make a difference, but the use of 100-cell trays may reduce transplant production cost by decreasing cost per transplant. For all crops, the 128-cell tray was inferior since plant weight and yield from this treatment were generally lower than for other treatments.

Effect of organic manures and starter fertilizer solutions on cabbage

Previous studies at AVRDC have shown that use of a small amount of inorganic fertilizer solution as a starter, basal, and/or well-timed sidedressing may help plants to overcome the immediate nutritional needs for active plant growth (*AVRDC Reports, 1998–2001*). This study was conducted to clarify the effects of starter fertilizer solutions, additional liquid fertilizer supplements, and organic manures on growth and yield of cabbage.

The experiment involved heading cabbage (*Brassica oleracea* var. *capitata*) as a test crop. Seedlings of cultivars Tropical Delight and Green Beauty were transplanted on 3 April 2002 and 26 August 2002, and harvested on 3 June and 29 October 2002, respectively. Seedlings were planted in twin rows on 1.5-m-wide raised beds with 45 cm spacing between plants. Initial growth responses were measured as dry weights of tops (leaf and stem) on the 12^{th} or 15^{th} day after transplanting (DAT). Head weight was measured at harvest. The experiment used a RCBD with four replications. Three application methods of organic fertilizer were compared in some treatments. Organic fertilizers as a basal application were applied in single or double bands at 10 cm below the surface of beds or broadcasted on top of the beds and mixed well with the upper 10 cm of soil. Small amounts of inorganic fertilizer with various compositions were prepared as liquid fertilizer and applied immediately after transplanting or at critical periods during crop growth. Additional details for each trial are listed in the Tables 77 and 78.

Adding starter solution to the chicken manure (CM) treatments resulted in 33–67% increase in top dry weight compared to CM alone (Table 77). Basal inorganic fertilizers added to CM did not enhance initial growth significantly. However, addition of starter solution enhanced early growth by 27% compared to the standard inorganic treatment (SI).

CM alone or in combination with starter solutions (St) and liquid fertilizers (LF) enhanced yields significantly to varying degrees compared to the SI check (Table 77). Chicken manure with starter solution and an additional liquid fertilizer supplementation 12 DAT (CM + St + LF 12 DAT) produced the highest yield (34.4 t/ha), which was significantly greater than the yield of the SI check (26.3 t/ha). But this fertilizer regime was not statistically superior than using CM alone either at one or two times the N rate. This implies that the rate of CM can be considerably reduced if St and LF is supplemented and applied once 12 DAT. Also, there was no significant yield advantage due to basal inorganic fertilizer or multiple applications of LF.

As with the spring trial, the autumn trial showed that an application of St alone accelerated the initial growth significantly, 33% higher than SI control and 47% compared to PM alone (Table 78). Adding PM either as a double or single band resulted in significant enhancement in early growth by 26–29% compared to the SI check. The commercial organic extract (STO) applied as a starter reduced the early growth significantly compared to the inorganic starter (St).

In contrast to early growth, yield was significantly enhanced by using SI alone. Its yields were 45.3 t/ha. Yields declined by using PM alone (29.9 t/ha). But when PM was combined with St, followed by LF 15 DAT, and sidedressed with solid inorganic fertilizer 25 DAT, yield increased to 42.0 t/ha, significantly more than PM alone.

In conclusion, the response of common cabbage differed based on the source of organic manure, nature and application of supplemental fertilizers, and crop season. Starter solutions and liquid fertilizers can be effectively used along with CM or with PM for cabbage production to enhance yields.

Table 77. *The effects of chicken manure and liquid nutrient supplements on early growth and yield of common cabbage*

Fertilizer treatment	Compost application method	Leaf dry weight at 12 DAT[1] g/plant	Leaf dry weight at 12 DAT[1] Index[2]	Yield (t/ha)	Yield Index
Chicken manure x 2[3]	Broadcast	2.4 c[4]	77	30.1 abc	115
CM + St[5] + LF[6] 12 DAT	Broadcast	3.2 b	102	33.8 a	128
CM + St + LF 12 DAT	Double band	3.2 b	103	34.4 a	131
CM + St + LF 12 DAT	Single band	3.9 a	123	32.0 ab	121
CM + Basal+ St + LF 12DAT	Single band	4.0 a	127	31.7 ab	120
CM + Basal + LF[6] 25, 36 DAT	Single band	3.2 b	101	27.5 bc	105
CM + St + LF 12 DAT+ Side 25 DAT	Single band	–[7]	–	29.9 abc	113
CM + St + LF 12, 25,36 DAT	Single band	4.0 a	126	33.2 a	126
CM + 1/2 SI[8]	Single band	3.1 b	99	27.2 bc	103
Standard inorganic[9] (ck)	Single band	3.2 b	100	26.3 c	100

Transplanted 3 April 2002 at AVRDC
[1] DAT = days after transplanting
[2] Percentage of standard inorganic treatment
[3] Amounts of chicken manure (CM) applied equivalent to 1x and 2x of N applied as inorganic solid fertilizer (11.2 and 22.3 t/ha of CM and CM x 2)
[4] Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$
[5] Starter fertilizer (St) was inorganic liquid compound fertilizer #4 (6N–5.2P–5K), diluted and applied at a rate of 240N–206P–199K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg/ha) after transplanting
[6] Inorganic liquid compound fertilizer (LF) #4 (6N–5.2P–5K), diluted and applied at a rate of 240N–206P–199K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg/ha) at 12, 25 and 36 DAT
[7] Not tested
[8] Conventional fertilizer recommendation that comprised of 1x of organic fertilizer and half dosage of standard inorganic (SI) inorganic fertilizer
[9] Standard inorganic fertilizer(SI) comprised a basal application of 60N–38.7P–49.8K kg/ha and sidedressings of 60N–0P–33.2K kg/ha at 12, 25 and 36 DAT

Table 78. *The effects of pig manure and liquid nutrient supplements on early growth and yield of common cabbage*

Fertilizer treatment	Compost application method	Leaf dry weight at 15 DAT[1] g/plant	Leaf dry weight at 15 DAT[1] Index[2]	Yield (t/ha)	Yield Index
PM[3]	Broadcast	5.52 d[4]	86	29.9 e	66
PM + St[5] + LF[6] 15 DAT	Broadcast	6.97 bc	108	33.5 d	74
PM + St + LF 15 DAT	Double band	8.30 ab	129	33.7 d	74
PM+ St + LF 15 DAT	Single band	8.14 ab	126	33.6 d	74
PM + St	Single band	–	–	31.6 de	70
PM + Basal + St + LF 15 DAT	Single band	8.24 ab[6]	128	39.7 b	88
PM + Basal + St + LF 15, 25, 37 DAT	Single band	7.43 abc	115	40.0 b	88
PM + St + LF 15 DAT + Side[7] 25 DAT	Single band	–	–	42.0 b	93
PM + St + LF 15, 25, 37 DAT	Single band	–	–	36.9 c	81
PM + STO[8] + LFO[9] 15, 25, 37 DAT	Single band	6.73 cd	104	33.9 d	75
Nil + St + LF 15, 25, 37 DAT	None	8.58 a	133	32.8 d	72
Standard inorganic (ck)[10]	Single band	6.44 cd	100	45.3 a	100

Transplanted 26 August 2002 at AVRDC
[1] DAT = days after transplanting
[2] Percentage of standard inorganic treatment
[3] Composted pig manure (PM) applications were equivalent to 1x the rate of N applied as inorganic solid fertilizer (15.2 t/ha of PM)
[4] Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$
[5] Starter fertilizer (St) was inorganic liquid compound fertilizer #4 (6N–5.2P–5K), diluted and applied at a rate of 240N–206P–199K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg/ha) after transplanting
[6] Inorganic liquid compound fertilizer (LF) #4 (6N–5.2P–5K), diluted and applied at a rate of 240N–206P–199K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg/ha) at 15, 25, and 37 DAT
[7] Side = sidedressing, applied at 60N–0P–33.2K kg/ha at 25 DAT
[8] STO, Commercial organic solution applied as a starter at an equivalent rate as to that of St
[9] LFO, Commercial liquid organic solution applied at 15, 25, and 37 DAT
[10] Standard inorganic fertilizer (SI) comprised a basal application of 60N–38.7P–49.8K kg/ha and sidedressings of 60N–0P–33.2K kg/ha at 15, 25 and 37 DAT

Reducing fertilizer needs of vegetables through use of composts and starter solution technology

Inorganic fertilizers are widely used because they contain higher levels of nutrients and release these nutrients more quickly compared to organic fertilizers. However, excessive use of inorganic fertilizers may contribute to soil and environmental degradation. Although organic fertilizers release their nutrients more slowly, they are sustainable sources of nutrition for plants. Previous studies at AVRDC have shown that a small amount of inorganic fertilizer solution as a starter, basal, and/or well-timed sidedressing may help organically-grown plants to overcome temporary shortages of nutrients (*AVRDC Reports, 1998–2001*). An incubation study was conducted to clarify the effects of starter solutions on the NPK availability after applications of organic composts.

Surface soils collected from field were air-dried, crushed, and passed through a 4-mm sieve. The soils tested contained 9.3, 16.4, 31.9 ppm of available N, P and K, respectively, and 0.487% of T-C. Pig manure (PM) and chicken manure (CM) composts were oven-dried at 65°C, ground, and then passed through a 30-mesh sieve. For each soil, a 200 g sample was placed into an Erlenmeyer flask, amended with composts at a rate equal to 330 kg N/ha, adjusted to 0.33 bar soil moisture, and then incubated at a constant temperature of 25°C. The compost characteristics and treatments are listed in Tables 79 and 80. The treatments were replicated three times. The flasks were taken out from the incubator at 1, 3, 7, 10, 14, 21, 28, 35, 42, 56, 84, 112, and 140 days for analysis of total inorganic N, and available P and K using standard procedures.

Figures 19 and 20 illustrate the available N releasing patterns of PM and CM composts during the incubation period of 140 days. Approximately 22% and 18% total N of PM and CM, which is equivalent to 74 and 55 kg N/ha, respectively, had been converted to available forms for plants within the incubation period (Table 80). Application of starter solution at a rate equivalent to 14N–12P–12K kg/ha enhanced N releases from PM and CM by 3–4% of total application. Even though the C/N ratios of the composts applied were below 20, net immobilization occurred, thereby depleting the available N during 3 to 21 days after compost application. Application of starter solution brought inorganic N levels of the tested soil from the initial level of 9.3 ppm to 25 ppm, a difference that may be critical for initial plant growth.

The release patterns of available P from both PM and CM are presented in Fig. 21. Unlike available N, the available P of both compost amended soils remained high from the beginning of application, i.e. 132 and 111 ppm for PM and CM, respectively. Later, mineralization of the composts increased the availability of P slightly,

Table 79. *Compost characteristics and rates of application*

Compost/Starter	Total N (%)	Total P (%)	Total K (%)	Total C (%)	C/N ratio	Application (kg N/ha)
Pig manure compost	3.02	3.13	0.53	36.46	12.1	330
Chicken manure compost	2.77	2.77	3.81	23.10	8.3	330
Starter (14N-12P–11.6K)	14.00	12.23	11.67	–	–	14

Table 80. *Total amounts of NPK application and releases from the pig and chicken manure composts*

	Application rate			Actual amounts of released[1]		
Treatments	N (kg/ha)	P (kg/ha)	K (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
Pig manure compost	330	342	58	74 b[2]	106 b	34 d
Pig manure compost + starter	344	355	70	91 a	117 a	43 c
Chicken manure compost	330	330	454	55 c	74 d	322 b
Chicken manure compost + starter	344	343	466	67 b	83 c	343 a

[1] Based on highest nutrient releasing percentage during the incubation period
[2] Mean separation within columns by Duncan's multiple range test, $P \leq .05$

but the overall available P was well above the level to meet requirements of plants. Starter application could enhance the available P by nearly 3%, but this additional P was not needed.

With regard to K, nearly 72% and 81% of total K applied in with PM and CM was available from the beginning of application, which resulted in 88 and 524 ppm of available K in PM and CM-amended soils, respectively (Fig. 22). There were no further increases in available K during the incubation period. Starter application also increased K releases by 3–4%, but the high available K in CM-amended soil was more than sufficient for plant growth. On the other hand, the K content in PM compost was low. Therefore, even though the K-releasing ratio was high, the total amount of available K from PM might not be enough for healthy plant growth. Supplemental application of inorganic K fertilizer or blended application with CM composts is recommended.

This study provides evidence of the benefit of starter applications when using composts. Although the increment of NPK provided by the starter fertilizer occupies 3–4% of total amounts released, this amount is critical to improve plant establishment during the first week after transplanting. These results indicate that the supplemental fertilization of N during the initial 30 days after application of PM and CM composts, and supplementation of K after application of PM may be needed for healthy plant growth.

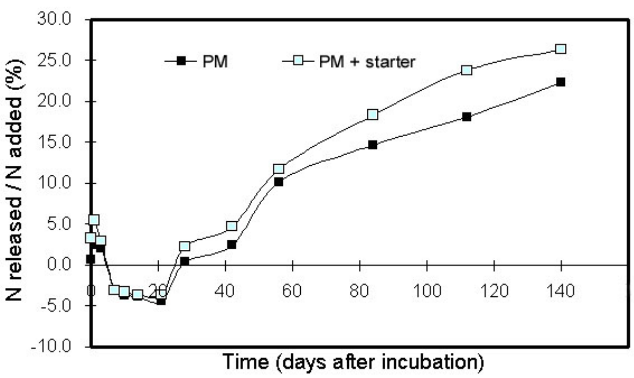


Fig. 19. *Available N released from pig manure compost amended soil as affected by starter application (as percentage of total application)*

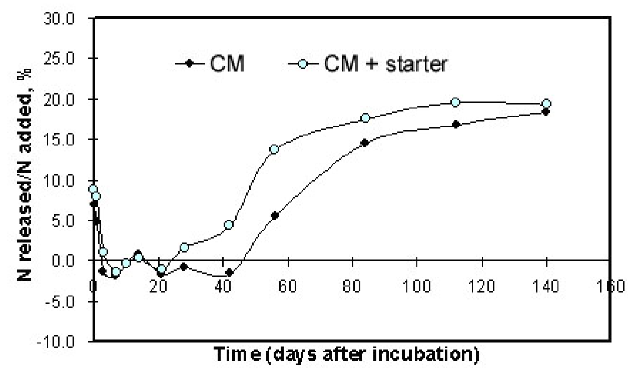


Fig. 20. *Available N released from chicken manure compost amended soil as affected by starter application (as percentage of total application)*

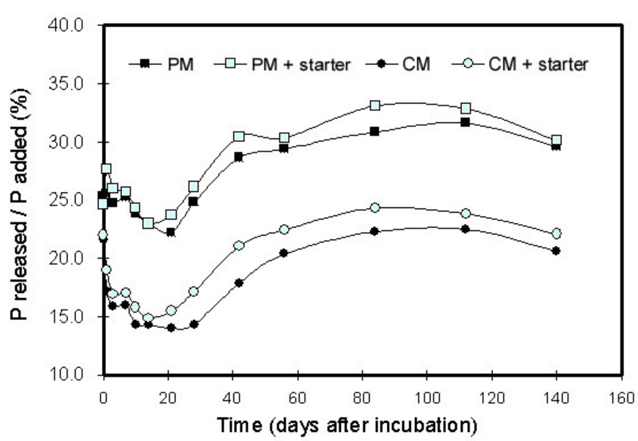


Fig. 21. *Available P released from pig and chicken manure composts amended soil as affected by starter application (as percentage of total application)*

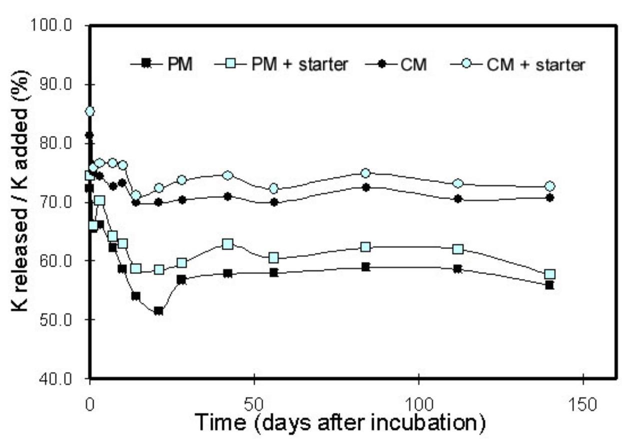


Fig. 22. *Available K released from pig and chicken manure composts amended soil as affected by starter application (as percentage of total application)*

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 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 safe vegetables available to consumers at affordable prices. At the same time, it reduces the risk that chemical pesticides poison humans and the environment.

Project Coordinator: NS Talekar

Detection of *Ralstonia solanacearum* by enrichment PCR method

Bacterial wilt (BW) caused by *Ralstonia solanacerum* is the most important disease for tomato production in the lowland tropics during the hot-wet season. The pathogen is able to survive in soil and travel along water, and it can associate with weeds with or without causing symptoms. A sensitive detection method is essential for designing an effective integrated disease management package. A new detection method called enrichment-PCR (Er-PCR) with good specificity and sensitivity was developed in 2001. The method utilizes primers specific to Rs and a selective medium to enrich the pathogen for better sensitivity. In preliminary tests, the sensitivity of Er-PCR was determined to be at the 10 to 100-cell level, which was higher than the commonly used method, direct plating on selective media like the modified selective media (SM-1). The objective of this study was to confirm the sensitivity of the Er-PCR methods using soil, weed, and irrigation water samples collected from different fields in Taiwan.

Field soil samples used for this study were collected from five fields where tomato or eggplant BW appeared at the sampling time or in the past (Table 81). Each field was divided into equal units of 5 m × 10 m. Nine sub-samples were collected randomly, at a depth of 5 to 20 cm, to form a composite sample for each unit. At each unit, 10 g of soil were taken to make a 100 ml-soil suspension for detection.

Weed samples were collected from in Chunglin and Hsintzu, where BW was infecting the current tomato crop (Table 82). Rhizosphere soils were collected from each weed plant by soaking the entire root in a flask with 20 ml water and shaking vigorously for 5 minutes. The soil suspensions were used for detection. Irrigation water samples were collected from three fields in Chunglin. Five samples each were collected (50 ml per sample) at the entrance and exit spots of the irrigation ditches for each field. All field samples were stored at room temperatures before processing for detection. For enrichment, 1 ml of soil suspension or water sample was added to 9 ml of liquid SM-1 medium. The culture was incubated at 30°C with 160 rpm for 3 days. After enrichment, two detection methods were used including direct plating on SM-1 (0.1 ml per plate) or PCR with AU759/760 primer pair, which is specific to different Rs strains regardless of their biovar and origin. For Er-PCR, 5 ml of bacterial suspension or enriched cultures were placed in a 200 ml-tube, covered with one drop of mineral oil, and placed into a boiling water bath for 5 minutes. Standard PCR analysis with 60°C as the annealing temperature was conducted. A 281-specific band indicating the presence of the pathogen was checked by electrophoresis.

Overall, the sensitivity in detecting Rs from field soil samples by Er-PCR method was similar or better than plating on SM-1 (Table 81). The pathogen population in Field KT and CL should be high, as bacterial wilt occurred in the current tomato crop. This might be the reason why both detection methods showed similar sensitivities. Fields HS, PL, and CS had been used as infested fields for evaluating resistance in tomato or eggplant (for CS) to bacterial wilt. The sensitivity of Er-PCR was much higher than plating method among samples from these three fields, particularly Field CS. Thus, the advantage of using Er-PCR was much more obvious under lower pathogen density conditions.

Table 81. *Sensitivity of SM-1 plating and Er-PCR for detecting* R. solanacearum *from field soils*

Field	Crop	BW symptoms	Rs detection (%)[1]	
			SM-1	Er-PCR
Kuan-tien (KT)	Tomato	Current	67	94
Chung-lin (CL)	Tomato	Current	85	85
Hsing-sheh (HS)	Melon	Past	35	60
Pu-li (PL)	Fallow	Past	15	40
Chi-san (CS)	Eggplant	Past	0	80

[1]There were 18 samples for KT, 20 for other fields

Many weed species have been reported to be a host or alternative host for Rs. Using Er-PCR method, Rs was detected from the rhizosphere of all weed species collected (Table 82). The importance of weeds as the shelter for Rs needs to be confirmed by collecting more species from more fields.

Table 82. *Sensitivity of SM-1 plating and Er-PCR for detecting* Ralstonia solanacearum *from weed rhizosphere in soils collected from fields in Taiwan showing tomato bacterial wilt symptoms*

Field	Weed	Samples	Rs detection	
			SM-1	Er-PCR
Shin-feng (SF)	*Ageratum houstonianum*	8	50	88
	Amaranthus viridis	1	0	100
	Eleusine indica	11	0	73
	Polygonum barbatum	11	0	64
Wen-lin (WL)	*Ageratum houstonianum*	6	33	67
	Cyperus rotundus	3	0	67
	Eleusine indica	2	0	100

In Chunglin area, the water from Tochain River is the main source for irrigation. The river water travels through an irrigation canal connecting with smaller ditches linked to individual fields. Separate ditches are installed for entry and exit of water and the drainage water travels back to the same canal. Among the water samples collected from the three fields in Chunglin, the frequency of positive detection ranged from 20 to 80% (Table 83). The positive detection frequency was not correlated with the presence or absence of the disease or with the sampling spots. This indicated the pathogen responsible for the positive detection might be carried into the irrigation water from the neighboring fields. Future research should focus on sampling methods and a thorough survey of the entire waterway in the Chunglin area to determine the importance of contaminated irrigation water in managing tomato bacterial wilt.

In summary, we have demonstrated the Er-PCR method is more sensitive for detecting Rs than the traditional plating method, particularly when the pathogen density was low. This method can be used in future ecological studies in determining the source of BW epidemics.

Table 83. *Sensitivity of SM-1 plating and Er-PCR for detecting* R. solanacearum *(Rs) from irrigation water samples collected at irrigation canal entrance and exit locations for three tomato fields in Chunglin, Taiwan*

Field	BW[1]	Sampling location	Rs detection (%)[2]	
			SM-1	Er-PCR
Shang-shan (SS)	-	Entrance	0	40
		Exit	0	80
Shin-feng (SF)	+	Entrance	0	80
		Exit	0	40
Wen-lin (WL)	+	Entrance/Exit	0	20

[1] Presence (+) or absence (-) of bacterial wilt symptoms in the tomato fields
[2]There were five samples per location

Identification of sources of genetic resistance to eggplant fruit and shoot borer

Eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis*, is a serious pest of eggplant in South and Southeast Asia. Its larvae bore inside tender shoots or fruits, causing severe damage. Since damaged fruits are not marketable, pest damage results in direct yield loss. Vegetable farmers spray frequently, at times daily, to kill larvae before they enter fruits. Such control practices are not sustainable since EFSB is becoming resistant to the chemicals and the pesticides are killing natural predators and parasitoids of EFSB.

The development of eggplant lines resistant to EFSB is one of the surest methods of combating the pest. In earlier studies we discovered eggplant accession EG058 to show moderate yet inconsistent resistance to the pest at various locations. EG508, however, is very susceptible to cotton leafhopper, *Amrasca biguttulla biguttulla*, a serious pest of eggplant in the cool-dry season. Commercial cultivar Turbo has been found to be consistently less damaged than AVRDC's standard susceptible check EG075 in studies at AVRDC-Asian Regional Center (ARC) in Thailand. Therefore, we tested both EG508 and Turbo for resistance to EFSB at AVRDC and ARC.

At both sites, land was roto-tilled and worked into 1.5-m-wide beds. At AVRDC, three adjacent beds were grouped into an overall plot size of 4.5 m × 10 m. At ARC, two adjacent beds were grouped into an overall plot size of 6 m × 10 m. Five-week-old seedlings of each entry were transplanted in four replications using randomized complete block design (RCBD). Transplanting dates were 8 April 2002 at AVRDC and 21 November 2000 at ARC.

In an observational trial at ARC, we screened five accessions of African eggplant, *Solanum aethiopicum*, for resistance to EFSB. Plants in this unreplicated trial were transplanted on 8 March 2001 on raised beds in plots 3.2 m × 10 m in size.

Crops were grown using customary cultural practices including basal fertilizer application, timely irrigation, weeding, and pruning leaves around basal part of stem. No insecticides or fungicides were applied. Starting after flowering (when pest damage begins), we recorded the number of plants showing damage to shoots. When fruits became ready for harvest, marketable fruits were harvested weekly and percentages of damaged fruits were recorded. Data were subjected to analysis of variance (ANOVA) followed by comparison using tests of least significant difference (LSD) at the 5% probability level.

The results of the experiment conducted at AVRDC are summarized in Table 84. The percentages of damaged fruits for EG058 and Turbo were significantly less than for other lines. Damage to shoots was very sporadic (data not shown). While EG058 is a land race with hard, round, green fruits, Turbo has tender, long, green fruits and is produced by East-West Seed Company, Thailand. Since green-fruited eggplant is popular in Thailand, the use of this cultivar will reduce the need for pesticide use in combating EFSB. Results of the test carried out at ARC were similar to those at AVRDC (Table 85).

All five accessions of African eggplant showed significantly less shoot damage compared to EG075 (Table 86). However, these African eggplant accessions were highly susceptible to foliar feeding by *Epilachna* spp. Plants of these entries were severely defoliated and could not bear fruit, thereby preventing analysis of resistance to fruit damage caused by EFSB.

Table 84. *Eggplant fruit and shoot borer damage to fruits of eggplant accessions*

Damaged fruits (%)	Date					
	28 June	4 July	22 July	31 July	8 Aug	21 Aug
EG075	8.83	9.11	39.62	12.66	9.81	14.78
EG058	3.64	3.93	3.21	1.22	0.00	1.31
Turbo	1.00	2.71	1.92	0.32	0.00	0.00
LSD (5%)	4.73	5.09	16.42	8.86	5.60	12.41

Transplanted 8 April 2001 at AVRDC

Table 85. *Infestation of three eggplant accessions by eggplant fruit and shoot borer*

Accession	Shoot-damaged plants (%)	Damaged fruits (%)
EG075	32.44	86.54
EG058	21.77	38.20
Turbo	24.88	38.75
LSD (5%)	6.49	7.41

Transplanted 21 November 2000 at AVRDC-ARC, Thailand

Table 86. *Infestion of African eggplant (*Solanum aethiopicum*) by eggplant fruit and shoot borer, compared to check EG075 (*S. melongena*)*

Accession	Shoot-damaged plants (%)
Large	5.53
Africa 2	3.54
Cherry	1.88
Africa 4	1.31
Tengeru	1.29
EG075 (ck)	35.20
LSD (5%)	5.97

Unreplicated trial transplanted 8 March 2001 at AVRDC

Influence of pest-resistant cultivar on parasitism of eggplant fruit and shoot borer larvae by *Trathala flavo-orbitalis*

Eggplant fruit and shoot borer (EFSB) is a major pest in South and Southeast Asia. Currently farmers use large quantity of chemical insecticides to control this pest. Breeding of pest-resistant cultivars represent one of the safest and most assured ways to combat pests, including EFSB. However, scattered reports indicate that pest-resistant cultivars may limit the role of natural enemies, especially parasitoids and predators in combating EFSB. Since we have discovered a commercial eggplant cultivar possessing a moderate level of resistance to EFSB, namely Turbo, we studied the effect of cultivating it on the parasitism of the pest by *Trathala flavo-orbitalis*, a larval parasitoid. Since the *T. flavo-orbitalis* is more widespread and shows high rates of parasitism in Thailand, this experiment was done at the AVRDC-Asian Regional Center (ARC) located at Kamphangsaen.

A parcel of land was plowed and worked into 1.6-m-wide beds. These beds were arranged in two 30 m × 30 m adjacent blocks separated by an open corridor of 3.2 m. Five-week-old seedlings of a EFSB-susceptible accession, EG075, was transplanted in one block and Turbo in the other block. The plants in both blocks were raised by customary cultural practices such as basal fertilizer application, timely irrigation, and weeding to assure proper growth and high fruit yield. No pesticide was used for combating any pest or diseases. Starting at flowering time, 29 January 2001, the crop was observed seven times at 14-day intervals for pest damage in shoots. The number of damaged shoots per 18 m row was recorded in each block. Damaged shoots were brought to a laboratory and larvae were extracted from shoots. These larvae were fed on fruits of EG075 until pupation. Pupae were placed in a cage and number of adults of either EFSB or *T. flavo-orbitalis* were recorded. All harvest-ready fruits were picked at irregular intervals from 12 February to 22 April. Damaged fruits were cut open and larvae transferred on fresh fruits of EG075. Pupae and adults from fruits were handled in same manner in the laboratory as for insects from shoots.

Results of the pest damage to both cultivars and the rate of parasitism of EFSB larvae are summarized in Table 87. As expected, pest damage both in shoot and fruit of Turbo was substantially less than EG075. The EFSB larvae found in shoots and fruits of Turbo were free of any *T. flavo-orbitalis* attack whereas the larvae feeding in shoots EG075 had a moderate level (11.55%) of parasitism. Parasitism of EFSB larvae feeding in the fruits of EG075 was very low, but it was present. Fruits of EG075 are rather big and larvae boring into the central core of the fruits are likely to escape parasitism. This is not the case with larvae feeding inside the shoot.

The mechanism of resistance to EFSB in Turbo has not yet been studied. So it is difficult to define the mechanism that deters *T. flavo-orbitalis* from attacking EFSB larvae feeding in Turbo. Whether such deterrence to this parasitoid is confined to Turbo only or other resistant cultivars is not known. More detailed studies are needed.

Table 87. *Parasitism of* Trathala flavo-orbitalis *upon EFSB larvae feeding in shoot or fruit of susceptible (EG075) and resistant (Turbo) eggplant accessions*

	EG075	Turbo
Damaged shoots per 18 m row	23.18	3.74
Parasitism (%) of larvae in shoot	11.55	0.00
Damaged fruits (%)	30.25	14.55
Parasitism (%) of larvae in fruit	0.92	0.00

Transplanted 18 December 2001 at AVRDC-ARC

Feeding attractants of eggplant fruit and shoot borer in eggplant

Eggplant fruit and shoot borer (EFSB), a damaging pest of eggplant, is a monophagous insect feeding principally on eggplant and only occasionally on closely related solanaceous plants. Our last year's research indicated that certain chemical stimulants in eggplant leaves and flowers attract adults of EFSB for laying eggs on eggplant. During 2002 we investigated whether similar biochemical stimulants or nutritional factors are responsible for feeding of EFSB larvae on eggplant.

A colony of EFSB was reared on an artificial diet developed by AVRDC. The diet consists of a 90% portion of commercial diet of polyphagous insects such as beet armyworm (BAW), *Spodoptera exigua*, or tomato fruitworm (*Heliocoverpa armigera*) fortified with a 10% portion of dry eggplant fruit powder. To initiate a new colony, EFSB larvae are collected from damaged fruits in the field and fed on the diet. Pupae, which are formed on diet container lids, are maintained in a cage and emerging adults are confined in a round plastic or acrylic chamber, the inner walls of which are lined with rough paper or nylon net. A seedling of eggplant, placed at the bottom of the chamber, is separated from the rest of the chamber by nylon netting. Adults readily mate and lay eggs on the netting. The eggs are then placed over artificial diet for hatched larvae to feed. Larvae can also be reared on fresh eggplant fruits in laboratory if the continuous supply of pesticide-free eggplant fruit is readily available.

In order to locate possible eggplant-specific feeding stimulants or nutrients in eggplant fruit, BAW diet was fortified individually with eggplant fruit powder, fruit juice, steam distillate of eggplant fruit, hexane extract of steam distillate, or the aqueous liquid after extraction with hexane. The quantity of fortified fraction was always maintained at 10% original dry eggplant fruit powder. In an additional experiment, the BAW diet was fortified with dry powder of eggplant fruit calyx or organic solvent extracts of the calyx or organic solvent-extracted calyx to detect possible antibiotic factors in that plant part.

In all these studies either first or second instar larvae were reared on the fortified diets and their growth and development was monitored daily until the larvae have pupated and adults emerged. We recorded insect mortality. Any diet that will allow successful pupation of larvae and emergence of pupae into adults, and normal duration of larval and pupal stages, was considered to contain the eggplant fruit-derived feeding stimulant or nutrient, if otherwise the diet was judged to contain anti-feeding or nutrient deficient factors.

The addition of either dry eggplant fruit powder or water extract of fresh eggplant fruit supported normal growth and development. One can therefore use either whole eggplant fruit powder or water extract to study feeding or nutritional factors present in eggplant fruit.

Results of the addition of steam distillate of eggplant fruits are summarized in Table 88. The duration of the larval stage for insects fed on BAW diet containing 10% hexane extract of steam distillate was equal to that of larvae on BAW diet containing 10% fruit powder. Larval period of the insects fed on these diets was significantly shorter than that of larvae fed on BAW diet alone.

Pupation percentage of *L. orbonalis* on diet fortified with hexane extract was similar to that of insects fed on BAW diet fortified with fruit powder, the check diet. It was also significantly higher than those of insects fed on either BAW diet fortified with steam distillate residue or BAW diet alone (Table 88).

Pupal weight of *L. orbonalis* on BAW diet containing hexane extract was similar to the pupal weight of insects fed on BAW diet fortified with fruit powder. It was also significantly higher than that of pupae on both BAW diet fortified with steam distillate residue and BAW diet alone.

The percentage of adults emergence of *L. orbonalis* on BAW diet containing hexane extract of steam distillate was similar to that of insect fed on BAW diet fortified with 10% fruit powder and BAW diet containing steam distillate. The adult emergence on BAW diet containing steam distillate residue was lower than on BAW diet fortified with steam distillate hexane extract. Pupae could not emerge into adults when larvae were fed on BAW diet alone.

These results indicate that certain chemical factors present in eggplant are extracted in steam distillate of fresh eggplant fruit. Those factors were responsible for stimulating *L. orbonalis* to feed, grow and develop normally on artificial diet. The insects could not complete its life cycle on BAW diet alone, possibly due to the absence of eggplant-specific feeding stimulants. Hexane can be used to extract those stimulants from steam distillate of fresh eggplant fruit.

Table 88. *Effect of eggplant fruit fortifications on growth and development of* L. orbonalis*. Diets consisted of 90% commercial beet armyworm (BAW) diet and 10% fortification.*

Fortification	Larval duration (days)	Pupation (%)	Pupal weight (mg)	Adult emergence (%)
Steam distillate of eggplant fruit	22.20 ± 1.80	55.00 ± 5.77	31.00 ± 1.55	59.17 ± 6.87
Hexane extract of steam distillate of eggplant fruit	23.35 ± 0.63	42.50 ± 9.57	32.50 ± 3.79	56.67 ± 11.54
Steam distillate residue of eggplant fruit	21.50 ± 2.08	17.50 ± 5.00	27.50 ± 2.89	25.00 ± 28.86
Fruit powder	22.33 ± 2.37	42.50 ± 9.57	32.00 ± 1.41	59.17 ± 6.87
BAW diet alone	29.00 ± 0.00	5.00 ± 5.77	20.00 ± 0.00	0.00 ± 0.00
LSD (5%)	2.84	11.30	4.00	27.76

The hexane extract needs to be processed further to isolate and eventually identity eggplant chemicals that are stimulating feeding and possibly providing nutrition of this insect.

The preliminary investigation showed that *L. orbonalis* could not grow normally on the artificial diet containing powder made from dried calyx of eggplant fruit. This indicated presence of some toxic chemicals in calyx that make larvae avoid this plant part. Identification of chemical compounds in calyx is necessary to understand the bio-chemical mechanism that prevents *L. orbonalis* feeding. The duration of the larval period was not significantly affected.

The pupation of larvae on BAW diet containing calyx powder after extraction by methanol was significantly higher than on BAW diet containing calyx powder, or calyx powder extracted by either hexane or dichloromethathe (Table 89). The weight of pupae on methanol-extracted calyx powder diet was significantly greater than on BAW diet fortified with calyx powder or calyx powder extracted with hexane or dichloromethane.

Emergence of adults developed from larvae on methanol-extracted calyx powder diet was also significantly higher than that on BAW diet fortified with calyx powder or calyx powder extracted with hexane or dichloromethane.

The development of *L. orbonalis* on BAW diet fortified with calyx powder extracted by methanol was therefore better than the BAW diet fortified with fruit powder. The pupation percentage of larvae, pupal weight, and adult emergence on this diet were significantly higher than those of *L. orbonalis* on the diet containing original calyx powder. These results show that the toxic chemical present in calyx is polar, and methanol could remove the chemicals present in calyx that inhibit the growth and development of *L. orbonalis*. Indeed when methanol extract of calyx was added to the check diet containing 10% fruit powder in BAW diet, all larvae died. The adding of calyx powder merely reduced the insect development and caused some mortality.

Production of safer vegetables in protective shelters

The increased use of pesticides to combat arthropod pests and diseases is of concern to both policymakers and general public due to the adverse effect of the toxic chemicals on consumers, farmers, and environment. Various counter measures have been adopted to reduce the use of pesticides and produce safer vegetables. Growing vegetables under protective structures to shield them from pests is becoming increasingly common, especially for leafy vegetables in peri-urban vegetable production areas. These protective structures in the tropics vary but generally consist of semi-permanent nylon nethouses or temporary nylon net tunnels erected over newly planted vegetable plots. More permanent structures that utilize transparent but sturdy rainproof plastics are used mainly for fruit vegetables such as tomatoes, sweet peppers and cucumbers, which are longer duration crops. Despite the protective nature of these structures, pesticide use for vegetables is only slightly less than in open field. This is mainly due to the lack of growers' knowledge of pests and their less than careful approach in preventing insects from entry into the structures. Over two years ago, in order to learn the pest problems inside these structures and how to overcome them with minimal use of pesticides, AVRDC started a project on production of safer leafy vegetables under nethouses and, starting in 2002, the production of safer tomatoes during the hot-wet season under plastic houses.

Table 89. *Effect of calyx fortifications on growth and development of* L. orbonalis

Fortification	Larval duration (days)	Pupation (%)	Pupal weight (mg)	Adult emergence (%)
Hexane-extracted calyx powder	19.50 ± 1.14	20.0 ± 5.00	24 ± 1.15	41.11 ± 8.39
Dichloromethane-extracted calyx powder	18.46 ± 0.47	23.3 ± 2.89	28 ± 4.73	50.00 ± 10.00
Methanol-extracted calyx powder	19.42 ± 0.37	35.0 ± 10.00	35 ± 6.35	87.83 ± 11.27
Calyx powder	19.42 ± 1.13	23.3 ± 5.77	23 ± 2.51	58.33 ± 14.43
Fruit powder	19.43 ± 0.21	46.7 ± 2.89	39 ± 6.66	71.48 ± 5.70
LSD (5%)	1.47	10.70	9.00	17.19

Diets consisted of 90% commercial beet armyworm diet and 10% fortification

Production of leafy vegetables in nethouses

Two nethouses constructed in year 2000 and 2001 are still in use. Detailed information on design, construction, and maintenance of these 32-mesh nylon net structures have been printed in *AVRDC Report 2001*. During 2002 we cultivated five crop cycles in each of the two nethouses. The leafy vegetables included two crucifers grown throughout five cycles rotated with water convolvulus (kangkong) and amaranth during hot-wet summer months and spinach and peas (grown for its leafy tendrils) during winter months. We grow crucifers in one nethouse and non-crucifers in the second nethouse and then rotate the crops in each house. Occurrence of insect pests was monitored twice a week. All vegetables during each of the five crop cycles remained free of insect damage. As in the past, larvae of common armyworm (CAW), *Spodoptera litura*, attacked the crop, irrespective of crop species, sporadically in 2002. The adult of CAW is a big moth that cannot itself pass through the net; but it lays eggs on the top of the net and tiny larvae emerging from the eggs pass through the net and descend onto the leafy vegetables growing underneath.

To control this pest without any chemical pesticides, we tested *Spodoptera litura* specific nuclear polyhedrosys virus (NPV), commercial *Bacillus thuringiensis* formulation, and neem. The labeled dosages were sprayed on potted water convolvulus plants and 10 fourth instar larvae were released on each of the four plants. After 7 days, the larval mortality was 93.75 ± 9.46% with NPV, 53.75 ± 14.36% with *B. thuringiensis* and 10.0 ± 4.08% with neem. The NPV was the most effective pest control agent whereas neem was disappointedly ineffective. Similar trends in pest mortality were observed when we tested these bio-pesticides on younger larvae or used cabbage leaves dipped in these bio-pesticide formulations in larval feeding studies.

Production of safer summer tomato under plastic houses

Starting summer season of 2002, we initiated research on production of safer tomatoes under plastic houses during summer, when supply of this vegetable is very low and prices are high. During this season bacterial wilt disease (BW), caused by soil-borne pathogen *Ralstonia solanacearum*, and flooding are major limiting factors. Recently whitefly-transmitted geminiviruses (WTG), vectored by *Bemisia tabaci*, have become equally important biological constraints. To overcome BW, we used tomato seedlings grafted onto BW-resistant eggplant rootstock (EG203). We used imidadoprid and acetamiprid to reduce vectors of WTG. For combating black leaf mold, caused by *Pseudocercospora fuligena*, we sprayed plants with mancozeb and benomyl. The crop was transplanted in three 22 × 1.5 m plots inside a 25 × 6.5 m plastic house. This house had a curved top and the upper half of its side walls were covered with UV-protected clear plastic. The bottom half of the side walls were covered with a double layer of 32-mesh netting with a spacing of 10 cm between the nets at the soil level and narrowed gradually until closed at 1.6 m above soil level. One end of the tunnel was closed tight with a single layer of 60-mesh nylon netting and at the other end we installed two double doors utilizing 60-mesh netting.

The first crop of tomato (line CLN 2026D) grafted on BW-resistant eggplant was transplanted on 5 July 2002, at the height of hot-wet rainy season. The crop was raised by standard cultural practices including timely application of fertilizers, weeding, pruning, and trellising of vines for easy management and harvest. Yellow sticky paper traps were hung at several locations above and among the plants to monitor incidence of whitefly. When insect populations increased, we sprayed insecticides. Since the summer was unusually dry, weekly spraying of this insecticide became necessary. When black leaf mold first appeared, we excised infected tomato leaves; however, when infection spread, we sprayed fungicides. Fruits were harvested and evaluated for marketability and incidences of blossom end rot and CAW. At two harvests, we sampled the marketable fruits and immediately sent for analysis of pesticide residues at Taiwan Agricultural Chemical and Toxic-substances Research Institute.

We harvested 1.24 kg blemish-free marketable yield of tomato (12.41 t/ha) compared with 0.37 kg/m^2 of unmarketable through 11 harvests from 27 August to 29 October 2002. We lost 0.29 kg/m^2 to blossom end rot and 0.18 kg/m^2 to unexpected CAW damage. Around six weeks after transplanting, we started noticing infection of WTG. The infection increased gradually and by mid harvest period practically all plants to varying degrees were damaged by WTG. In future years, we will use WTG-resistant cultivars. Flooding and BW were not a problem. Black leaf mold was present throughout the season but was kept under check by fungicide. CAW probably came from the pupae that remained alive in soil from previous crop. In future tests, plans will be made to solve these problems.

The initial pesticide residue analysis was performed on crop sprayed with imidacloprid, benomyl, and mancozeb on 4 October and harvested on 17 October 2002. Residues of imidacloprid, benomyl, and mancozeb were 0.11 ppm, 0.11 ppm, and below the detectable limit of 0.10 ppm, respectively. The maximum residue limit (MRL) for the three pesticides on tomato in Taiwan is 0.5, 1.0, and 2.5 ppm, respectively, for imidacloprid, benomyl, and mancozeb.

A second analysis was conducted on 28 October. Residues of acetamiprid were 0.06 ppm; the tomato crop was sprayed with labeled amount of this chemical 7 days earlier. The MRL for this chemical on tomato in Taiwan is 0.06 ppm. It is concluded that protecting tomato crops with judicious use of pesticides does not necessarily leave hazardous amounts of pesticide residues and harvested crops can be considered safe to eat.

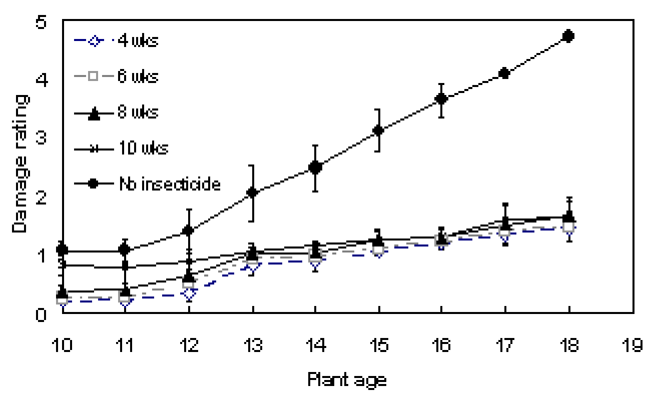
Timing of insecticide application for control of onion thrips on bulb onions

Bulb onion, *Alium cepa*, is an important vegetable crop around the world, especially in South and Southeast Asia. In this part of the world, a polyphagous species, *Thrips tabaci*, commonly called "onion thrips," causes serious damage to onion foliage, which adversely affects the bulb yield. The pest larvae and adults scrape leaf surface and feed on oozing plant sap. As a result, the chlorophyll is destroyed and small white patches dot the tubular leaf surface. Loss of chlorophyll affects photosynthesis and subsequent bulb enlargement. This insect is especially serious during the cool-dry season when onions are traditionally cultivated. During the past few years, AVRDC has conducted research to understand the nature of damage and interaction between onion crop development stage and thrips damage. Our past work indicated that the onion crop remains tolerant to the pest during early growth but becomes susceptible later during the bulb enlargement stage. Spraying insecticides to protecting the crop during this critical time, rather than from the seedling stage as is currently practiced in the region will achieve pest control, minimize pesticide use, and allow natural enemies to flourish during early growth stages. This test was conducted to refine control recommendations.

Twenty 3 m × 3.3 m plots were prepared, arranged in four blocks (replicates) of five plots each. Five-week-old onion seedlings of cultivar CAL606 were transplanted in each plot on 29 October 2001. Starting 4, 6, 8, or 10 weeks after transplanting (WAT), and once a week thereafter, four randomly selected plots (one plot in each of four blocks) were sprayed with either profenofos or carbosulfan, in rotation, to control onion thrips. The remaining four plots were maintained as untreated check plots. Once a week, we observed each plot for onion thrips infestation and the pest damage was rated on 0 to 5 scale where 0 = no damage, 1 = 1–20% leaf area damaged, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, and 5 = 81–100% leaf area damaged by the pest. This observation was performed on two 1-m-long sections of the central two rows of crop in each plot. Total bulb yield in each plot was determined at harvest time.

Onion thrips damage was significantly lower in plots sprayed starting 4, 6, or 8 WAT compared to check plots and, at least in early stages, 10 WAT (Fig. 23). In 2002 the onset of thrips was delayed, hence the difference among the insecticide treatments, especially the 10 WAT and the 4, 6, and 8 WAT treatments are not as distinct as in the past.

Spraying of insecticides resulted in increased bulb yield, and in the case of 6 WAT, significantly higher yields than the no spray treatment (Table 90).



Damage was rated on 0 to 5 scale where 0 = no damage, 1 = 1–20% leaf area damaged, 2 = 21–40%, 3 = 41–60%, 4 = 61–80%, and 5 = 81–100% leaf area damaged by the pest

Fig. 23. *Effect of initiation of insecticide spray at various intervals after transplanting on the damage of onion thrips to onion crops*

In southern Taiwan the period of 10 WAT coincides with bulb enlargement, when onion plants become highly susceptible to onion thrips damage. It is advisable, therefore, to initiate spraying two weeks before the initiation of bulb enlargement. This period may vary slightly depending upon latitude, temperature, and onion cultivar used.

Table 90. *Effect of initiation of insecticide spray at various intervals after transplanting for the control of onion thrips on the bulb yield of onion*

Initiation of weekly insecticide sprays (weeks after transplanting)	Bulb yield (t/ha)
4	47.03
6	50.33
8	47.70
10	45.90
No spray	39.45
LSD (5%)	9.34

Trial conducted during Winter 2001–2002

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 socio-economic and nutritional impacts of vegetables. Methodologies are developed to assess the potential contribution of vegetables in the nutritional and socio-economic development of producers and consumers, and to conduct ex-ante and ex-post impact evaluation of vegetables and AVRDC technologies.

The nutrient contents of the Center's principal crops and promising indigenous vegetables are analyzed to develop a comparative database, and food preparation methodologies are being developed that will enhance micronutrient availability.

Project Coordinator: M Ali

Role of food diversity in human productivity

Diversified food is considered as a function of income and economic development. The role of food diversification in stimulating broader-based rural development is not widely recognized. We consider diversified food as quality food, representing a balanced diet. This study hypothesizes that diversified food improves earning capacity of workers through improving nutritional status of the diet and therefore health. So we quantify the relationship between human productivity and diversification along with the causal factors affecting food diversity. Understanding such relationship will validate the increasing emphasis on diversity, and help policy makers to focus on important factors that can boost broader rural development through enhanced food diversity.

Theoretical framework

Two measures involved in this analysis are Diversity Index and Wage Earning.

Diversity index

The most common diversity indices used are some special case of the form:

$$DI = \sum_{i-1}^{m}(S_i^{\alpha})^{1/(1-\alpha)} \qquad (1)$$

where DI is the measured diversity index, S_i is the share of the *i*th item and α is the parameter, such that $\alpha \geq 0$ and $\alpha \neq 1$. For $\alpha = 2$, the index becomes $1/\sum Si^2$ or the inverse of the Herfindahl-Index, which is used to measure food diversity in this analysis.

Wage rate

The efficiency-wage hypothesis or relationship between labor productivity and nutrition has been widely tested in the literature. Most literature on efficiency-wage hypothesis so far relates labor productivity with overall quantity of food, calories intake, individual nutrient intake, or some measures of nutritional outcome (such as body-mass index). However, the effect of food quality or balanced diet, as far as our review suggests, was never studied. In the present study, we relate wage earning of manual workers with the quality of food, measured as its diversity, along with the level of food consumed, socio-economic environment in which workers live, and types of profession they work in.

To control the effect of simultaneity, the relationship between wage earning (W) as a measure of human productivity and food diversity (DTF) was set in two stages as:

$$\begin{aligned} DTF &= f\ (H, I, R) \\ W &= f\ (DTF, H, I, R) \end{aligned} \qquad (2)$$

where *H* are variables related to human characteristics, *I* are infrastructure related variables, and *R* are regional variables which specify opportunities for earning capacity as well as food diversity. The system of equations in (2) was estimated through the Two Stage Least Square (2SLS) method.

Data sources

The household consumption survey data collected by the Federal Bureau of Statistics (FBS) of Pakistan were used to estimate diversity in food and its relationship with wage earning. The FBS collected these data in two consecutive surveys conducted throughout Pakistan during 1990–91 and 1992–93. These surveys, spread randomly selected over 20,000 households from 57 administrative units (districts) across the country, provide detailed information on the monthly consumption of individual food items along with income and its sources, and other socio-economic characteristics of the household and household head. As income of the urban labor may involve complex factors, this study confines to rural labor. Moreover, as earnings were not recorded on individual basis, the households having a single earning member engaged in a certain type of manual work were selected from the sample. In this way, a sample of 1655 households was used in this study.

Results and discussion

Total food diversity and its effect on earning capacity

The average food diversity index of the sample manual workers in rural areas of Pakistan was at 8.8 compared to 21.0 in Taiwan. The quality of food in both Taiwan and Pakistan is related with the extent of its diversity, as more diversified foods contain more micronutrients, especially iron and vitamins A and C.

The estimated relationship suggests that more diversified food in fact does significantly increase earning capacity of the manual workers after controlling the effect of socio-economic and regional variables. One unit increase in diversity will increase the earning capacity of the workers by 0.076%. The estimated elasticity of wage rate with respect to food diversity is 0.67 (Table 91). This implies that a 10% increase in food diversity is expected to increase workers income by nearly 6.7%.

Increase in food expenditure would also enhance the capacity of the workers. The elasticity of wage with respect to per capita food expenditure (0.06), however, is far less than the improvement due to increase in food diversity. This suggests that food diversity can play a far greater role in poverty alleviation than merely increasing food expenditure by preserving the existing food composition.

The other factors affecting the earning capacity of the workers are their education (higher education improved wage) and sex (females earn less because of the discrimination against women in the job market).

Contrary to common notion, income is not an important factor in inducing food diversification. Instead, human and physical infrastructure, such as education and the presence of a refrigerator in the house, are critical factors determining the food diversity. The education variable captures the effect of better understanding of the household head about the food needs of the family, while the refrigerator variable is a composite measure of the developed surroundings, such as presence of electricity, better housing condition, and connection with the market.

Table 91. *Effect of food diversity on earning capacity, and factors affecting food diversity in Pakistan*[1]

			Wage equation[2]		DTF equation[2]		
Variable description (unit)	Variable name	Mean value	Estimated coefficient	Standard error	Estimated coefficient	Standard error	Wage elasticity
Total food diversity index	DTF	8.84	0.0762*	0.0409	-	-	0.6732
Monthly per capita food expenditure (rupees)	EXF	249.53	0.0003**	0.0001	-	-	0.0629
Education of the worker (years)	EDU	1.16	0.0276**	0.0053	0.0751**	0.0251	0.0377
Ownership of refrigerator (1 = yes, 0 = no)	REF	0.01	-	-	1.5219**	0.5513	0.1159
Sex of the worker (1 = female, 0 = male)	SEX	0.03	-0.2403**	0.0738	-	-	-0.2403
Age of the worker (years)	AGE	37.72	0.0013	0.0011	-	-	0.0478
Per capita monthly income from all sources (rupees)	INC	390.0	-	-	0.0001	0.0001	0.0042
			F-value = 11.4**		F-value = 9.46**		
			Adjusted R^2 = 0.29		Adjusted R^2 = 0.25		
Number of observations = 1655							

*,** Coefficient is significant at $P \leq 0.10$ and 0.01, respectively

[1]The estimated coefficients for district dummy variables are not reported in the table, as these variables were included just to control the regional differences and have little relevance in the discussion. We also omitted the values of the intercept, and year, profession, and season dummies from the table.

[2]Endogenous variables: W (monthly wage earnings in rupees of the manual work) in the log form, DTF; instrument variables: EXF, EDU, REF, SEX, AGE, INC, PRF_1, PRF_2, SES_1–SES_3, DIS_1–DIS_{56}, DYR

Impact of food shares on wage

The disaggregated analysis of food diversity at the food-group level was carried out by relating wage rate with budget shares and diversity within each food group. The estimation suggests that *ceteris paribus*, increasing the budget share of any food group, except milk products, positively affects wage rate (Table 92).

As the positive elasticities of wage with respect to budget share varies from 0.10 for other cereals to 1.16 for fruits and vegetables (last column of Table 92), the reallocation of food budget from the group with low elasticities to the group with high elasticities can improve the wage rate. For example, a 10% increase in the share of fruits and vegetables in the diet (equivalent to 9.5% decrease in the share of wheat) will increase the wage rate by about 7.5% in Pakistan. Other variables affecting the wage rate have similar effect, with slightly higher magnitude, compared to

Table 92. *Effect of food group share and diversity within group on labor productivity, and factors affecting the share of vegetables*[1]

Variable Description and Unit	Variable names	Wage equation	Food share (FDS) equation[2] Wheat	Other cereals	Pulses	Milk products	Fats	Meats	Fruits & vegetables	Wage elasticity
Share of wheat in food expenditure (%)	FDS_1	0.023*	-	-	-	-	-	-	-	0.433
Share of other cereals in food expenditure (%)	FDS_2	0.014	-	-	-	-	-	-	-	0.099
Share of pulses in food expenditure (%)	FDS_3	0.057*	-	-	-	-	-	-	-	0.229
Share of milk products in food expenditure (%)	FDS_5	–0.006	-	-	-	-	-	-	-	–0.102
Share of fats in food expenditure (%)	FDS_6	0.048**	-	-	-	-	-	-	-	0.533
Share of meats in food expenditure (%)	FDS_4	0.041**	-	-	-	-	-	-	-	0.294
Share of fruits & veg. in food expenditure (%)	FDS_7	0.084**	-	-	-	-	-	-	-	1.160
Diversity index of other cereals	DTF_2	–0.043	-	-	-	-	-	-	-	–0.076
Diversity index of pulses	DTF_3	0.013	-	-	-	-	-	-	-	0.030
Diversity index of meats	DTF_4	–0.006	-	-	-	-	-	-	-	–0.007
Diversity index of milk products	DTF_5	0.268*	-	-	-	-	-	-	-	0.293
Diversity index of fats	DTF_6	–0.001	-	-	-	-	-	-	-	–0.001
Diversity index of fruits and vegetables	DTF_7	–0.058	-	-	-	-	-	-	-	–0.363
Monthly per capita food expenditure (rupees)	EXF	0.001**	-	-	-	-	-	-	-	0.261
Age of the worker (years)	AGE	0.002	-	-	-	-	-	-	-	0.075
Sex of the worker (1=female, 0=male)	SEX	–0.345**	-	-	-	-	-	-	-	–0.345
Education of the worker (schooling year)	EDU	0.038**	–0.120	–0.057	–0.067**	–0.031	–0.016	0.178**	0.037	0.047
Per capita monthly household income from all sources (00 rupees)	INC	-	–0.075	–0.037*	–0.010	–0.028	–0.029*	0.064**	0.026	0.003
Ownership of refrigerator (1=yes, 0=no)	REF	-	–1.556	–0.393	0.499	–0.150	–1.156	3.332**	1.477	0.002
Wheat price (rupees per kg)[3]	PC_1	-	4.624**	–0.531**	–0.0001	–0.001	–0.174**	0.022	0.164*	0.391
Other cereals' price (rupees per kg)[3]	PC_2	-	–0.531**	0.298**	–0.034	–0.012	–0.025*	–0.001	0.014	–0.060
Pulses' price (rupees per kg)[3]	PC_3	-	–0.0001	–0.034	0.195**	–0.012	–0.039**	0.007	–0.045*	0.072
Milk product price (rupees per kg)[3]	PC_5	-	–0.174**	–0.012	–0.012	0.013	0.033**	–0.022	–0.009	–0.006
Fats price (rupees per kg)[3]	PC_6	-	0.022	–0.025*	–0.039**	0.033**	0.265**	–0.014*	–0.101**	0.040
Meats price (rupees per kg)[3]	PC_4	-	–0.001	–0.001	0.007	–0.022	–0.014*	0.090**	–0.050**	–0.130
Fruits and veg. price (rupees per kg)[3]	PC_7	-	0.164*	0.014	–0.045*	–0.009	–0.101**	–0.050**	–0.049*	–0.084
F-Values		4.85**	16.78**	17.28	7.84**	5.76**	19.04**	12.80**	10.90**	
Adjusted R^2		0.15	0.41	0.42	0.23	0.17	0.45	0.34	0.30	

*,** Coefficient is significant at $P \leq 0.10$ and 0.01, respectively

[1]We omitted the value of the intercept and year dummy from the table.

[2]Endogenous variables: W (monthly wage earning in rupees), FDS_1–FDS_6; instrument variables: EXF, AGE, EDU, SEX, INC, REF, PRF_1–PRF_6, PC_1–PC_7, DTF_1–DTF_6, SES_1–SES_3.

[3]The weighted average prices of commodities at the group level were used here. These were estimated as $Exp[\Sigma_i s_i \ln(p_i)]$ where p_i is the price of the ith commodity in the group, and s_i is the share of the ith commodity in the group food cost (i.e. $p_i{*}q_i/\Sigma_i p_i{*}q_i$, q_i is the quantity of the ith commodity).

Note: Intercept and year, profession, and season dummies are not reported in the table.

those reported earlier in Table 91. The elasticity of wage with respect to food expenditure increased more than four times, but still remained far below the elasticity with respect to overall food diversity, reported in Table 91. Other important factors affecting earning capacity are education, age, and sex.

Looking at determinants of budget shares, variables related to human and physical infrastructure significantly enhance the share of high nutrient crops, such as fruits and vegetables and meats, and reduce the share of a major cereal like wheat. For example, a one-year increase in schooling of workers will increase the share of fruits and vegetables by 0.04% and meats by 1.78%, while such policy measures will reduce the share of wheat in food expenditure by 1.2%. Similarly the presence of a refrigerator in the house will increase the share of pulses, meats, and fruits and vegetables by 0.5%, 3.3% and 1.5%, respectively, and reduce the share of all other food items. The increased income of the workers will also enhance the share of meats and fruits and vegetables, but reduces the share of all other food items.

Commodity price is an important variable affecting the earning capacity of manual workers through commodity shares. Despite the positive own-price effect, a decrease in most commodity prices increases the earning capacity of the workers in Pakistan. For example, a 10% decrease in the prices of other cereals, milk products, meats, and fruits and vegetables will increase the earning capacity by 0.60%, 0.06%, 1.3%, and 0.84%, respectively.

However, as the effect of increasing wheat share on wage is relatively small, price policy measures will have trivial impact through enhanced share of wheat. This implies that research to develop low-cost technologies and management practices in other than main cereal crop cultivation and marketing will reduce relative prices and improve their share in the diet, enhance food diversity, and increase the earning capacity of the workers. Therefore, such investment has wider implication for alleviating poverty and inducing overall socio-economic development processes. In addition, improvements in physical and human infrastructure can go a long way in improving the earning capacity of poor workers and therefore reduce poverty through enhanced food diversity.

Role of production diversity in rural development

The demand for diversifying agricultural production systems is arising from both consumers and producers. For consumers, their enhanced incomes, effects of urbanization, and greater awareness on the advantages of a balanced diet have increased demand for a greater diversity of agricultural products. For producers, declining cereal prices, growing scarcity of water resources, and concerns about the sustainability of cereal-cereal production systems have provided new interest in agricultural diversification.

Although diversification of agriculture production is already understood as a means to reduce poverty, generate employment, reduce risk, and sustain productivity of agricultural resources, its role in stimulating rural development is not widely recognized. This study quantifies the relationship between agricultural productivity and production diversification. Understanding such relationship will help policy makers to focus on important factors that can boost agricultural productivity, and in a broader sense, promote rural development.

Theoretical framework

Enhanced agricultural productivity is the key to inducing rural development. The basic hypothesis of this study is that diversity in the cropping system enhances overall productivity of the system. To test this hypothesis, some measures of overall productivity of the cropping system and its diversity are required. The productivity of the cropping system was measured by estimating its Total Factor Productivity (TFP) using the chain-linked Tornqvist-Theil indexing procedure. The TFP is a composite measure of productivity including the value of all outputs and inputs employed during the given period of time by the management unit. It contains the net effect of technological change, infrastructure development, improvement in managerial skill of farmers, degradation of resources or change in the agronomic environment— such as soil mining and pest infestations—due to factors such as levels of diversification of the cropping system.

The causality between TFP and diversity can run in both directions, and wide variety of factors, such as human, institutional and physical infrastructure, production technology and quality of production resources all may affect both productivity and production diversity. To resolve the simultaneity problem, the relationship between TFP and crop diversity (DTP) was established in two stages as follows:

$$\begin{aligned} TFP &= f(DTP, T, H, I, Y) \\ DTP &= f(T, H, I, R) \end{aligned} \qquad (1)$$

where T represents variables related to production technology, Y denotes resource quality variables, H are set of variables related to human characteristics, I are infrastructure-related variables, R are regional variables and DTP represent diversity in the cropping system. The DTP in the cropping system was measured using the Herfindahl-Index as follows:

$$DI = \sum_{i-1}^{m}(S_i^{a})^{1/(1-\alpha)}$$

where S_i is the share of the *i*th crop in gross sown area of all crops.

Data source

To measure the diversity in cropping system and quantify its relationship with productivity, a comprehensive set of data was collected from secondary sources through the financial support of the World Bank. This data contain district-level, annual production areas and levels for 33 crops and quantities of 17 input categories during the period 1971–94 for 16 districts of the Pakistani Punjab.

The data on traditional inputs used in the production system were combined with the data on non-traditional inputs. These include average education level of farmers, distance from road, size of holding, etc. of each district. This data were collected from various Agricultural Census of Pakistan conducted during the study period, and observation for the years in between census years were generated using linear extrapolation. Finally, district-level data for the variables on resource quality based on soil and water testing were collected from Soil Fertility Department of the Punjab.

Trends in crop diversity

Average crop diversity in Pakistani Punjab during 1994 was 3.8 compared to 7.2 in Taiwan. Trends in crop diversity in the Punjab were estimated by cropping region as well as for the whole of Punjab and Taiwan. The four cropping regions defined on the basis of dominant kharif (summer season) crop in a district are: wheat-mixed, wheat-cotton, wheat-rice, and wheat-mungbean. The results show that crop diversity based on area under different crops has declined during 1971–94 (Table 93). The declining crop diversity trend in Pakistan is opposite to what happened in Taiwan where the diversity increased at an annual rate of 1.9% per annum during 1980–2000.

Looking at the trends of individual crop-group shares in total crop area suggest that concentration of cereals has increased during 1971–94, while pulses and minor crops were gradually pushed out of the cropping. The only sign of relief for crop diversity in Punjab was the increasing shares of vegetable and fruits (Table 93).

Determinants of crop diversity and productivity impact

The estimated relationship between TFP and crop diversity suggests that a 1% increase in crop diversity will enhance the sectors' productivity by 0.56% at the given level of resources (last column in Table 94). This is because the diversity disrupts insect pest cycles, reduces soil micronutrient mining, and utilizes spare farm and non-farm resources. Above all, enhanced managerial capacity gained from incorporating high value crops in the cropping system improves the system's performance as a whole.

Consistent with literature, other factors affecting TFP were technological changes, infrastructure-related variables, human capital, and institutions. The soil and water quality also significantly affect the TFP.

Looking at the factors affecting crop diversity, improved terms of trade for agriculture is one of its important determinants. A 10% increase in the prices received compared to the prices paid by farmers will increase crop diversity by 0.8%. This implies that agriculture tax had negative consequences on production diversity and productivity.

Both technological variables (modern variety and irrigated area) negatively affect crop diversity in Pakistani Punjab (DTP equation in Table 94). This suggests biases towards specialization and against diversity in technological development. Moreover, relatively easy access to credit and other inputs, assured crop prices, irrigation supply, and extension services were also solely geared towards major crops. Under such policy biases against diversification, it is natural that educated farmers focus on major crops. Therefore, diversity and literacy were found negatively correlated.

Table 93. Trends in crop diversity by cropping region and major crop group[1] in Pakistani Punjab (1971–94)

Cropping region	Growth in diversity (% per annum)	Percentage per annum change in the share in total area					
		Cereals	Commercial crops	Minor crops	Vegetables	Fruits	Pulses
Wheat-rice	–1.4	2.6	–7.6	–5.5	1.3	0.7	–4.7
Wheat-cotton	–0.6	–0.3	4.4	–5.2	1.3	8.1	–8.9
Wheat-mix	–0.2	0.5	–0.7	–3.7	1.4	7.3	–4.2
Wheat-mungbean	–0.6	–0.7	–1.2	1.2	–1.9	0.8	3.7
Punjab	–0.6	0.4	–0.5	–3.5	0.7	5.1	–4.2

[1]The crop group specification is as follows: cereals include wheat, rice, and corn; commercial crops include cotton, sugarcane, tobacco, and potato; minor crops include juwar, bajra, barley, rapeseed and mustard, guar seed, and non-traditional oils; vegetables include onion, garlic, chili, and all other vegetables; fruits include citrus, mango, banana, guava, dates, and other fruits; pulses include gram, mungbean, mash, masoor, peas, and other pulses.

Table 94. *Relationship between TFP and diversification, and factors affecting the crop diversity*[1]

Description of variable[2]	Variable name	TFP equation[3]		DTP equation[3]		TFP elasticity
		Coefficient	Std error	Coefficient	Std error	
Diversity index	DTP	0.558**	0.2712	-	-	0.558
Terms of trade for agriculture[4]	TTA	-	-	0.082**	0.027	0.046
Technological change						
Index of % of cropped area to cultivated area	CPI	0.389**	0.093	-	-	0.389
Index of irrigated area as % of cultivated area	IRA	-	-	–0.075*	0.022	0.042
Index of % of modern wheat variety area	MWV	-	-	–0.038**	0.013	–0.021
Infrastructure, human capital, and farm structure						
Index of % farmers who are literate	EDU	0.422**	0.162	–0.217**	0.047	0.301
Index of inverse of distance from road	ROD	0.310**	0.082	0.0830**	0.026	0.356
Index of % area owned	AOD	-	-	0.372**	0.114	0.208
Index of average farm size	FAS	-	-	–0.139*	0.101	–0.078
		F-value = 32.33***		F-value = 65.1***		
		Adjusted R^2 = 0.699		Adjusted R^2 = 0.820		
Number of observations = 366						

*, **, *** Coefficient is significant at $P \leq 0.10$, 0.05, and 0.01, respectively

[1]The estimated coefficients for district dummy variables are not reported in the table, as these variables are just to control the regional differences and have little relevance in the discussion. Similarly, intercept is also not reported.

[2]All continuous variables were converted into index with 1971 = 100 as base, and in logarithmic form.

[3]Endogenous variables: TFP (total factor productivity index), DVT; instrument variables: TTA, CPI, IRA, MWV, EDU, ROD, ELC, SOP, SOM, SST, AOD, FS

[4]Index of prices received/index of prices paid. The weighted average prices of all inputs and outputs were used here. The weighted average prices of outputs were estimated as $Exp[\Sigma_j s_j \ln(p_j)]$ where p_j is the price of the jth crop, and s_j is the share of the jth crop in the total revenue from all crops (i.e., $p_j{*}q_j/\Sigma_j p_j{*}q_j$, where q_j is the output of the jth crop). Similarly, the weighted average prices for all inputs (material, machinery, labor, land) were used.

Infrastructure helps to alleviate some of these biases against crop diversity. For example, a 10% decrease in the distance of a village from road can improve crop diversity by 0.8%. Reducing the distance also affects TFP directly. The total effect of reducing 1% distance of a village from road on TFP was 0.36%.

Crop diversity is less on larger farms. It is high on farmer-owned compared to tenanted farms (DTP equation in Table 94), because tenancy may limit a farmer's access to agricultural inputs and institutions, such as credit, which are necessary for diversification.

Share of different crops and their effect on TFP

The disaggregated effect of crop diversity was conducted by regressing the TFP on the share of different crop groups. The estimated results suggest that increasing the share of commercial crops, vegetables, fruits, and pulses area within the total area significantly improves overall productivity of the agriculture production system, after controlling the effect of prices, technology, soil and water quality, and infrastructure variables. For example, a 10% increase

Table 95. *Productivity and diversification with crop groups, and factors affecting the vegetable share*[1]

Variable	Variable name	TFP equation[2]	Individual crop share (CRS) equations[2]: Cereals	Commercial crops	Minor crops	Vegetables	Fruits	Pulses	TFP elasticity
Index of share of crops in total cropped area									
Cereals	CRS_1	–0.5901***	-	-	-	-	-	-	–0.5901
Commercial crops	CRS_2	0.3680***	-	-	-	-	-	-	0.3680
Minor crops	CRS_3	–0.2935*	-	-	-	-	-	-	–0.2935
Vegetables	CRS_4	0.0835**	-	-	-	-	-	-	0.0835
Fruits	CRS_5	0.1379**	-	-	-	-	-	-	0.1379
Pulses	CRS_6	0.2942**	-	-	-	-	-	-	0.2942
Index of normalized relative one-year lag prices (output/input)[3]									
Cereals	NCP_1	-	0.0500**	–0.3419***	–0.3265***	0.4146**	–0.3581	–0.1178	–0.1089
Commercial crops	NCP_2	-	–0.0209	0.0781*	0.0833	0.0530	0.20234	0.0126	0.0527
Minor crops	NCP_3	-	–0.0433***	0.1369***	0.0678*	–0.1028	–0.0470	–0.0881*	0.0150
Vegetables	NCP_4	-	–0.0041	–0.0193	0.0998***	0.1701***	–0.067**	0.1727***	0.0218
Fruits	NCP_5	-	0.0145	0.1305***	0.0433	–0.1868*	0.0439	–0.0299	0.0084
Pulses	NCP_6	-	0.0039	0.0156	0.0323	–0.0078	0.3258**	0.0505	0.0531
Technological change									
Index of cropped as % of cultivated area	CPI	0.2623*	-	-	-	-	-	-	0.2623
Index of irrigated as % of cultivated area	IRA	-	0.0812***	0.1586***	–0.2239***	–0.0875	–0.0982	–0.3762***	–0.0554
Infrastructure, human capital, and farm structure									
Index of % farmers who are literate	EDU	0.3535	–0.0514	0.4186***	–0.8472***	1.0855***	-0.2331	–1.1259***	0.1603
Index of inverse of distance from road	ROD	0.1947	–0.0296	0.2241***	–0.2224**	0.9410***	0.4379*	–0.0786	0.2810
Index of % area owned	AOD	-	–0.4488***	–0.1610	–0.18631	–0.3116	–0.9898	3.0406***	0.9923
Index of average farm size of the district	FAS	-	0.5759***	–0.1938	–0.6329*	–0.1063	1.3849	–0.3364	–0.1423
F-value	-	14.3***	40.9***	54.2***	83.1***	45.4***	10.7***	64.3***	-
Adjusted R^2	-	0.55	0.77	0.81	0.87	0.78	0.44	0.84	-
Number of observations = 366									

*, **, *** Coefficient is significant at $P \leq 0.10$, 0.05, and 0.01, respectively

[1]We estimated all the share equations. All continuous variables are in the index form with 1971=100 as base, and these were converted into log form.

[2]Endogenous variables: TFP, CRS_1–CRS_6

[2]Instrument variables: CPI, IRA, MWV, EDU; ROD, ELC; SOP, SOM, SST, AOD, FAS, NCP_1–NCP_6

[3]The weighted average prices of all inputs and each output group were used here. The weighted price of each crop group was estimated as $Exp[\Sigma_j s_j \ln(p_j)]$ where p_j is the price of the jth crop, and s_j is the share of the jth crop in the group revenue (i.e., $p_j*q_j/\Sigma_j p_j*q_j$, q_j is the total output of the jth crop). Similarly, the weighted average prices for all inputs (material, machinery, labor, land) were estimated.

in the proportion of vegetable area can enhance productivity of the overall agriculture system by 0.8%. Corollary to these results is that a 10% increase in the concentration of cereal and minor crop area decreased productivity by about 6% and 3%, respectively (TFP equation and last column in Table 95). As before in the overall TFP and diversity relationship, the effect of education, distance from road, and technology variable remained significant here as well. Soil and water quality variables also were significant.

The major factors affecting the share of different crops in total crop area are relative prices, technological change, infrastructure and human capital (individual crop share equation in Table 95). To estimate the total effect of these variables on TFP, elasticities of TFP with respect to these variables were estimated (last column of Table 95). These elasticities include both the direct effect of a policy variable on diversity as well as indirect effect through influencing the crop share.

Crop price is one of the major tools to influence the share of different crops. The estimated elasticities of TFP with respect to the prices of respective crops are positive, except cereal prices. A 10% increase in the price of commercial crops, minor crops, vegetables, fruits, or pulses will improve TFP by 0.53%, 0.15%, 0.22%, 0.08%, and 0.53%, respectively, through changing the crop shares of different crops, while a 10% increase in cereal price will reduce TFP by 1.09%. One possible way to improve farmers' return is to reduce unit costs through the introduction of science-based technological innovations in the production and marketing systems of various crops.

An increase in irrigated area significantly increased the share of wheat and other cereals, while decreased the share of pulses and minor crops. This can be explained in terms of release of irrigation-responsive varieties in wheat and other cereals, and lack of such varieties in pulses and minor crops. Irrigation insignificantly affected the share of fruits and vegetables. Therefore, lack of irrigation is not a major constraint on crop diversification with fruits and vegetables in the irrigated Punjab, where about 80% of the area is linked to canal or underground water supply systems.

A higher rate of literacy significantly increased the share of commercial crops and vegetables, but more strongly reduced the share of minor crops and pulses. The negative relationship between the share of latter two crops and education in fact caused a negative relationship between overall crop diversity and education as discussed earlier. This is because the incentive structure (especially floor prices), institutions (especially extension and credit system), infrastructure (especially markets), and technology related inputs such as irrigation supplies were all geared toward increasing cereal production, while ignoring the production of pulses, vegetables, and minor crops. This was added by the laxity of researchers in generating input-responsive varieties and modern technologies for the latter group of farmers. All these factors induced educated people to harvest the benefits of the incentives by concentrating on the production of cereal crops. The total effect of an increase in rural literacy by 1% was, however, positive at 0.16%, because of its high direct impact on TFP.

Lowering the distance of a village from road positively influenced productivity both directly in the TFP equation as well as indirectly through improving the crop shares of high value crops. The total effect of this was 0.28% increase in TFP.

Ownership of land provides significant incentive to decrease the share of cereals in total crop area, but increase the share of pulses. The impact of land ownership on the share of other crops is negative but not significant. Those districts with larger farm size have higher proportion of area under cereals crops. However, the impact of farm size on the share of other crops, except fruits, was negative, but none of them were significant.

In summary, diversification of agriculture production systems can greatly enhance their productivity. The impact of diversification on productivity can be as great as the Green Revolution as a whole. The increased share of vegetables in the cropping system could have the greatest influence. To achieve diversity in the production system requires to remove policy biases against high value crops, increase research and development resources to encourage their share in the system, and develop physical and human infrastructure necessary to incorporate these crops in the cropping system.

Combating micronutrient deficiency by increased vegetable use: A case study of Pakistan

Efforts to tackle protein-energy malnutrition have been fairly successful through the introduction of cereal-based Green Revolution technologies. However, other important food crops such as legumes and vegetables, which were once an integral part of the cropping system, were neglected during the first phase of the Green Revolution. This has resulted in a decline in their supplies, an upward trend in their prices, and reduced consumption of these crops. In this way, micronutrient deficiency has surfaced more prominently. Now about 3.5 billion people are iron deficient and 250 million children are victimized by the deficiency of vitamin A. An estimated 250–500 thousand vitamin A deficient children become blind every year. These estimates may rise in the future if appropriate strategies are not devised to tackle these deficiencies. Food-based approaches are promising strategies to control micronutrient deficiency. Under this approach, increased vegetable use carries special importance, as they are rich and inexpensive sources of numerous essential micronutrients. However, the information on the role of vegetables and response of policy measures to mitigate these deficiencies through vegetables are not widely available.

The present study was aimed at fulfilling this information gap in Pakistan, where the prevalence of micronutrient malnutrition is rising. For this purpose, nutrient demand elasticities were estimated for seven major nutrients from major food groups and compared with the elasticities from vegetables. Moreover, nutrient demand elasticities were estimated for major individual vegetables. It is hoped that these estimates will provide a sound basis for policy makers to target appropriate food items and individual vegetables to mitigate micronutrient deficiencies.

Data source and estimation procedure

National level consumption data of two consecutive surveys was used which enabled us to analyze information on 20,967 households. The data used pertain to monthly consumption and expenditure on various food and non-food items, family structure, and other socio-economic variables. The food items were classified into eight food groups: wheat, other cereals, meats, pulses, milk products and fats, fruits, vegetables, and miscellaneous. The vegetables were further grouped into five sub-groups as fruit, bulb, stem/root, leafy, and gourd types. The nutrient analysis is pertained to seven essential micronutrients: iron, vitamins A, C, B_1, B_2, calcium, and niacin. Taking average monthly household income as the dividing line, the sample families were grouped into low and high-income categories. A two-stage budgeting approach, first the Linear Estimation System (LES) and then the Almost Ideal Demand System (AID), was used. The problem of incidence of zero purchases was tackled by following Heien and Wessells' approach. The nutritional shares of various food groups, vegetable groups, and individual vegetables were combined with corresponding demand elasticities in order to estimate nutrient elasticities.

Results and discussion

On average, more than 1 kg of food per person per day is consumed in Pakistan. Vegetables are the third largest consumed food group. More than 20 different types of vegetables are consumed. Fruit type is the most consumed vegetable sub-group followed by bulb and leafy types. The per capita intake of vegetables among high-income households is about 11% higher as compared with low-income households. This is also true for all vegetable sub-groups, except leafy type, which is consumed more among the low-income group.

All considered micronutrients are consumed below their Recommended Dietary Allowances (RDA). The overall deficiencies vary from about 8% for calcium to nearly 71% for niacin and 70% for vitamin A. The high-income households are relatively less deficient in all micronutrients as compared with their counterpart (Table 96).

Among food groups, vegetables are the major contributor in supplying vitamins A and C while they are the second leading contributor in total availability of iron and vitamin B_2. They are the third highest supplier of calcium, vitamin B_1, and niacin in diets (Table 97).

The own-price elasticity of vegetables is quite high, i.e. –0.93. This implies that a 10% reduction in vegetable prices (say through technological innovation)

Table 96. *Average daily per capita nutrient availability by income class*

Nutrient types	RDA[1] (g)	Low income Intake (g)	Low income Deficiency (%)	High income Intake (g)	High income Deficiency (%)	Overall Intake (g)	Overall Deficiency (%)
Calcium (mg)	968.3	875.1	9.6	935.6	3.4	892.4	7.8
Iron (mg)	12.2	8.8	27.6	9.6	20.8	9.0	25.6
Vitamin A (mg)[2]	4757.8	1350.7	71.6	1644.2	65.4	1434.7	69.8
Vitamin C (mg)	54.7	42.1	22.9	52.6	3.7	45.1	17.4
Vitamin B_1 (mg)	1.2	0.4	64.8	0.5	59.9	0.4	63.4
Vitamin B_2 (mg)	1.3	0.8	43.5	0.9	31.2	0.8	40.0
Niacin (mg)	14.9	4.1	72.7	5.2	65.1	4.4	70.5

[1]Recommended dietary allowances were estimated at average household level using age and sex composition, and dietary recommended levels for each composition.

[2]Vitamin A was estimated as b-carotene. One mg of β-carotene is equivalent to 0.167 mg of retinol.

will increase the consumption of vegetables by 9.3%. Out of 56 cross-price elasticities, 50% were positive. Vegetables have complementary relations with other food groups. The income elasticity of vegetables is 0.91 (Table 98). The price and income elasticity differences across income groups (not reported in the table) are very small.

The own-price elasticities were very high for stem/root and gourd type vegetables. Income elasticities above unity came for stem/root, leafy and gourd types. Out of 20 cross-price elasticities, 15 were positive, which suggests that substitution relations are dominant among vegetable groups and its extent varies by type (Table 99).

At the individual vegetable level, the magnitude of own-price elasticities ranged from –0.17 for red chilies to –1.54 for cabbage, while the income elasticities varied from 0.33 for red chilies to 1.75 for other vegetables. The income elasticities of half of the vegetables were greater than unity, indicating that the rise in household income will generate proportionately more demand than the percentage increase in income. Out of 420 cross-price elasticities, 243 are positive, signifying that substitution relations dominate among individual vegetables (Table 100). Similar to the first stage, the differences in price and income elasticity across income groups for vegetables as a group and individual vegetables were small. This suggests that

Table 97. *Share (%) of various food groups in total micronutrient supply*

Nutrient types	Wheat	Other cereals	Pulses	Milk products	Meats	Fruits	Vegetables	Miscellaneous
Calcium	30.6	1.6	3.3	55.0	0.5	1.2	5.2	2.7
Iron	32.8	2.8	8.7	13.1	6.3	3.8	20.8	11.6
Vitamin A	0.0	1.3	0.3	19.6	0.9	10.4	66.7	0.9
Vitamin C	0.0	9.1	0.0	0.1	0.0	34.8	55.0	1.0
Vitamin B_1	0.0	31.0	10.9	24.6	4.6	5.7	21.2	2.1
Vitamin B_2	0.0	6.0	5.7	63.1	7.5	2.7	13.1	2.0
Niacin	0.0	36.4	9.8	8.8	20.4	5.8	17.3	1.5

Table 98. *Demand elasticities of major food groups*

	With respect to the price of								
Food group	Wheat	Other cereals	Pulses	Milk products and fats	Meats	Fruits	Vegetables	Miscellaneous	Income
Wheat	–0.4023	–0.0823	–0.0486	–0.1156	–0.0930	–0.1245	–0.0871	–0.0895	0.3769
Other cereals	–0.0036	–0.8701	–0.0044	–0.0105	–0.0084	–0.0113	–0.0079	–0.0081	0.8530
Pulses	–0.0068	–0.0141	–0.5461	–0.0198	–0.0159	–0.0213	–0.0149	–0.0153	0.4904
Milk & fats	0.0269	0.0555	0.0328	–1.1255	0.0627	0.0839	0.0587	0.0604	1.2846
Meats	0.0002	0.0004	0.0003	0.0006	–1.0039	0.0006	0.0005	0.0005	1.1694
Fruits	0.0029	0.0060	0.0036	0.0085	0.0068	–1.1593	0.0064	0.0066	1.6203
Vegetables	–0.0033	–0.0069	–0.0041	–0.0096	–0.0078	–0.0104	–0.9315	–0.0075	0.9136
Miscellaneous	0.0201	0.0414	0.0244	0.0581	0.0467	0.0626	0.0438	–1.1580	1.0939

Table 99. *Unconditional demand elasticities of vegetable groups (second stage analysis)*

	With respect to the price of					
Vegetable group	Fruit types	Bulb types	Stem/root types	Leafy types	Gourd types	Income
Fruit types	–0.9885	0.0790	0.1962	–0.0391	0.0333	0.9141
Bulb types	0.0154	–0.8038	0.1080	0.0277	–0.2707	0.6488
Stem/root types	0.0647	0.1428	–1.5821	–0.2065	0.3538	1.1426
Leafy types	0.0244	0.1235	–0.3037	–0.8683	0.0419	1.1121
Gourd types	0.0401	–0.0033	0.5080	0.0365	–1.1831	1.1880

Table 100. *Unconditional demand elasticities of vegetables*

Vegetable type	Own-price elasticity	Income elasticity
Tomato	–0.836	1.073
Onion	–0.577	0.613
Turnip	–0.672	1.022
Cabbage	–1.538	1.113
Cauliflower	–0.636	0.879
Brinjal	–0.830	0.966
Gourd	–0.869	1.314
Okra	–0.950	0.992
Cucumber	–1.005	1.364
Spinach	–0.473	1.014
Bottle gourd	–0.760	0.940
Pumpkin	–0.724	0.951
Radish	–0.453	1.127
Pea	–1.172	1.186
Mustard	–1.235	0.972
Carrot	–0.905	1.260
Green chili	–0.204	1.053
Red chili	–0.173	0.333
Ginger	–1.316	1.129
Garlic	–0.743	0.923
Other vegetables	–1.440	1.746

lowering the prices of vegetables by appropriate technological or policy intervention will almost equally benefit both income classes.

At the first stage, out of 56 price elasticities of nutrients, only 48 are negative, implying that lowering prices of most food groups will improve their consumption, and in turn, reduce micronutrient deficiencies. These elasticities include the net effect of complementarities and substitutions when price of commodities is changed. For example, a 10% reduction in the prices of vegetables will increase iron, vitamin A, C, B_1, B_2, and niacin consumption by 2.1%, 6.1%, 5.1%, 1.9%, 0.9%, and 0.6%, respectively. Similar implications, although at a lower level, can be achieved by lowering the wheat and other food prices. The negative elasticities of most nutrients suggest that a food-based approach in which food supplies are enhanced through technological innovation is an effective way to mitigate micronutrient malnutrition. However, the appropriate food group needs to be selected to overcome a specific micronutrient deficiency, as the range of nutrient elasticities widely varies across different commodities.

Nutrient elasticities across food groups revealed that lowering vegetable prices is the most effective way of alleviating the deficiencies of iron, and vitamins A and C. The highest nutrient elasticities of vitamins A and C are explained in terms of highest share of these nutrients supplied by vegetables as well as high own price demand elasticity. The contribution of vegetables in supplying iron is the second highest share, but iron elasticity from vegetables is the highest. This is mainly because of the relatively high own price elasticity of vegetables and complementary relationship of vegetables with iron-rich food groups, such as wheat and other cereals. In any case, highest nutrient elasticities of iron, and vitamins A and C imply that investment on technological innovation in vegetables is the most effective food-based approach to mitigate micronutrient deficiency. Low vegetable prices will also facilitate mitigating the deficiency of vitamin B_1 and niacin. Nutrient elasticities with respect to change in income are also quite high for all micronutrients (Table 101). Therefore, development strategies focused on enhancing income, such as increased vegetable cultivation, will also help to mitigate micronutrient deficiencies.

Looking nutrient elasticities by vegetable group, out of 35 price elasticities of nutrients, only 29 were negative, suggesting that lowering prices of any group will help alleviate micronutrient deficiency. Nutrient elasticities across vegetable groups revealed that lowering prices of stem/root and leafy types is most important for controlling vitamin A deficiency while leafy types are most important for alleviating iron deficiency. On the other hand, lowering prices of fruit and leafy types would help relatively more in alleviating the deficiencies of calcium, vitamins C, B_1 and B_2. All income elasticities of nutrients were above 0.93 (Table 102).

Nutrient elasticities of various micronutrients across various vegetables show that reduction in the prices of spinach and peas are most effective to overcome the deficiency of vitamin A, whereas cabbage and tomatoes are most relevant crops to address vitamin C deficiency. Cheaper availability of okra and cucumber will be most effective to increase calcium intake, while gourd and cucumber should be selected to reduce iron deficiency. Similarly, tomato and okra are more important crops to eradicate the deficiency of vitamin B_1, while reduction in the prices of gourd and cucumber will be most effective in case of vitamin B_2 deficiency. For niacin, mustard and carrot are most relevant crops (Table 103).

Table 101. *Nutrient elasticities of major food groups (first stage analysis)*

Nutrients	With respect to the price of								Income
	Wheat	Other cereals	Pulses	Milk products and fats	Meats	Fruits	Vegetables	Miscellaneous	
Calcium	–0.1081	–0.0083	–0.0144	–0.6544	0.0014	–0.0052	–0.0419	–0.0258	0.9531
Iron	–0.1275	–0.0421	–0.0569	–0.1825	–0.0836	–0.0709	–0.2113	–0.1583	0.8117
Vitamin A	0.0035	–0.0040	0.0026	–0.2259	–0.0006	–0.1102	–0.6090	–0.0025	1.0613
Vitamin C	–0.0009	–0.0804	–0.0011	–0.0036	–0.0024	–0.4097	–0.5104	–0.0138	1.1563
Vitamin B_1	0.0046	–0.2578	–0.0530	–0.2824	–0.0357	–0.0516	–0.1854	–0.0145	0.9954
Vitamin B_2	0.0164	–0.0176	–0.0104	–0.7113	–0.0373	0.0194	–0.0850	0.0130	1.1621

Table 102. *Nutrient elasticities of major vegetable groups (second stage analysis)*

Nutrient	With respect to the price of					Income
	Fruit types	Bulb types	Stem/root types	Leafy types	Gourd types	
Calcium	–0.3259	–0.0549	–0.1553	–0.2970	–0.0521	0.9722
Iron	–0.2263	–0.0383	–0.1202	–0.3983	–0.1039	1.0018
Vitamin A	–0.1108	0.1153	–0.5535	–0.5269	0.0788	1.0937
Vitamin C	–0.5930	0.0254	-0.0627	–0.1413	–0.0447	0.9689
Vitamin B_1	–0.6704	–0.0176	0.0850	–0.1012	–0.0740	0.9319
Vitamin B_2	–0.4113	0.0181	–0.0308	–0.2982	–0.1108	1.0005
Niacin	–0.6073	0.0647	–0.0763	–0.1596	–0.0358	0.9867

Table 103. *Nutrient elasticities of major vegetables in Pakistan*

Vegetable type	Calcium	Iron	Vitamin A	Vitamin C	Vitamin B_1	Vitamin B_2	Niacin
Tomato	–0.0923	–0.0922	–0.0775	–0.1384	–0.1324	–0.0673	–0.0660
Onion	–0.0210	0.0297	0.1342	0.0524	–0.0245	0.0615	0.0295
Turnip	–0.0133	0.0299	–0.0199	–0.1279	–0.0430	–0.0159	–0.0881
Cabbage	–0.0352	–0.1808	–0.0838	–0.1536	0.0038	–0.0516	0.0817
Cauliflower	0.0108	0.0136	–0.1313	–0.1090	0.0080	0.0047	–0.0416
Eggplant	–0.0822	–0.0640	–0.0250	–0.0528	–0.0894	–0.1101	–0.1147
Gourd	–0.0766	–0.2142	–0.1038	–0.0103	0.0525	–0.1364	0.1083
Okra	–0.1699	–0.0350	0.0650	–0.0775	–0.0979	–0.0544	–0.0511
Cucumber	–0.1436	–0.2167	–0.1517	–0.1121	–0.0620	–0.1296	–0.0487
Spinach	–0.0389	–0.1234	–0.2306	–0.0199	–0.0809	–0.1024	–0.1085
Bottle gourd	–0.0849	–0.0413	0.0372	–0.0498	–0.0464	–0.0238	0.0092
Pumpkin	–0.0487	–0.0572	–0.0360	–0.0460	–0.0504	–0.0433	–0.0113
Radish	–0.0364	–0.0283	–0.0368	–0.0955	–0.0445	–0.0462	–0.1010
Pea	–0.0442	–0.1472	–0.2663	–0.0911	–0.0963	–0.0401	–0.0533
Mustard	–0.0490	0.0348	–0.0497	–0.0920	–0.0459	–0.0287	–0.1584
Carrot	0.0000	0.0149	–0.1638	–0.1925	–0.0894	0.0145	–0.1403
Green chili	–0.0283	–0.0183	0.0708	–0.0629	–0.0896	–0.0522	–0.0813
Red chili	0.0284	0.0644	0.0627	0.0697	0.0098	0.0851	0.0265
Ginger	–0.0556	–0.1069	–0.1422	–0.0082	–0.0673	–0.0322	–0.0738
Garlic	–0.0325	–0.0447	–0.0479	–0.0207	–0.0718	–0.0814	–0.0831
Other vegetables	0.3467	0.1320	0.3448	0.4067	0.4403	0.1644	0.4111
Income elasticity	0.8387	0.7996	1.0795	0.9447	0.7985	0.7810	0.7726

Like demand elasticities, the differences in price and income elasticities of nutrient intake across income groups are minor in nature. This signifies that lowering the prices of vegetables by appropriate technological or policy intervention will almost equally benefit both income classes.

It is concluded that in developing countries like Pakistan where micronutrient deficiency is rising, increased vegetable use is a viable option to alleviate micronutrient deficiency. Due consideration should be awarded to further promote vegetable cultivation. Increased allocation of funds for vegetable research with other appropriate price measures would be helpful to increase cheap availability of vegetables and to alleviate micronutrient deficiencies.

Optimization of peri-urban vegetable production systems in the Philippines

This research undertaking was primarily done to develop a user-friendly optimization model for the peri-urban vegetable production system in Manila, Philippines. Specifically the optimization model was used to come up with an efficient set of solutions to the multiple objectives of peri-urban production system. In addition, the model can be used to evaluate the range of possibilities where the peri-urban technologies can be economically viable.

Because of multiplicity of objectives in the vegetable production system, a multiple goal linear programming (MGLP) model is developed for the peri-urban production system. The MGLP procedure consists of a number of optimization rounds and each round comprises several optimizations. In each optimization run, the model is optimized for one objective function, while the other objectives are used as constraints. The programming model is made interactive to allow investigation of effect of changes in the objectives and constraints.

The technical coefficients required by the optimization model were assembled from primary and secondary sources. Cost and return information came from surveys conducted by the socio-economics group of the peri-urban project in the Central Luzon State University. Experiment input and output data for the peri-urban package of technologies (for pak-choi and tomato) were also used to construct cost and return data for these two technologies. The PhilRice survey data under the Rice-based Farming Systems Program were similarly used for the cost and return information of other crops that are being considered in the model. Focus group discussions with farmers were also used to generate information on changes in yields and inputs when the crops are planted in different months of the year. Scientists were also interviewed to solicit their expert opinion on the potential yields of the crops when planted in different months of the year. Time series data on output prices were taken from the provincial office of the Bureau of Agricultural Statistics in Nueva Ecija.

The performance of peri-urban technologies were evaluated under the following objective functions:

1. Net income maximization
2. Employment maximization
3. Total product maximization
4. Cost minimization
5. Minimization of pesticide use
6. Minimization of inorganic nitrogen application

A three-period model was formulated for the above-mentioned objective functions and optimization was done using Microsoft Excel-based What's Best?

Under zero-round, maximization of net income, (1), yielded P496,991 total income with a corresponding 1,091 man-day of labor, 66.91 tons of vegetables, 49 liters of pesticides, and 712 kgs of inorganic nitrogen (N) fertilizer. The total expenditure incurred was P485,109 and a return on investment (ROI) of 102%. Maximization of employment, (2), yielded a total employment of 1,251 man-days, 160 man-days more employment than (1) but with lower income and an increase in cost of production. Maximizing production, (3), gave a higher output than (1), however, income declined by P81,841. Although production cost declined, the ROI also declined tremendously. Minimizing cost, (4), yielded a lower capital requirement than (1) but income and output declined tremendously. Minimizing pesticide usage, (5), has significantly reduced pesticide use and capital requirement compared with (1) but also significantly reduced income and production. Minimizing N fertilizer use, (6), had tremendously reduced inorganic N usage and investment, however, there was a substantial decline in income.

As can be seen there exists conflict between the objective functions considered. For example, a one man-day increase in employment will cause a P512 decrease in income and P180 increase in capital requirement for producing the vegetable output mix in the basic solution. Similarly, a one ton increase in output mix in the basic solution will cause a reduction of around

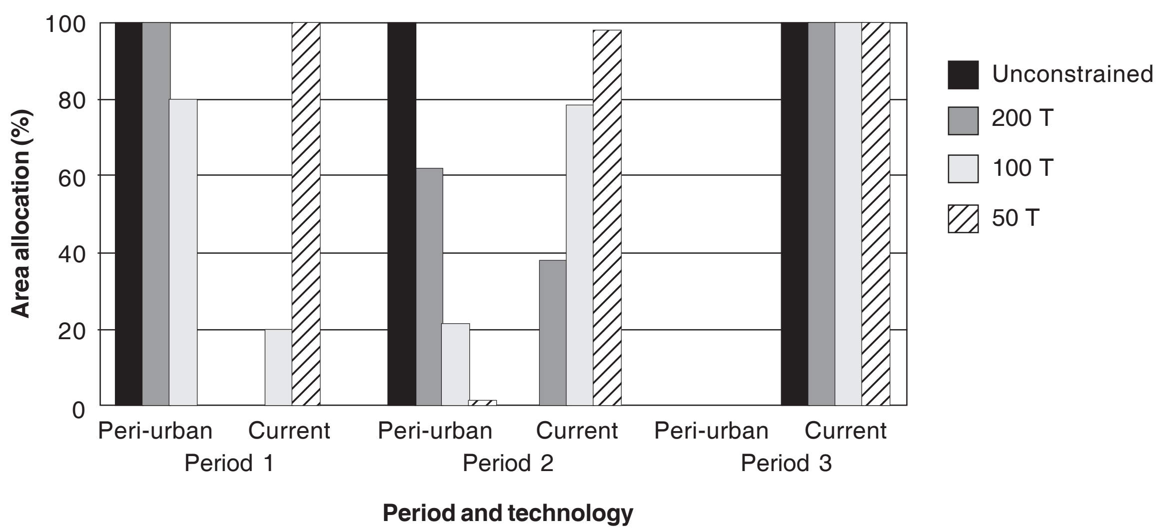
Table 104. *Achievement under zero-round optimization of different objective functions*

Obj. Function		Achievement						
		Net income (PhP)	Employment (man-day)	Production (ton)	Capital (PhP)	Pesticide (liter)	N fertilizer (kg)	ROI (%)
1	Max net income	**496,991**	1,091	66.91	485,109	49.0	712	102
2	Max employment	415,150	**1,251**	76.40	513,849	51.0	778	81
	1 vs 2	81,841	(160)	(9)	(28,740)	(2)	(66)	
3	Max production	213,131	1,074	**78.00**	332,868	24.0	1,026	64
	1 vs 3	283,860	17	(11)	152,241	25	(314)	
4	Min cost	159,162	367	30.20	**92,537**	10.9	450	172
	1 vs 4	337,829	724	37	392,572	38	262	
5	Min pesticide use	114,605	241	35.65	122,544	**6.5**	556	94
	1 vs 5	382,386	850	31	362,565	43	156	
6	Min N fertilizer use	180,462	768	30.00	216,900	96.0	**168**	83
	1 vs 6	234,688	483	46	296,949	(45)	610	

Note: Area limit is 1 ha per period, effective area is 3 ha
Bold figures are ideal values

P25,000 in income and increase in capital by around P14,000. A reduction in pesticide use will also cause a decrease of around P9,000 in income per liter of pesticide. However, it will also reduce the capital requirement by an equal amount for the vegetable output mix in the basic solution. A reduction in N fertilizer application will reduce income by P380 per kg., but there will be a reduction in investment by P490 given the vegetable output mix in the basic solution.

A scenario that simulates the impact of capital availability on land allocation was done to determine where the peri-urban technologies would be acceptable. Under the unconstrained capital condition, all the land is used in the production of pak choi cultivated using peri-urban technology (pak-choi–PE) in Period 1 (January to April), while tomato produced using per-urban technology (tomato–PE) is cultivated in Period 2 (May to September). On the other hand, other sponge gourd is produced during Period 3 (October to December) (Fig. 24). When the available capital is set at P200,000 per period, pak-choi–PE is produced in the available area. This is because the capital requirement of pak-choi–PE is less than P200,000. In Period 2, tomato–PE is planted in 68%



Note: Peri-urban = Project-espoused technology, grafted tomato under rain shelter, pak choi under net tunnels; current = farmers' practice of veg. production

Fig. 24. *Land allocation between peri-urban technologies and current production practices under varying levels of capital availability*

of the land while 38% is devoted to other vegetable cultivated using current production practice in the area. Reduction in capital availability to P100,000 per period further reduces the share of peri-urban technology to available area. The share of pak-choi–PE is reduced to 80% in Period 1 while that of tomato–PE is reduced to 21%. When the capital available is only P50,000 per period, the available area is devoted to vegetable output mix produced using farmers' current practices.

This scenario showed that if enough capital were available, farmers would likely adopt peri-urban technologies because it gives higher profits and stable yields. This would also lead to more pak-choi and tomatoes being available for metro Manila consumers. On the other hand, given its relatively higher costs, peri-urban technologies will not be able to compete with current production practices of the farmers during the regular planting season because the market price is low, leading to low or even negative profit.

The production environment in dryland farming is very uncertain and farmers are not sure about the outcome of their production activity. Risk was introduced into the model in terms of income variability. Higher income variability indicates a higher level of risk and vice-versa. The results of optimization runs under varying risk are presented in Table 105.

Without regards to risk, maximization of income leads to allocation of available land to highest income giving crop, e.g., pak-choi–PE in Period 1, tomato–PE in Period 2, and sponge gourd in Period 3. The introduction of risk into the model changed the crop mix and area allocation. For example, in Period 2, if the income variance is set to P500 × 10^6 (SD = P22,360), the area allocated to tomato–PE is reduced to 17% while risk-neutral output and other crops, eggplant and finger pepper, are entered into the crop mix. Similarly, the net income from the cropping system was reduced to P165,268. Production was also reduced as well as input use. As acceptable variability in income is lowered, the net income derived from the cropping system declined and the cropping pattern becomes more diversified. For example, in Period 2, when the income variance was set to P65 × 10^6 (SD = P8,062), the area planted to tomato–PE is reduced to 10% while other crops entered into the basic solution, namely, finger pepper, 29%, eggplant 30%, and squash 31%.

Table 105. *Net income and resource allocation under varying risk*

	Total variance of income			Total variance of income			Total variance of income		
	No risk consideration			200	500	200	25	65	25
Particular	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3	Period 1	Period 2	Period 3
Net income	123,044	273,063	100,884	110,423	165,268	97,598	89,958	112,344	73,218
Labor use	358	535	199	342	323	237	335	252	265
Pesticides use	8	35	6	9	14	6	8	10	7
Organic fertilizer	140	200	-	114	35	-	70	19	-
N-fertilizer	342	94	276	295	192	228	234	187	176
Total investment	110,956	291,937	82,216	100,647	91,302	77,704	87,775	68,060	66,414
ROI	111	94	123	110	181	126	102	165	110
Production	26.00	22.60	18.30	22.78	11.54	17.53	18.47	10.66	15.10
Crop mix	Area allocation, by period								
Pak-choi–PE	1.00			0.78			0.50		
Tomato–PE		1.00			0.17			0.10	
Tomato–Upl				0.05					
Tomato–FP									0.11
Sponge gourd			1.00			0.70			0.28
Red onion				0.05			0.17		
String beans				0.11		0.30	0.43		0.42
Finger pepper					0.10			0.29	0.01
Eggplant					0.73			0.30	0.18
Squash								0.31	
Area allocated	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Note: Pak-choi–PE = pak-choi produced under tunnel nets; Tomato–PE = grafted tomato under rain shelter cultivation; Tomato–Upl = tomato produced in upland areas; Tomato–FP = tomato produced using farmers conventional technology

Impact of mungbean research in China

Mungbean has been a valuable source of nutrition in Chinese diets for centuries. During the 1950s China was a major producer of mungbean, but then production declined through the 1960s and 1970s as the national government placed higher priority on other grains. It was not until the 1980s that mungbean production gradually recovered. In 1986, the total area under mungbean was 547,000 ha, total production was about 500,000 tons, and the average yield reached 914 kg/ha. This recovery was in large part due to joint efforts between Chinese researchers and AVRDC. Based on AVRDC genetic material, Chinese breeders were able to develop several new varieties, which are now grown to a large extent all over the country. The major areas of production today are located in the Yellow River drainage area, Huai River drainage area, Huabei plain, and northeastern China. The provinces can be separated into two regions by the main varieties grown. One is the *'Ming Lu dou'* region, which contains Jilin and Inner Mongolia; another one is the *'Zai Lu dou'* region, which contains Henan, Shandong, Shanxi, Shannxi, Hebei, and Anhui.

Total mungbean production has increased by an annual average of 2.4% between 1986 and 2000, largely due to yield increases (1.7% annually)(Fig. 25). In 2000, the total area under mungbean production was nearly 772,000 ha, overall production increased to 891,000 tons, and the average yield increased to 1154 kg/ha. Compared to the production both of 'dry beans' and of 'total pulses', the share of mungbeans has risen steadily. In 1986 approximately 9% of all pulses produced in China were mungbeans; in 2000, 19% of all pulses grown were mungbeans. The same trend holds true for 'dry beans'. In 1986 approximately one-third (35%) of all 'dry beans' grown were mungbeans; the share rose in 2000 to two-thirds (66%).

Mungbean consumption in China has been relatively steady, compared to a general decline in 'total pulse' consumption. Annual per capita mungbean consumption fluctuated between 0.3 and 0.5 kg during the period 1986–2000. The share of mungbean consumption in total pulse consumption has hence risen steadily, from 14.2% in 1986 to 28.0% in 2000.

Similarly, the total value of mungbean exports has risen over the years, with an average annual growth rate of 5.8%, from 45 million US$ in 1986 to 50 million US$ in 2000. Over the years the share of mungbeans in the value of all agricultural exports has varied between 0.3% and 0.9%, indicating the relative importance of this single commodity. In contrast, the value of mungbean imports has decreased strongly, at an annual rate of 14.4%. This becomes obvious also in the share of mungbean imports among all imports. While it was still 0.25% in 1986 (13.6 million US$), in the year 2000 the value of mungbean imports accounted for only 0.01% of all agricultural imports (1.4 million US$). Since total mungbean consumption has increased slightly over the same time period this shows that Chinese mungbean growers are able to meet the domestic demand for mungbeans. China is and has always been a net exporter of mungbean.

The real price of mungbean has grown with an annual average growth rate of 5.7% between 1986 and 2000. The price analysis has shown that mungbean prices vary across regions and seasons. Prices are highest in the eastern region, followed by the central and western regions. Periodically, the price has a peak in June and July and will decrease to its lowest point in October, then increase again. The biggest variation in prices occurs during the months of October and November, as a result of the large quantities traded in this period, and the variation in this period has an important impact on the price level in the period of January to July of the following year.

A cost-benefit analysis shows that the benefits of this research investment have been substantial. Under the scenario of a closed economy, and not including AVRDC's research cost, the net present value of total benefits ranges from 129.9 to 32.1 million US$, depending on the reduction in production cost for farmers. The sensitivity analysis is based on the assumption that the reduction in production cost, due to new improved varieties, lies between 25 and 5%. The internal rate of return (IRR) in this scenario ranges from 119.9 to 59.9%. Including the benefits of this research to consumers from other countries, and also including the research cost for AVRDC, the net present value of research benefits remains approximately the same, at 127.8 to 32.1 million US$. The IRR is slightly lower under this assumption, ranging from 119.4% under the 25% cost reduction scenario to 59.9% under the 5% cost reduction scenario. In summary, mungbean research has been a highly productive investment.

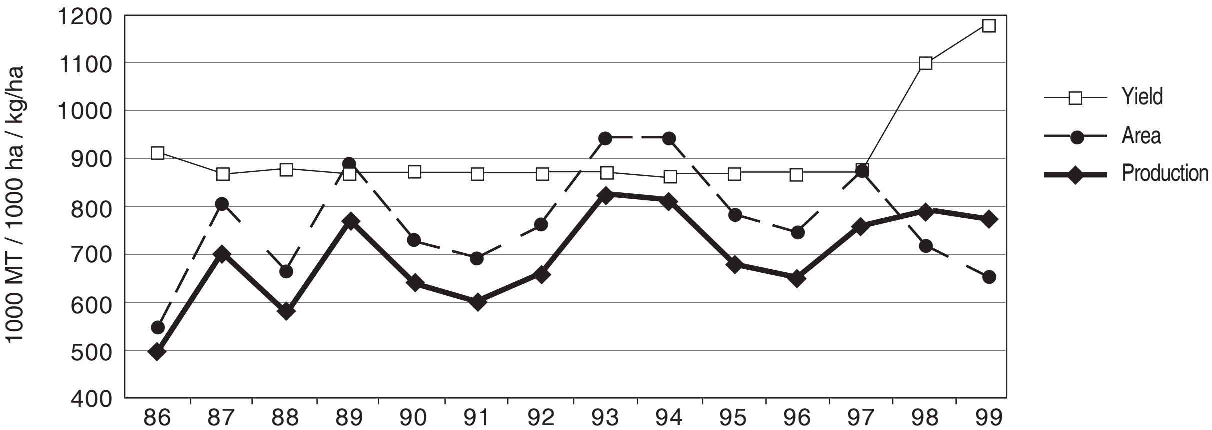


Fig. 25. *Mungbean production, area harvested and yield, 1986–1999*

Average annual growth rates: production = 2.4%, yield = 1.7%, area cultivated = 0.7%. Source: 1989, 1991, and 1992 production figures and area figures from 1986–1994 are estimates based on provincial yearbooks. Production and area figures for the remaining years have been provided by the Ministry of Agriculture of China (unpublished).

Modeling antioxidant activity–vegetable concentration relationships to determine antioxidant capacities of selected tropical vegetables

Antioxidants have been used for a long time by the food industry for preservation of nutrition and taste qualities and to suppress rancidity. With the recent research on the pathogenesis of free radicals in human diseases, antioxidants have gained broader interest due to their role in inhibiting free radical reactions, which help protect the human body against damage by reactive oxygen species (ROS). Dietary antioxidants have become especially important when the human body is under oxidative stress caused by the imbalance between generation of ROS and endogenous antioxidants.

Vegetable crops differ in levels and types of antioxidants, which include dithiolthiones and isothiocyanate of cruciferous vegetables, isoflavones of soybean, and lycopene of tomato. In addition, antioxidants function differently in different environments. Consequently, comparison of antioxidant activities among a wide range of vegetable species is difficult.

Instead of determining contents or antioxidant activities of individual antioxidants, total antioxidant activities have been estimated in order to compare entries from highest to lowest. However, use of a single method to estimate total antioxidant activity of vegetables is questionable because of the multitude of antioxidants and the complexity of antioxidant combinations in vegetables. Our preliminary tests indicated that ranking of vegetables varied in expressions of antioxidant activity; therefore, it is necessary to clarify the expression of antioxidant activity for antioxidant assays.

The objectives of this study were to investigate the relationships between different concentrations of selected vegetables and three measurements of antioxidant activity and then to fit these relationships in models that would permit comparison of total antioxidant capacities among different vegetables. Antioxidant properties were estimated by super oxide scavenging (SOS), ABTS radical scavenging, and inhibition of lipid peroxidation (ILP).

Plant samples used in this study are listed in Table 106. The fresh materials of 1–2 kg were obtained from the AVRDC indigenous vegetable display garden in 2002.

The SOS was measured by the XA/XOD system with some modifications. Superoxide is generated from

Table 106. *Plant samples used in the study*

Common name	Scientific name	Plant part
Aromatic turmeric	*Curcuma aromatica*	Tube
Chard	*Beta vulgaris*	Young shoot
Chinese cedrus	*Cedrela sinensis*	Leaf
Drumstick tree	*Moringa oleifera*	Leaf
Oriental pickling melon	*Cucumis melo*	Fruit
Tree of Damocles	*Oroxylum indicum*	Leaf

the oxidation of xanthine to uric acid by xanthine oxidase. It reacts with NBT of light yellow color to form a dark purple complex, which can be measured at OD 560. The ability of samples to scavenge superoxide radical can be determined by the inhibition of NBT reductions. The ABTS/HRP decoloration method was carried out base on the capacity of different components in vegetable extracts to scavenge the ABTS radical cation as compared to a standard antioxidant ascorbic acid and Trolox in a dose response curve. The ability of samples to inhibit lipid peroxidation at pH 7 was tested using linoleic acid with the free radical generator azobis 2-amidinopropane hydrochloride (AAPH). Peroxidation was started by adding APPH. The lipid peroxide formed in the reactions was measured by the formation of the red pigment, iron thiocyanate ($Fe(SCN)_3$) oxidized by iron (III) which is oxidized by iron (II) though the auto-oxidation with lipid peroxide The statistical analyses of concentration (X)-inhibition (Y) relationship were performed using trend prediction function in ChartWizard of Excel software. Linear and non-linear regression models were tested by R^2.

Inhibition-concentration relationships in SOS, ABTS, and LP assays

Increased SOS activity was observed with higher concentrations of vegetable water extracts for the five tested samples except in chard (Fig. 26a). Chinese cedrus, aromatic turmeric, drumstick tree, and tree of Damocles showed stronger SOS activity than pickling melon, but their curve patterns were not similar. SOS activity of Chinese cedrus increased sharply up to about 60% at concentration lower than 20 mg/ml, whereas, aromatic turmeric and drumstick tree leaves reached SOS activity of 70% and 60%, respectively, at concentrations about 100 mg/ ml and slowed at higher concentrations. Water crude extracts of chard exerted oxidative capacity in the SOS assays; a peak of –30% inhibitions was observed at 100 mg/ml and lower or higher concentrations showed less oxidative effect.

Curve patterns for SOS activity of methanol extracts were different from those of water extracts (Fig. 26b). Comparing to the water extracts, SOS activity increased more sharply for Chinese cedrus and tree of Damocles in methanol extracts and saturated at 85% and 95%, respectively. In contrast, drumstick tree and aromatic turmeric had higher SOS activity in their water extracts. Pickling melon showed slightly oxidative effect in the methanol extract as indicated by the negative values of inhibition measured. Chard at the concentration lower than 100 mg/ml showed similar oxidative behaviors in both water and methanol extracts, and became less oxidative at concentration lower than 200 mg/ml.

ABTS activity increased with the increase of the concentration for all the testing samples (Fig. 27). The curve saturated at 100% inhibition for Chinese cedrus of 5 mg/ml. The inhibition-concentration relationships were similar among all the samples. Higher ABTS activity was found in methanol extracts of drumstick tree leaves by comparing the maximum inhibition values. A slight oxidative effect (–4% inhibition) was observed in methanol extracts of drumstick tree at lower concentrations less than 20 mg/ml.

Similar trends in ILP assays were observed among the tested vegetables, in which ILP activity increased with the increase of the sample concentration and saturated at different levels among vegetables (Fig. 28). At 200 mg/ml, tree of Damocles had the highest values of ILP activity among the samples, followed, in a descending order, by Chinese cedrus, drumstick tree, aromatic turmeric, and pickling melon.

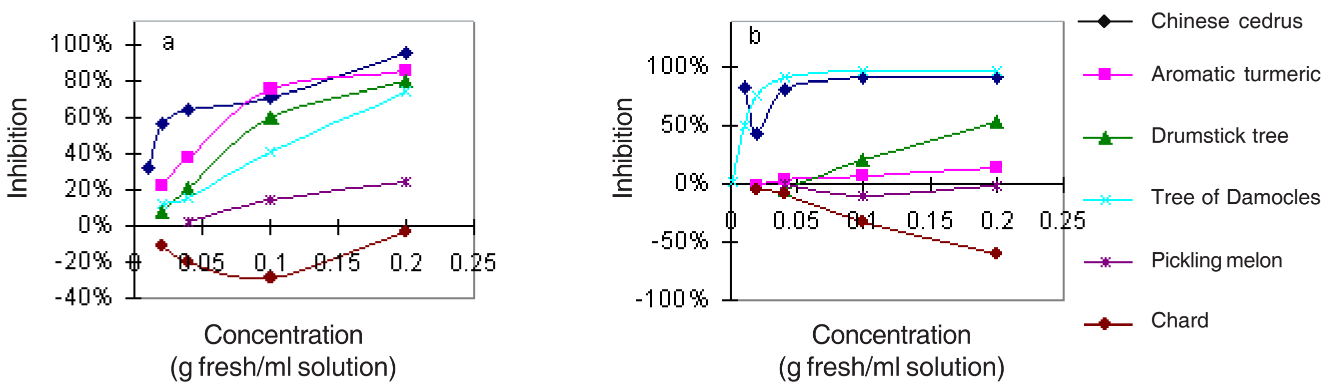


Fig. 26. *Inhibition-concentration relationship in SOS evaluation for water (a) and methanol extract (b) from selected plants*

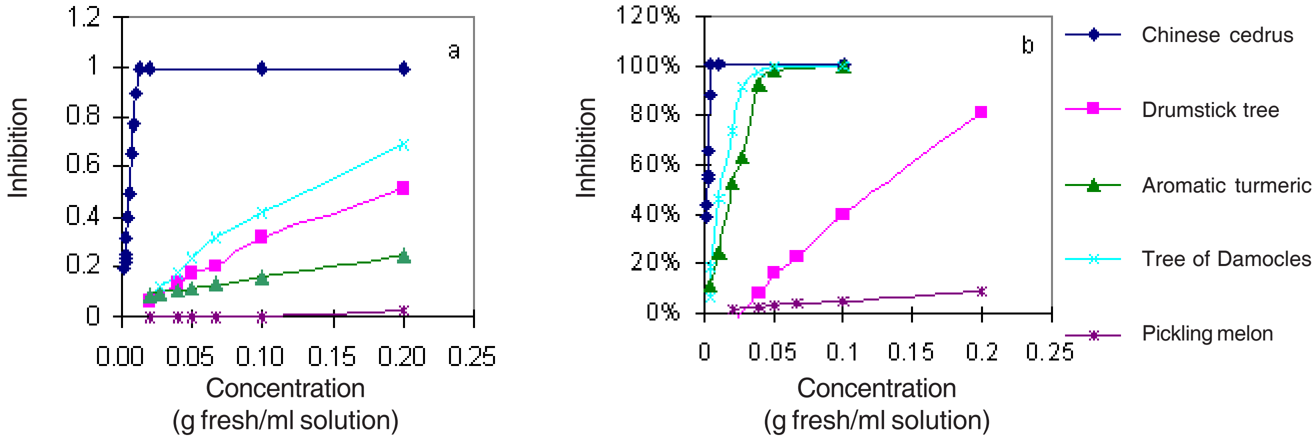


Fig. 27. *Inhibition-concentration relationship in ABTS evaluation for water (a) and methanol extract (b) from selected plants*

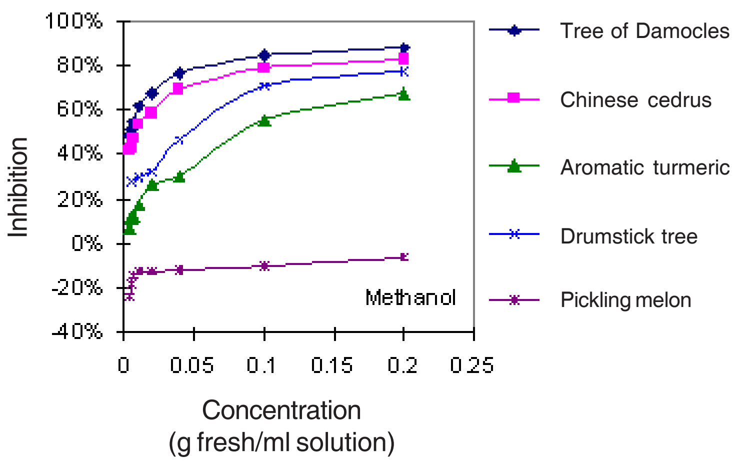


Fig. 28. *Inhibition-concentration relationship in ILP assay*

Modeling fitting

The goodness of fit of the linear model of inhibition-concentration (I-C) relationships in ABTS assay was tested by R^2. Data points at the saturation phase of the samples were not included in the fitness test. $R^2 > 0.96$ was obtained for all the tested samples (Table 107). A linear model can explain the I-C relationship at the growth phase for ABTS assay, but plots of I-C for the SOS and ILP activities exhibit as non-linear trends. Therefore, non-linear models were tested for goodness-of-fit (Table 107). For IPL assay, an inverse exponential decay ($Y=a + b\log_e X$) was fitted with $R^2 > 0.98$ with the exception of picking melon, which had $R^2 = 0.8399$. A higher R^2 was achieved using the model $Y=a + b\log_e X + c(\log_e X)^2$; however, the improvement was not significant. The model $Y=a+b\log_e X$ can be used to predict the inhibition value in response to the concentrations used in the ILP assay. In SOS reaction, samples of water extracts (five out of six) fitted the model $Y=a + b\log_e X$, but only three samples of methanol extracts fitted well with the model. R^2 of both water and methanol extracts could be improved with the model $Y=a + b\log_e X + c(\log_e X)^2$, especially for the water extract of chard and the methanol extracts of Chinese cedrus and picking melon. The methanol extract of chard exhibited strong oxidative behavior and the pattern fitted a linear regression with $R^2 = 0.9945$. In conclusion, antioxidant activities for both SOS and ILP assays in response to concentration showed best fit to the model $Y=a + b\log_e X + c(\log_e X)^2$, with the exceptions of SOS activity of the methanol extract of chard and ILP activity of pickling melon.

Table 107. *R^2 of potential models for the SOS, ILP, and ABTS assays*

		Models		
Assays	*Vegetables*	$Y = a + bX$	$Y=a + b\log_e X$	$Y=a + b\log_e X + c(\log_e X)^2$
SOS-W	Aromatic turmeric		0.9698	0.9747
	Chard		0.0268	0.9943
	Chinese cedrus		0.9256	0.9264
	Drumstick tree		0.9817	0.9849
	Pickling melon		0.9995	1.0000
	Tree of Damocles		0.9078	0.9998
SOS-M	Aromatic turmeric		0.8931	0.9566
	Chard	0.9945		
	Chinese cedrus		0.3259	0.7028
	Drumstick tree		0.9811	1.0000
	Pickling melon		0.0576	1.0000
	Tree of Damocles		0.9382	0.9882
ILP	Aromatic turmeric		0.9830	0.9979
	Drumstick tree		0.9795	0.9889
	Chinese cedrus		0.9914	0.9951
	Tree of Damocles		0.9830	0.9972
	Pickling melon		0.8399	
ABTS-W	Aromatic turmeric	0.9995		
	Chinese cedrus	0.9627		
	Drumstick tree	0.9828		
	Pickling melon	0.8956		
	Tree of Damocles	0.9805		
ABTS-M	Aromatic turmeric	0.9919		
	Chinese cedrus	0.9745		
	Drumstick tree	0.9923		
	Pickling melon	0.9864		
	Tree of Damocles	0.9641		

Comparison of antioxidant capacities of vegetables

Concentration curves show that the values of antioxidant activities vary depending on sample concentrations. Concentration should be taken into consideration in the expression of antioxidant capacity of a sample. In this study, the antioxidant activity was defined as the amount of antioxidants per ml solution necessary to obtain *Y* inhibition, which is the concentration of inhibition (CI). The CI at *Y*% was named CI_Y (g fresh/ ml solution), e.g., CI_{50} when *Y*=50%. Lower concentration of a sample needed to inhibit oxidative reactions indicates more efficient or greater amounts of antioxidants in a sample. For clarity, we expressed the antioxidant activity in terms of antiradical power (ARP) for SOS and ABTS assays and ILP power for ILP assay. It was calculated as 1/ IC_Y (ml solution/ g fresh). For ABTS and ILP assays, Trolox was used as a standard, so their antioxidant activity was represented by Trolox equivalent (µM Trolox/g fresh). In this study, Y was set at 20%, so the Trolox concentration was 0.8 µM/ ml solution for ABTS assay and 0.4 µM/ ml solution. ARP and ILP of the vegetables were calculated accordingly and listed in Table 108.

Among all the vegetables tested, Chinese cedrus and tree of Damocles showed the highest values for SOS, ABTS, and ILP activities. Water-soluble portions of Chinese cedrus demonstrated a higher SOS activity than its methanol soluble portion. On the other hand, tree of Damocles showed higher SOS activity in the methanol extract. Also, higher ABTS activity was detected in the methanol extracts of all five vegetables. Among them, the methanol extract of Chinese cedrus showed the highest ABTS activity, which was about six fold higher than that of tree of Damocles. The highest ILP activity, however, was detected in tree of Damocles.

Project 7. Computer-based decision-making tools

Research on different vegetable crops at AVRDC involves a multi-disciplinary and problem-oriented approach conducted by teams of plant breeders, plant pathologists, entomologists, soil scientists, and others. These teams generate much useful and diverse data in the course of their research activities. To extract the full benefit of this information, it must be collected, managed, and packaged in a form useful to other researchers and extensionists.

The objective of Project 7 is to develop computer-based decision-making tools to help our partners in national agricultural research and extension systems (NARES) and nongovernmental organizations (NGOs) to design year-round vegetable production systems.

Contact: JF Wang

Tomato Information System

This comprehensive tomato database includes information on AVRDC inbred lines, important diseases and insects in the tropics and subtropics, and crop management recommendations. Within the database, the Tomato Disease Diagnostic System (TDDS) is an interactive decision-making tool that aids in the identification of diseases based on photos and descriptions of symptoms. Management recommendations are also included. In 2002, the number of diseases in TDDS was increased from 25 to 28.

The contents and structure of the tomato information system was updated and revised in 2002 based on the comments and suggestions made by 11 researchers and 22 trainees at AVRDC. The system is currently under review and is expected to be released in 2003 on CD-ROM.

Integrated Information System for Indigenous Vegetables (IISIV)

The database contains information on names, parts used, germplasm source, agronomic/botanical/ecological characteristics, nutrient and phytochemical contents, and recipes. In 2002, the database was expanded from 80 to 173 species. The whole system is linked to the passport database of the Genetic Resources and Seed Unit and the indigenous vegetable reference database of the AVRDC library. The structure was designed to include evaluation data, characterization data, and horticultural traits.

The Nutrition Database System for Indigenous Vegetables (NDSIV) was developed as a spin-off from IISIV. NDSIV includes more extensive nutrition information than what is found in IISIV. Data on 30 vitamins and nutrients (including most essential micronutrients) are provided for 124 of the 173 species. Health benefits and deficiency symptoms are provided for 15 vitamins and nutrients. The phytochemical database within NDSIV contains data for 333 phytochemical compounds coming from 60 phytochemical groups and five phytochemical categories. There are 61 recipes written in Chinese and plans are underway to translate the recipes into English.

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 and extension 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 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.

Program Director: G Kuo

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.

GRSU works in close collaboration with the Center's research and training units, outreach offices, and national agricultural research systems worldwide to collect, characterize, and conserve vegetable germplasm for utilization. Emphasis in recent years has been on indigenous vegetables.

Project Coordinator: LM Engle

Ex-situ conservation of vegetable germplasm

The Genetic Resources and Seed Unit (GRSU) of AVRDC holds one of the largest ex-situ collections of vegetable germplasm, which it holds in trust for the global community. As part of its commitment to the conservation of vegetable genetic resources and the promotion of its utilization, the unit regularly collects germplasm, regenerates and characterizes the collected material, and then preserves it. The total germplasm collection maintained at AVRDC is shown in Table 108.

During the last three years the unit has coordinated an Asian Development Bank financed project (RETA 5839) entitled "Collection, Conservation, and Utilization of Indigenous Vegetables," which has collaborating institutes from five countries, namely Bangladesh, Indonesia, Philippines, Thailand, and Vietnam. Collected genetic material and related information are centralized at GRSU.

GRSU also hosted a seconded staff from the Japan International Research Center for Agricultural Sciences (JIRCAS). The collaborating scientist worked on the characterization of indigenous vegetables for functional properties and did genetic diversity analysis using random amplification of polymorphic DNA (RAPD).

Training in germplasm conservation was provided to national agricultural research and extension system (NARES) staff of Bangladesh, Indonesia, Philippines, Thailand, and Vietnam as well as to undergraduate students from the University of the Philippines-Los Baños and several universities in Taiwan.

Table 108. *Accessions of vegetable germplasm conserved at AVRDC as of 31 December 2002*

Crop	No. of accessions
Principal crops:	
Glycine	14,195
Capsicum	7,521
Lycopersicon	7,231
Vigna radiata	5,648
Solanum	2,804
Brassica	1,756
Allium	1,078
Subtotal	40, 242
Other crops:	
Vigna unguiculata	1,388
Luffa	700
Phaseolus	633
Amaranthus	487
Vigna mungo	478
Cucumis	472
Cucurbita	452
Vigna unguiculata ssp. *sesquipedalis*	377
Abelmoschus	375
Lagenaria	290
Others	3,565
Subtotal	9,217
Total	49,459
No. of genera	153
No. of species	376
No. of countries	151

Regeneration of vegetable accessions conserved at GRSU for preservation and exchange

GRSU regularly regenerates germplasm accessions for preservation and exchange. Table 109 shows the number of accessions regenerated and characterized from autumn of 2001 to 2002. A total of 1751 accessions including at least 50 species were regenerated. Seeds were stored under long-term storage condition (–10 and –16ºC) as part of the base collection and under medium-term storage condition (5ºC) as part of the active collection. Accessions of *Allium sativum* and *Allium cepa* ssp *aggregatum* were maintained in a field genebank.

National agricultural research and extension systems (NARES) participating in the ADB-funded RETA 5839 reported regeneration and characterization of 3497 accessions of indigenous vegetable germplasm. Characterization data is centralized at GRSU, AVRDC.

Enhancing vegetable germplasm utilization through widespread distribution

A total of 11,123 samples, including breeding lines, were sent out from headquarters in 2002 (Table 110). About 88% went to 71 countries, and about 2% went to AVRDC regional centers. A total of 2181 samples (20% of the samples sent out) came from the AVRDC genebank (Table 111). A total of 1096 samples from the genebank were given to other AVRDC units for various researches.

Collection of vegetable germplasm for food security and biodiversification

On 1 July 1999, the Asian Development Bank (ADB) funded a technical assistance project (RETA 5839) entitled "Collection, Conservation, and Utilization of Indigenous Vegetables." The project was conceptualized with the objective to improve the conservation and utilization of indigenous vegetables in South and Southeast Asia. This objective was to contribute toward the long-term goal to improve nutrition and reduce poverty. The project was undertaken in five countries: Bangladesh, Indonesia, Philippines, Thailand, and Vietnam with AVRDC as executing agency. One component of the project was

Table 109. *Germplasm accessions regenerated in 2001–2002 at AVRDC headquarters*

Scientific name	No. of accessions
Allium cepa ssp. *aggregatum*	23
A. sativum	247
Amaranthus blitum	1
A. dubius	4
A. spinosus	6
A. palmeri	1
A. tricolor	5
A. viridis	8
Apium graveolens	1
Basella alba	12
Beta sp.	2
Brassica juncea	18
B. oleracea cvg. *capitata*	2
B. oleracea cvg. *Chinese kale*	2
B. rapa	15
Cajanus cajan	7
Capsicum annuum	4
C. chinense	2
C. frutescens	16
C. sp.	82
Celosia argentea	9
Corchorus capsularis	4
C. olitorius	2
Eryngium foetidum	11
E. sp.	1
Glycine max	1000
Lablab purpureus	20
Luffa acutangula	5
L. aegyptiaca	11
Lycopersicon esculentum	36
L. pimpinellifolium	1
Macrotyloma uniflorum	9
Momordica balsamina	1
M. charantia	86
Ocimum americanum	4
O. basilicum	5
O. gratissimum	3
O. minimum	1
O. sanctum	5
O. tenuiflorum	5
Perilla frutescens	6
Phaseolus coccineus	1
P. lunatus	15
P. vulgaris	1
Solanum americanum	18
S. indicum	2
S. macrocarpon	3
S. villosum	3
S. xanthocarpum	5
Spinacia oleracea	9
Talinum triangulare	5
Vigna unguiculata ssp. *sesquipedalis*	4
V. unguiculata ssp. *unguiculata*	2
V. umbellata	1
Total	1751

Table 110. *Recipients of germplasm from AVRDC in 2002*

Recipient	Samples	Total
Outside Headquarters		9,839
Korea	2,620	
Taiwan	958	
Philippines	836	
USA	535	
China	423	
India	369	
Vietnam	365	
Tanzania	283	
Ethiopia	250	
Reunion	200	
Others (61 countries/territories)[1]	3,000	
Regional Centers		188
ARC	150	
RCA	38	
Headquarters Units		1,096
Technology Promotion and Services	521	
Mycology	141	
Legume	102	
Crop and Soil Management	98	
Pepper	95	
Tomato	49	
Nutrition and Analytical Laboratory	33	
Olericulture	24	
Virology	23	
Physiology	22	
Entomology	11	
Bacteriology	1	
Total		11,123

[1]Afghanistan, Albania, Angola, Australia, Austria, Bahamas, Bangladesh, Bhutan, Botswana, Brazil, Cambodia, Cameroon, Canada, Congo, Dominican Republic, Egypt, France, Germany, Ghana, Hong Kong, Indonesia, Iran, Israel, Italy, Ivory Coast, Japan, Kenya, Laos, Lesotho, Liberia, Malawi, Malaysia, Mauritius, Mayotte, Mexico, Mozambique, Myanmar, Nepal, Netherlands, New Caledonia, Nicaragua, Nigeria, Pakistan, Republic of South Africa, Rwanda, Saudi Arabia, Singapore, Spain, Sri Lanka, St. Kitts, Sudan, Swaziland, Switzerland, Syria, Thailand, Turkey, Uganda, United Kingdom, Zambia, Zimbabwe

the conservation of indigenous vegetable germplasm. The activities include collecting a total of 2500 accessions, or about 500 accessions per participating country, of indigenous vegetables.

During the final workshop of the project, held in Bangkok in 16–19 December 2002, participants reported collecting 4405 accessions of vegetable germplasm: Bangladesh 987, Indonesia 302, Philippines 1118, Thailand 1463, and Vietnam 535. The collected materials are conserved in the following institutions of the participating countries: Plant Genetic Resources Center (PGRC) of Bangladesh Agricultural Research Institute (BARI), Bangladesh; Research Institute for Vegetables (RIV), Indonesia; National Plant Genetic Resources Laboratory (NPGRL) of Institute of Plant Breeding (IPB) at University of the Philippines-Los Baños (UPLB), Philippines; Tropical Vegetable Research Center (TVRC) at Kasetsart University, Thailand; and Plant Genetic Resource Center (PGRC) of Vietnam Agricultural Science Institute (VASI), Vietnam. A total of 2686 accessions has been received for conservation at GRSU, where collecting information is centralized.

The total of 4405 new accessions in national genebanks is a significant contribution to the conservation of biodiversity. It is also an important addition to the number of vegetable germplasm available for utilization.

Table 111. *Recipients of germplasm accessions from the AVRDC Genetic Resources and Seed Unit in 2002*

Classification	No.	Samples	Purpose
Genebanks	4	1283	Safety duplication, gene identification, core collection, evaluation, RAPD analysis, and breeding and genetics
Government organizations	14	379	Trials and screening for resistance to rust, bacterial diseases, insect pests and early maturity
Private individuals	17	148	Trials and home gardens
Universities	16	125	RAPD analysis, demonstration material, identifying resistant genes in species, trials, and other research
Seed companies	9	105	Trials, observation and crossing, and other research
Private companies	6	90	Trials
International projects	2	51	Trials and screening for resistance to insect pests and diseases
Total		2,181	

Characterization and analysis of genetic diversity in the vegetable germplasm collection

Evaluation of genetic diversity in Moringa *spp. and* Cajanus cajan *(pigeon pea)*

Taxonomic identification as part of germplasm characterization is the first step done for newly introduced materials in a gene bank and also the breeding laboratory. Morphological and ecological characterization in the field is also essential not only for the preliminary evaluation of germplasm but also seed production and conservation. In addition to these kinds of characterizations, the polymerase chain reaction (PCR)-based technique such as RAPD has been recently and frequently adopted in the characterization of germplasm.

Young shoots and leaves of *Moringa oleifera* (drumstick tree) and *Cajanus cajan* (pigeon pea) are among the indigenous leafy vegetables with highly functional properties. Within these species diversity in antioxidant activity, ascorbic acid, and total phenol contents were also observed among the accessions tested. In order to analyze the genetic diversity of these interesting materials, RAPD-PCR was carried out using 27 accessions of *Moringa* spp. and 38 accessions of *Cajanus cajan* conserved at GRSU.

Total DNA was extracted using K. Edwards DNA extraction method with some modification. DNA concentration was adjusted at 2.5 ng/µl as template DNA for PCR. Reaction mixture for PCR (total 20 µl) were 1 µl of template DNA, 0.2 µl of Taq DNA polymerase (10 units/µl), 2 µl of 10 × PCR buffer, 2 µl of dNTP mixture (2.5 mM each), 1µl of primer (Operon 10-Mer kit, 5 pmols) and 13.8 µl of sterilized distilled water. A Takara PCR Thermal Cycler SP (TP400) was used with the following thermal programs: 94°C for 30 sec; 45 cycles of 94°C for 30 sec, 40°C for 1.5 min, and 72°C for 2.5 min; and then 72°C for 7 minutes. PCR products were fractionated by electrophoresis using 1.5% agarose gel with 1 × TBE buffer containing ethidium bromide. All unambiguously polymorphic bands were identified and scored as present or absent. Similarity matrices were generated according to the Jaccard's similarity coefficient and used in the unweighted pair-group method using arithmetic average (UPGMA) cluster analysis using the software NTSYS-PC version 2.0.

Moringa spp.

A total of 75 primers out of 98 tested could be scored as unambiguously polymorphic bands (76.5%). A total 524 unambiguously polymorphic bands were generated using 75 primers, which means that by using a specific primer, an average of seven unambiguously polymorphic bands could be obtained per primer. The UPGMA dendrogram constructed using the Jaccard's similarity matrix based on the 524 unambiguously polymorphic bands for *Moringa* spp. accessions is shown in Fig. 29.

Moringa spp. accessions tested were divided into four clusters. All *M. oleifera* accessions were included in cluster I. Furthermore, this cluster I could be divided into three groups. All of the accessions from Thailand were classified into cluster I-A. This cluster included one accession from the Philippines (TOT5474). From this result, this accession from the Philippines is suggested to be closely related to the accessions from Thailand and may have a common origin. Accessions from India (La-Mu E), Philippines (Davao Malunggay), Taiwan (TOT4100), USA (TOT4880) and Tanzania (RCA *Moringa*) were included in cluster I-B. Among cluster I, TNAU-1 from India was different from the other *M. oleifera* accessions. Genetic diversity recognized among *M. oleifera* accessions tested here such as clusters I-B and I-C might be a reflection of geographical isolation. Accession 97113-971 (*M. peregrina*), Mo28 (*M. stenopetala*) and African *Moringa* (unknown species) were very low in similarity compared with *M. oleifera* accessions.

As far as morphological characteristics such as leaf size and shape of leaflet, 97113-971 (*M. peregrina*) and the African *Moringa* (unknown species) are completely different from *M. oleifera* accessions. However, Mo28 (*M. stenopetala*) is relatively similar to *M. oleifera* accessions. *M. oleifera* is indigenous and found growing in northern India and Pakistan. Our *M. oleifera* accessions are mainly from Thailand. Accessions near the origin or in the neighboring Indochinese Peninsula can be expected to show more genetic diversity. It may be possible to find superior accessions with higher functional property from these areas.

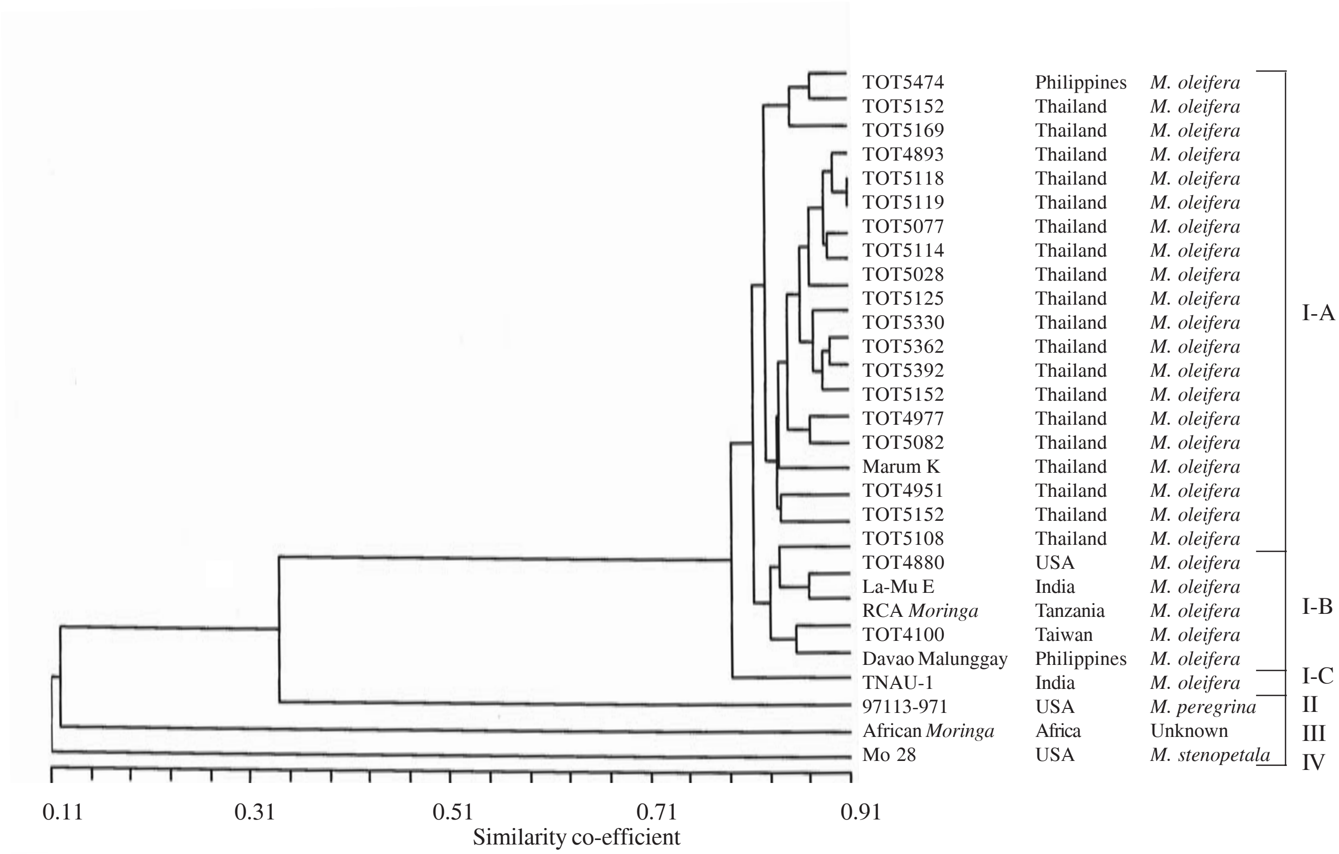


Fig. 29. *Cluster analysis of drumstick tree (*Moringa *spp.) accessions based on RAPD data*

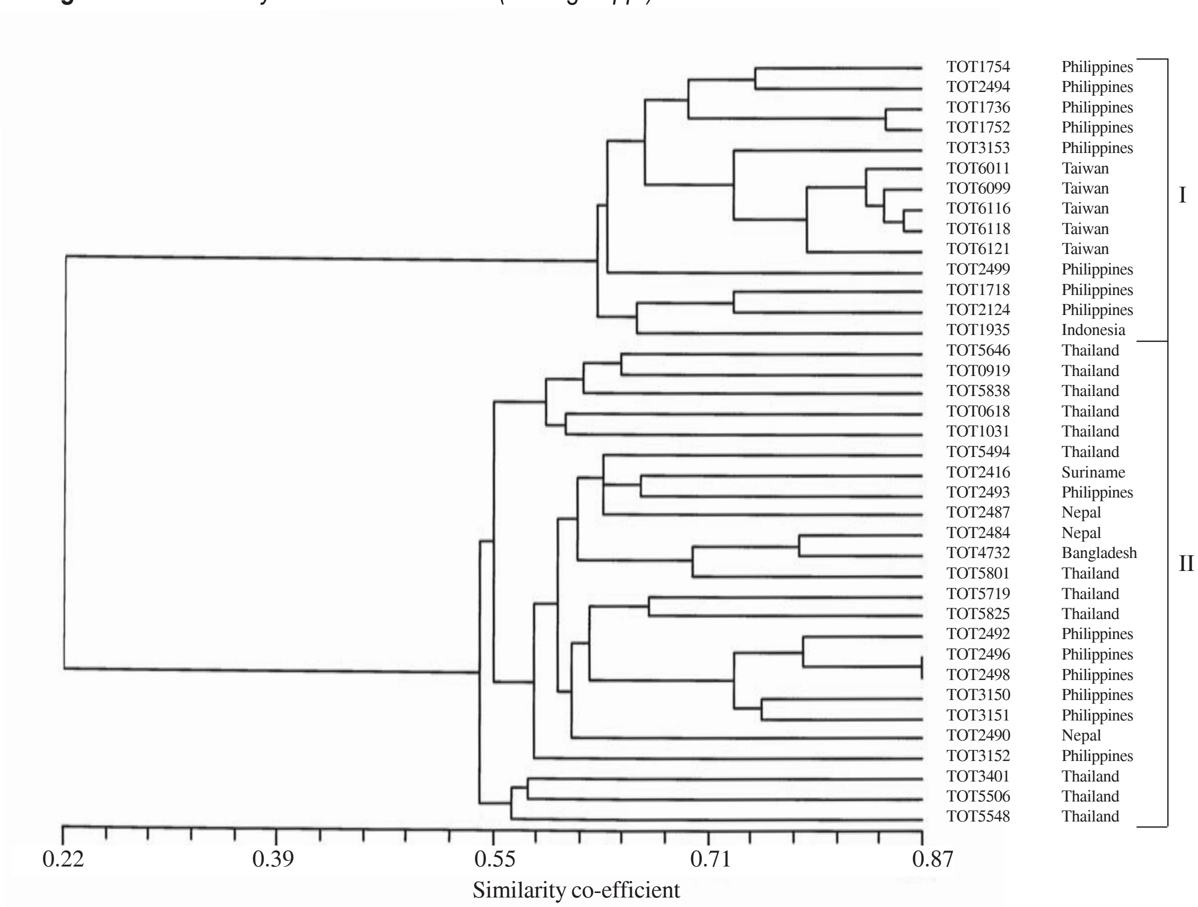


Fig. 30. *Cluster analysis of pigeon pea (*Cajanus cajan*) accessions based on RAPD data*

Evaluation and pre-breeding activities on selected newly introduced indigenous vegetable species

In order to generate information that can be used in the selection of desirable materials, data on morphological characteristics, total yield, functional properties such as antioxidant activity were gathered.

Promising accessions identified during regeneration

The genetic materials planted by genebanks for regeneration and characterization offer a diverse array of genotypes that breeders, entomologists, pathologists and other researchers can observe and possibly identify materials that show promise for utilization. Under the ADB RETA 5839 project "Collection, Conservation, and Utilization of Indigenous Vegetables," participating NARES were encouraged to invite other researchers to observe the materials and make recommendations. As a result, several accessions were identified as promising and were recommended for further evaluation. In Bangladesh selection was based on early female flowering, first green fruit/green leaf harvest, and number of fruits per plant.

Abelmoschus esculentus: In Vietnam four accessions were selected. In the Philippines four accessions were also selected: GB 54 881, GB 54 896, GB 55 251, and GB 55 253.

Amaranthus: Collaborators in Bangladesh identified four promising accessions: AEMM 68 (purple leaf), AEMM 76 (green leaf), AEMM 176 (purple leaf), and AEMM 234 (purple leaf). The Thais chose 11 accessions on the basis of preference: TOT1807, TOT1810, TOT2261, TOT2263, TOT2272, TOT2337, TOT2353, TOT4096, TOT4510, TOT4545, and TOT4685. In Thailand, red-colored accessions were rejected due to their red extract, which was associated with blood.

Basella: Two accessions were identified by the Thais as promising: TOT1586 and TOT3578.

Benincasa hispida: In Bangladesh six accessions were selected: MHA 35 (long fruits), MHA 65 (high number of fruits per plant), MHA 149, MA 95 (high number of primary branches), MA 118 (high number of primary branches), and MA 156. In Vietnam, nine accessions were selected.

Beta vulgaris cvg. *bengalensis*: In Bangladesh, seven accessions were selected: BD 4324, BD 4326 (shorter days to green leaf stage), BD 4332, BD 4335 (narrow leaves), BD 4341, BD 4343 (tall plant), BD 4346 (high leaf yield per plant).

Brassica oleracea cvg. *acephala*: In Vietnam, two accessions were selected.

Corchorus: In the Philippines, GB 54 742 was considered promising.

Cucurbita moschata: In Bangladesh, 18 accessions were selected: BD 4351, BD 4352 (shorter vine) from Chittagong, BD 4356, BD 4359, BD 4363, BD 4369, BD 4378, BD 4386, BD 4387, BD 4398, BD 4399, BD 4401, BD 4403, BD 4412, BD 4419, BD 4424, BD 4427.

Cucumis sativus: In Bangladesh four accessions were selected: BD 4307, BD 4310, BD 4317, and BD 4320. All were chosen for shorter days to flower emergence and green fruit harvest.

Dolichos lablab: In Bangladesh AEMM 570 was selected for early flowering. One plant from AEMM 370 may be resistant to collar rot disease and is recommended for further evaluation. Some accessions (32 of 42) were less infested by aphids in the field.

Lagenaria siceraria: In Bangladesh two accessions were selected: BD 4559 and BD 4572.

Luffa acutangula: In Vietnam three accessions were identified as promising. In Bangladesh seven were selected: AEMM 19/1, AEMM 5919, AEMM 574, NAW 95/1, OD 177 (early flowering), OM 52, and T 71-1 (early green fruit harvest).

Luffa aegyptiaca: In Vietnam, 10 accessions were selected.

Momordica charantia: In Bangladesh, five accessions were selected: BD 4467, BD 4477, BD 4484 (early fruit maturity), BD 4487 (high fruit number), and BD 4488 (early days to female first flowering and first green fruit harvest, small fruited).

Trichosanthes cucumerina: In Bangladesh, 11 accessions were selected: BD 4428, BD 4433, BD 4440, and BD 4441 (all had high fruit number); BD 4444 (high fruit weight); BD 4446, BD 4447; BD 4449 (shorter vine, small seeds); BD 4451; BD 4453 (high number of primary branches); and BD 4456.

Trichosanthes dioica: In Bangladesh four accessions were selected: NI 12, NI 13, NI 14, and RM 24. All of these accessions were selected for early edible fruit development (days from flowering to edible fruit size).

Vigna unguiculata ssp. *sesquipedalis*: The following eight accessions were selected in Bangladesh: AEMM 23, AEMM 24, AEMM 171, AEMM 345, AEMM 353, AEMM 359, AEMM 489, and AEMM 587.

Yield evaluation of indigenous leafy vegetables

High yield is one of the most important characteristics for vegetable production especially during the hot and wet summer season in tropical and sub-tropical regions. Yield fluctuates significantly due to abiotic problems such as high temperature, high moisture, water logging, and biotic problems such as diseases and insects.

Yield evaluations were carried out in Summer 2002 at AVRDC headquarters in Taiwan. A total of 110 accessions (acc) of *Amaranthus* spp., 30 acc of *Basella alba*, 30 acc of *Corchorus* spp., and 10 acc of *Ipomoea aquatica* were grown. All plant materials were sown and grown in the greenhouse and transplanted in the field. Ten plants were harvested weekly and evaluated for yield.

Amaranthus spp.

In 2001, total yields of *Amaranthus* spp. grown in summer cultivation were very low and harvesting could only be done one or two times from 25 July to 1 August 2001. For this reason, yield evaluation for *Amaranthus* spp. in 2002 was carried out about one month earlier than the usual summer cultivation in 2001. Weekly harvests from 110 acc were carried out two to eight times during the period 12 June to 31 July 2002; the difference due to early flower induction in some accessions. The average of harvesting times for all entries was 4.3 times, average total yield for all entries was 2,033 g, average yield/week for all entries was 473 g, and average yield/plant for all entries was 205 g (Table 112). During this period, some accessions did not flower even after more than two months after seeding. The yield of the check variety was similar to the average for all 110 accessions. The highest yielding accession of *Amaranthus* spp. had about three times the average yield. Usually, the higher yielding accessions had green or dark green leaf color, intermediate leaf/stem plant type, and were harvested seven times during this period.

The check variety (TOT5472, Taiwan) was grown in Summers 2001 and 2002, and Spring 2001. Yield in Summer 2002 (220 g/plant) was similar to Spring 2001 (178 g) and much greater than Summer 2001 (35 g). Plants in Summer 2001 suffered from waterlogging.

By harvesting within three weeks after seeding, growers of amaranth will avoid the adverse effect of early flower induction and seed production. Amaranth produces large quantities of seeds that can scatter and become weeds. For this reason, the use of day-neutral *Amaranthus* accessions can be used to stabilize production.

Table 112. *High yelding accessions of* Amaranthus *spp.*

Accession	Origin	Leaf color[1]	Plant type[2]	Total yield[3] (g)	Avg yield/ week[4] (g)	Avg yield/ plant (g)
TOT5829	Thailand	DG	LS	6,030	861	603
TOT4510	Bangladesh	LG	LS	5,920	846	592
TOT3502	Vietnam	G	LS	5,490	784	549
TOT5137	Thailand	G	LS	5,220	746	522
TOT5177	Thailand	DG	LS	4,980	711	498
TOT5142	Thailand	G	LS	4,910	701	491
TOT4303	Bangladesh	G	LS	4,830	(690)[5]	483
TOT3572	Vietnam	DG	LS	4,710	785	471
TOT5151	Thailand	G	LS	4,670	(667)	467
TOT5141	Thailand	G	LS	4,610	(659)	461
TOT3920	Vietnam	G	LS	(4,550)	(650)	(455)
TOT5233	Thailand	G	LS	(4,310)	(616)	(431)
TOT5365	Thailand	DG	LS	(4,270)	(610)	(427)
TOT5264	Thailand	G	LS	(4,190)	(599)	(419)
TOT4942	Thailand	G	LS	(4,170)	695	(417)
TOT4982	Thailand	G	LS	(4,080)	816	(408)
TOT4170	Vietnam	G	LS	(3,970)	794	(397)
TOT3503	Vietnam	G	LS	(3,950)	(564)	(395)
TOT1803B	Indonesia	G	S	(3,945)	(493)	(395)
TOT1803A	Indonesia	G	S	(3,520)	(440)	(352)
TOT5472 (ck)	Taiwan	LG	L	2,200	550	220
Avg for all entries (110 accs)				2,033	473	205

Grown in Summer 2002 at AVRDC

[1] DG = dark green, G = green, and LG = light green

[2] L = leafy type, S = stem type, LS = leafy/stem type

[3] Each plot had 10 plants.

[4] Weekly harvests were conducted two to eight times from 12 June to 31 July, the difference due to early flower induction in some accessions.

[5] Data in parentheses were not among the ten highest for yield.

Basella alba

Table 113 shows the top 15 yielders in *Basella alba* in Summer 2002. Weekly harvests from 30 acc were carried out seven or eight times from 18 June to 7 August. This harvesting period was similar to that of the trial Spring 2001. Average yield/plant for all entries in Spring 2002 (820 g) was very similar that of Spring 2001 (881 g) and Summer 2002 (737 g). Average yield/ plant in accessions from Bangladesh, TOT4263A and TOT4241A were almost at the same levels as observed last Spring 2001. However, data for one of the check varieties TOT5900A, an accession from Japan, was very different from that of Spring 2001. One reason for this might be the lower plant density for this accession in Spring 2001. With lower density, yield/ plant is usually higher. Other factors correlated to high yields in *Basella alba* are morphological characteristics such as medium sized and relatively thick leaves, stems of medium (rather than narrow) thickness, and multiple branching. Usually stem color is not correlated with yield. From the results of trials in Spring and Summer 2001 and Summer 2002, *Basella alba* is a good indigenous leafy vegetable for cultivation during spring or summer in tropical and sub-tropical regions, even in wet conditions.

Table 113. *High yielding accessions of* Basella alba

Accession	Origin	Stem color[1]	Total yield[2] (g)	Avg yield/ week[3] (g)	Avg yield/ plant (g)
TOT5068	Thailand	G	13,500	1,929	1,350
TOT4263A	Bangladesh	G	12,610	1,576	1,261
TOT4241A	Bangladesh	P	12,440	1,555	1,244
TOT5113	Thailand	G	11,100	1,586	1,110
TOT0489	Thailand	P	10,650	1,331	1,183
TOT5724	Thailand	G	9,830	1,404	983
TOT4908	Thailand	P	9,640	1,205	1,607
TOT4684A	Bangladesh	G	9,520	1,360	1,190
TOT5426	Thailand	G	8,330	1,190	833
TOT3576	Vietnam	G	8,260	(1,033)[4]	826
TOT5083	Thailand	P	(8,160)	1,166	(816)
TOT5571	Thailand	G	(8,010)	(1,001)	(801)
TOT5626	Thailand	G	(8,010)	(1,001)	(801)
TOT4091	Vietnam	G	(7,890)	(986)	(789)
TOT5643	Thailand	G	(7,880)	(985)	(788)
TOT5900A (ck)	Japan	G	4,570	571	457
TOT5900B (ck)	Japan	P	4,150	519	415
Average for all entries (30 accs)			7,875	1,036	820

Grown in Summer 2002 at AVRDC
[1]G = green, P = purple
[2]Plots had 6–10 plants.
[3]Weekly harvests were conducted seven or eight times from 18 June to 7 August.
[4]Data in parentheses were not among the ten highest for yield.

Corchorus *spp.*

Except in Bangladesh, *Corchorus* spp. is very minor leafy vegetable in the five participating countries. However the National Plant Genetic Resources Center (NPGRC) of Taiwan Agricultural Research Institute (TARI) in Taiwan conserves more than 180 *Corchorus* spp. accessions. In order to compare *Corchorus* accessions with those collected from South and Southeast Asia, 21 accessions from NPGRC, especially local accessions from Taiwan, were evaluated with accessions from Vietnam and Bangladesh. Table 114 shows the highest yielding accessions of *Corchorus* spp. grown at AVRDC in Summer 2002. TOT4316 and TOT4721, both from Bangladesh, were used as checks because these two accessions were among the highest yielders in 2001. In Summer 2002, only one Taiwanese accession, 98A03170, showed yield that was higher than the two check varieties. Except for *C. olitorious* (98A03170) and *C. capsularis* (97A00731) from NPGRC, many accessions of *C. capsularis* from Taiwan could be harvested only a few times. Most of these accessions did not produce lateral shoots and finally died after the main stem was cut to induce lateral shoots. Based on morphological characterization data, if the main stem is not cut, these plants could grow very high but usually very few lateral shoots are formed. Therefore, the accessions from Taiwan are difficult to use as leafy vegetables.

Table 114. *High yielding accessions of* Corchorus

Accession	Origin	Species	Total yield[1] (g)	Avg yield/ week[2] (g)	Avg yield/ plant (g)
98A03170	Taiwan	*olitorius*	4,980	623	498
97A00731	Taiwan	*capsul.*	3,790	541	379
TOT5999	Taiwan	*capsul.*	3,440	573	344
TOT4071	Vietnam	*capsul.*	3,150	394	315
TOT4235	Bangla.	*capsul.*	3,020	378	302
TOT4541	Bangla.	*olitorius*	2,970	371	330
TOT4067	Vietnam	*capsul.*	2,770	346	277
TOT4051	Vietnam	*capsul.*	2,720	340	272
TOT4316 (ck)	Bangla.	*olitorius*	4,610	576	461
TOT4721 (ck)	Bangla.	*olitorius*	4,240	530	424
Avg for all entries (30 accs)			1,594	319	188

Grown in Summer 2002 at AVRDC
[1]Each plot had 10 plants, except TOT4541 which had 9.
[2]Weekly harvests were conducted up to eight times from 13 June to 31 July, the difference due to early flower induction in some accessions.

Ipomoea aquatica

Only 10 acc of *Ipomoea aquatica* were included in the yield evaluation in Summer 2002 because of shortage of seeds in several newly introduced accessions (Table 115). However, morphological and ecological characterizations were done using a total of 26 accessions from Indonesia and Thailand. Indonesian accessions TOT1920A and TOT1923 were used as check varieties because of their relatively high yield in previous studies. However, all accessions from Thailand included in the trial showed yields higher than the checks. These accessions from Thailand all had green stems and were leafy. Their leaves were also relatively larger. Accessions planted for characterization showed variation in stem color (brown to purple). Leaf size was small. These accessions will be evaluated for yield next year after enough seeds have been produced.

Table 115. *High yielding accessions of* Ipomoea aquatica

Accession[1]	Origin	Total yield[2] (g)	Avg yield/ week[3] (g)	Avg yield/ plant (g)
TOT6155	Thailand	16,730	2,091	1,673
TOT6154	Thailand	14,110	1,764	1,411
TOT6153	Thailand	14,010	1,751	1,401
TOT6152	Thailand	13,420	1,678	1,342
TOT5916	Thailand	12,170	1,521	1,217
TOT5917	Thailand	12,100	1,513	1,210
TOT4212	Thailand	11,720	1,465	1,172
TOT1929	Indonesia	7,560	945	1,512
TOT1923A (ck)	Indonesia	11,150	1,394	1,115
TOT1920A (ck)	Indonesia	9,305	1,163	931
Avg for all 10 entries		12,228	1,528	1,298

Grown in Summer 2002 at AVRDC
[1]All of these high yielding accessions had green stems.
[2]Each plot had 10 plants, except TOT1929 which had 5.
[3]Weekly harvests were conducted eight times from 18 June to 7 August.

Evaluation of antioxidant compounds in indigenous leafy vegetables

Vegetables possess various nutritional elements, the most of important of which are vitamins, micronutrients, and fiber. Diversification of vegetables in the diet may enhance nutritional well-being and overall health. In recent years, the physiological functionality of foods such as vegetables and fruits has received much attention. In order to select superior indigenous leafy vegetables, functional properties such as antioxidant activity, contents of ascorbic acid, and total phenolic compounds were evaluated using accessions (acc) introduced mainly from South and Southeast Asia. *Amaranthus* spp. (25 acc), *Basella alba* (30 acc), *Corchorus* spp. (15 acc), *Ipomoea aquatica* (31 acc), young shoots of *Cajanus cajan* (51 acc), and young shoots of *Moringa* spp. (26 acc) were used as plant materials.

Antioxidant activity was assayed by a modified thiocyanate method using ethanol extracts (10 g sample with 40 ml ethanol). The degree of oxidation was measured using peroxides and reading the absorbance at 500 nm after 3 minutes. T-Butyl-4-hydroxyanisole (BHA) was used as positive antioxidant control. A final concentration of 40 µM BHA (in case of 10 mM BHA) and 2 mg sample (FW)/ml was used. Ascorbic acid content was determined by RQflex plus with the analytical test strip (MERCK) using metaphosphoric acid extracts. The final concentration of metaphosphoric acid was 5%. Ascorbic acid was used as standard solution. Total phenolic compounds were assayed by Folin-Denis method (AOAC 1984) using ethanol extracts (10 g sample with 40 ml ethanol). Total phenolic compounds were measured using the absorbance at 760 nm. Chlorogenic acid was used as standard solution.

The highest rated *Amaranthus* spp. accessions for antioxidant activity, ascorbic acid, and total phenol content in 2002 are shown in Table 116. The antioxidant activity of the top four accessions (TOT5177, TOT5264, TOT1371 and TOT5448) was at the same level or stronger than the 10 mM BHA positive control. The *Amaranthus* spp. accessions with the highest antioxidant activity were the ones with green or dark green leaf color with the exception of TOT4412, which had dark purple leaf color. Six accessions out of the top 10 for antioxidant activity also had the highest contents of ascorbic acid and total phenol compounds. TOT5177, TOT5137, TOT4412 and TOT3920 were recognized as high yielding accessions.

In *Basella alba*, all accessions had lower antioxidant activity than the 10 mM BHA positive control (Table 117). However, the average measurements for ascorbic acid and total phenolic compounds (98 mg/100 g FW and 402 mg chlorogenic acid equivalent/100 g FW, respectively) were higher than obtained in *Amaranthus* spp. (84 and 289, respectively). *Basella alba* is one of few vegetables that grows well in the hot-wet season and can be a valuable source of ascorbic acid and total phenols during that season.

Results in 2002 confirm that *Corchorus* spp. is an indigenous leafy vegetable with strong antioxidant activity. The average for all 15 entries for antioxidant activity was 73%. The 10mM BHA positive control was 71% (Table 118). However, ascorbic acid and total phenol contents for this summer were lower than in Summer 2001; possible factors for this may be differences in accessions planted, more rainfall in 2001, and a one-month difference in sampling dates. *Corchorus* spp. accessions with higher antioxidant activity also showed higher ascorbic acid and total phenol contents. Comparing the two species tested, *C. capsularis* had stronger antioxidant activity than C. *olitorius*. This tendency was also observed last year.

The kangkong accessions tested last year had pale purple stems with large green leaves. However, some kangkong accessions evaluated this year had brown to purple stem color, small leaf size, and late maturing. From the results of the evaluation for antioxidant activity in 2002, the top three were accessions with purple stems and small leaves. These purple-stem small-leaf accessions also had higher total phenol contents (Table 119). These accessions might not be suitable for once-over harvesting because of their late maturity; however, these accessions have high functional properties and should be included in yield evaluation trials in the future.

Total phenol contents of kangkong accessions grown in Summer 2001 and those grown in Summer 2002 were different; these differences might be due to cultural conditions or genotype differences. In 2002, the kangkong accessions were grown inside net cages

Table 116. *Highly rated* Amaranthus *spp. accessions for antioxidant activity, ascorbic acid, and total phenol content*

Accessions	Origin	Leaf color[1]	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
TOT5177	Thailand	DG	77	111	398
TOT5264	Thailand	G	77	100	435
TOT1371	Thailand	G	75	107	282
TOT5448	Thailand	G	75	(55)[5]	(231)
TOT4942	Thailand	G	74	93	427
TOT5137	Thailand	G	74	92	431
TOT5740	Thailand	G	74	101	(270)
TOT5829	Thailand	DG	74	(84)	299
TOT4412	Bangladesh	DP	74	(85)	(213)
TOT3920	Vietnam	G	73	106	452
TOT5365	Thailand	DG	73	(84)	380
TOT3462	Vietnam	G/IP	(72)	135	(262)
TOT3498	Vietnam	DP	(72)	89	(210)
TOT4510	Bangladesh	LG	(72)	(80)	414
TOT3572	Vietnam	DG	(71)	(84)	313
TOT4740	Bangladesh	DP	(71)	90	(189)
TOT5472 (ck)	Taiwan	LG	(63)	(56)	(175)
Avg for all entries (25 accs)		72	84	289	
SD			4	20	91
Max.			77	135	452
Min.			63	52	172

Grown in Summer 2002 at AVRDC
[1]D = dark green, DP = dark purple, G = green, G/IP = green/inside purple, LG = light green
[2]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 75%
[3]Mg/100 g fresh weight
[4]Mg chlorogenic acid equivalent/100 g fresh weight
[5]Data in parentheses were not among the top ten highest scores.

Table 117. *Highly rated* Basella alba *accessions for antioxidant activity, ascorbic acid, and total phenol content*

Accessions	Origin	Stem color[1]	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
TOT5042	Thailand	G	67	121	547
TOT5809	Thailand	G	67	103	481
TOT5528	Thailand	G	67	(86)[5]	463
TOT5724	Thailand	PG	67	113	(412)
TOT5083	Thailand	P	65	124	518
TOT4908	Thailand	P	64	116	413
TOT5626	Thailand	PG	64	103	(390)
TOT5426	Thailand	G	63	(100)	431
TOT5571	Thailand	PG	63	(71)	416
TOT4684A	Bangladesh	G	(62)	117	428
TOT5635	Thailand	PG	(62)	102	(395)
TOT4907	Thailand	PG	(60)	154	546
TOT5113	Thailand	PG	(59)	116	(412)
TOT5491	Thailand	G	(58)	90	426
TOT5900A (ck)	Japan	PG	65	(83)	(385)
TOT5900B (ck)	Japan	P	65	(82)	356
Avg for all entries (30 acc)			63	98	402
SD			3	18	60
Max.			67	154	547
Min.			58	71	312

Grown in Summer 2002 at AVRDC
[1]G = green, PG = pale green, P = purple
[2]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 71%
[3]Mg/100 g fresh weight
[4]Mg chlorogenic acid equivalent/100 g fresh weight
[5]Data in parentheses were not among the top ten highest scores.

covered with cheesecloth for seed production. However, accessions grown in 2001 were raised without net cages.

This led to an experiment to analyze the effect of net cages on functional properties of kangkong. Total phenol content of kangkong grown outside the net cage (970 mg chlorogenic acid equivalent/100 g FW) was higher than that grown inside the net cage (560 mg). Antioxidant activity of kangkong grown outside the net cage was slightly higher than inside the net cage, but ascorbic acid content was the same for both treatments. The higher antioxidant activity of accessions grown outside the net cage may be correlated with higher content of chlorogenic acid.

Time-of-day sampling for total phenol content of kangkong was also analyzed in October. Using four accessions for sampling, total phenol contents gradually increased through the day. Contents were 770, 841, 982, 1039, and 1154 mg chlorogenic acid equivalent/ 100 g FW at 08:00, 10:00, 12:00, 14:00 and 16:00 hours, respectively.

Table 118. *Highly rated* Corchorus *spp. accessions for antioxidant activity, ascorbic acid, and total phenol content*

Accessions	Origin	Species	Antioxid. activity[1]	Ascorbic acid[2]	Total phenol[3]
TOT97A00843	Taiwan	*capsul.*	75	98	455
TOT97A00830	Taiwan	*capsul.*	75	93	414
TOT4051	Vietnam	*capsul.*	74	107	468
TOT97A00853	Taiwan	*capsul.*	74	111	433
TOT4064	Vietnam	*capsul.*	74	98	484
TOT97A00731	Taiwan	*capsul.*	73	96	413
TOT97A00770	Taiwan	*capsul.*	73	92	(326)[4]
TOT98A03170	Taiwan	*olitorius*	73	(84)	434
TOT5999	Taiwan	*capsul.*	73	(86)	(366)
TOT4541	Bangla.	*olitorius*	(72)	(70)	411
TOT4067	Vietnam	*capsul.*	(71)	101	459
TOT4071	Vietnam	*capsul.*	(71)	96	495
TOT4235	Bangla.	*capsul.*	(71)	103	(373)
TOT4316 (ck)	Bangla.	*olitorius*	(71)	(75)	(394)
TOT4721 (ck)	Bangla.	*olitorius*	74	(79)	(398)
Avg for all entries (15 acc)			73	93	422
SD			1	12	47
Max.			75	111	495
Min.			71	70	326

Grown in Summer 2002 at AVRDC
[1]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 71%.
[2]Mg/100 g fresh weight
[3]Mg chlorogenic acid equivalent/100 g fresh weight
[4]Data in parentheses were not among the top ten highest scores.

Total phenol contents of different leafy vegetables harvested in the morning (08:00) and in the afternoon (13:00) were also evaluated (data not shown). The extent of difference in total phenol content in the morning harvest and afternoon harvest varied among vegetables. For example, young shoots of *Capsicum* pepper (*Capsicum annuum*, dark purple accession), young shoots of ivy gourd (*Coccinia grandis*), sweet potato vine (*Ipomoea batatas*) and kangkong differed in total phenol content depending on time of harvest, all increasing in the afternoon. However in *Basella alba* both green and purple-stemmed accessions had the same level of total phenol irregardless of time of day.

Table 119. *Highly rated* Ipomoea aquatica *accessions for antioxidant activity, ascorbic acid, and total phenol content*

Accessions	Origin	Stem color[1]	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
TOT6156	Thailand	P	77	(36)[5]	545
TOT6167	Thailand	P	74	(33)	561
TOT6166	Thailand	P	74	(49)	(486)
TOT6162	Thailand	G	72	(47)	627
TOT6158	Thailand	P	72	(50)	572
TOT4212	Thailand	G	71	54	588
TOT1929	Indonesia	G	71	58	(377)
TOT6157	Thailand	P	71	53	(529)
TOT5917	Thailand	G	71	(47)	(523)
TOT6165	Thailand	P	71	(34)	(527)
TOT5875	Taiwan	G	71	(31)	(437)
TOT0051	Malaysia	G	(70)	(34)	595
TOT5981	Taiwan	G	(70)	(34)	580
TOT6155	Thailand	G	(70)	51	(438)
TOT5915	Thailand	G	(69)	67	(275)
TOT6152	Thailand	G	(69)	54	(532)
TOT6153	Thailand	G	(69)	51	(411)
TOT5916	Thailand	G	(68)	59	(505)
TOT6169	Thailand	P	(67)	(41)	541
TOT5465	Thailand	P	(66)	54	(380)
TOT1920A (ck)	Indonesia	G	(68)	(45)	540
TOT1923A (ck)	Indonesia	G	(69)	56	558
Avg for all entries (31 accs)		70	46	497	
SD			2	9	76
Max.			77	67	627
Min.			66	31	275

Grown in Summer 2002 at AVRDC
[1]G = green, P = purple
[2]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 70%.
[3]Mg/100 g fresh weight
[4]Mg chlorogenic acid equivalent/100 g fresh weight
[5]Data in parentheses were not among the top ten highest scores.

Results from the evaluation of functional properties of *Moringa* spp. using young leaves are shown in Table 120. Twenty-three *Moringa* accessions out of 26 were *M.oleifera* and the others were *M. stenopetala* (Mo 28), *M. peregrina* (97113-971) and unknown species (African *Moringa*). Nine of the top 10 *Moringa* accessions for antioxidant activity were *M. oleifera* accessions, the other being the *M. stenopetala* accession. *Moringa oleifera* accessions contained higher antioxidant activity, ascorbic acid, and total phenol contents compared with other leafy vegetables. RCA *Moringa* and Davao Malunggay accessions contained more than 300 mg/100 g FW of ascorbic acid. Accessions La-Mu E, TOT4880, and RCA *Moringa* contained higher total phenol (more than 800 mg chlorogenic acid equivalent/100 g FW). In addition to the above four accessions, the top three for antioxidant activity (TOT5028, TOT5118, and TOT5474) also had higher functional properties, in general.

A study was conducted to comparing the functional properties of leaves at different stages of development.

Table 120. *Highly rated* Moringa *spp. accessions for antioxidant activity, ascorbic acid, and total phenol content in young leaf*

Accessions	Origin	Antioxid. activity[1]	Ascorbic acid[2]	Total phenol[3]
TOT5028	Thailand	84	228	697
TOT5118	Thailand	82	287	691
TOT5474	Philippines	82	230	711
TOT4951	Thailand	82	239	(669)[4]
TOT4893	Thailand	82	(221)	(656)
La-Mu E	India	81	275	843
Marum K	Thailand	81	280	703
TOT4880	USA	81	(211)	809
RCA *Moringa*	Tanzania	79	323	853
Davao Malunggay	Philippines	79	302	721
Mo28	USA	79	256	983
African *Moringa*	Africa	(77)	295	915
Avg for all entries (26 accs)		80	245	713
SD		3	40	102
Max.		84	323	983
Min.		65	158	566

Grown in Autumn 2002 at AVRDC

[1]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 71%

[2]Mg/100 g fresh weight

[3]Mg chlorogenic acid equivalent/100 g fresh weight

[4]Data in parentheses were not among the top ten highest scores.

Young shoots (unexpanded leaf) and young leaves (completely expanded but still soft leaf) were compared. No apparent differences for antioxidant activity, ascorbic acid content, and phenolic content were found, but young shoots were considered more edible.

The very young and dried seeds of pigeon pea are widely consumed, but its leaves and young shoots are also cooked as a potherb. Antioxidant activity of pigeon pea using young shoots was compared with other indigenous leafy vegetables. Total phenol content in young shoots of pigeon pea was very high and the average for all 51 entries was around 1000 mg chlorogenic acid equivalent/100 g FW (Table 121). Ascorbic acid content ranged from 78 to 198 mg/100 g FW. Almost all the accessions were grown inside a net cage with white-color cheesecloth for seed reproduction, but two accessions were grown both inside and outside the net cage (open field). Ascorbic acid and total phenol contents of plants grown outside the net cage were higher. This result was similar to that observed in kangkong. For this reason, after seed reproduction is completed, an evaluation of functional properties of pigeon pea growing outside net cages will be conducted, followed by selection of superior accessions.

From the results of yield evaluation and functional property such as antioxidant activity, several accessions were selected for further evaluation. For *Amaranthus* spp., TOT4303, TOT4510, TOT5137, TOT5829, and TOT3502 were selected for yield properties and TOT5177, TOT5264, TOT1371, TOT4942, and TOT5740 for functional properties. Likewise for *Basella alba*, TOT5068, TOT4263A, TOT4241A, and TOT5113 were selected for yield and TOT5042, TOT5083, TOT5809, and TOT4907 for functional properties. For *Corchorus* spp., 98A03170 (*C. olitorius*), TOT4721 (*C. olitorius*), TOT4316 (*C. olitorius*), 97A00731 (*C. capsularis*), and TOT4541 (*C. olitorius*) were chosen for yield properties and 97A00843 (*C. capsularis*), TOT4051 (*C. capsularis*), 97A00853 (*C. capsularis*), TOT4721 (*C. olitorius*), and 98A03170 (*C. olitorius*) for functional properties. Lastly for kangkong, TOT6155, TOT6154, TOT5917, TOT4212, TOT1923A were selected for their yield properties and TOT6156, TOT6167, TOT4212, TOT6162, TOT6158 for functional properties.

Table 121. *Highly rated pigeon pea (*Cajanus cajan*) accessions for antioxidant activity, ascorbic acid, and total phenol content in young shoot*

Accessions	Origin	Antioxid. activity[1]	Ascorbic acid[2]	Total phenol[3]
TOT2124 (OF)[4]	Philippines	81	178	(1,015)[5]
TOT2125	Philippines	79	(164)	(887)
TOT5810	Thailand	78	(160)	(936)
OT6118	Taiwan	77	198	(895)
TOT1754	Philippines	77	(150)	(1,003)
TOT2124	Philippines	77	(146)	(876)
TOT6120	Taiwan	76	184	(810)
TOT2490	Nepal	76	(87)	1,109
TOT6119	Taiwan	(75)	174	(924)
TOT2494	Philippines	(73)	183	(991)
TOT2416 (OF)	Suriname	(72)	186	(988)
TOT5838	Thailand	(67)	176	1,101
TOT3151	Philippines	(64)	193	1,035
TOT2495	Philippines	(63)	(136)	1,348
TOT2497	Philippines	(63)	(126)	1,106
TOT0618	Thailand	(62)	(129)	1,114
TOT0919	Thailand	(62)	(101)	1,122
TOT3401	Thailand	(61)	173	1,141
TOT2496	Philippines	(60)	181	1,049
TOT2498	Philippines	(60)	(160)	1,178
TOT6121 (ck)	Taiwan	78	172	(925)
TOT6011 (ck)	Taiwan	76	(151)	(894)
Avg for all entries (51 acc)		70	143	975
SD		6	30	118
Max.		81	198	1348
Min.		60	78	757

Grown in Autumn 2002 at AVRDC

[1]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 70%.

[2]Mg/100 fresh weight

[3]Mg chlorogenic acid equivalent/100 g fresh weight

[4]OF = open field. Other accessions were grown in net shelters.

[5]Data in parentheses were not among the top ten highest scores.

Project 9. Collaborative research and networks for vegetable production

The objectives of Project 9 are to increase the capacity of national agricultural research and extension systems (NARES) 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 NARES partners and advanced laboratories.

Project Coordinator: G Kuo

AVRDC-ROC cooperative program

Regional yield trials

The purpose of regional yield trials (RYTs) is to serve as one of the means for transferring AVRDC's research outputs to Taiwan. In cooperation with Taiwan national agricultural research and extension system (NARES), RYTs were conducted to evaluate promising AVRDC lines/varieties in the field under seasons and/or locations in Taiwan.

Vegetable soybean

Nine lines, including three AVRDC lines, three Tainan District Agricultural Improvement Station (DAIS) lines, and three Kaohsiung DAIS lines were evaluated against three check varieties, Kaohsiung No. 1 (KS#1), KS#2, and KS#5 at AVRDC headquarters. The lines were evaluated in four seasons: Autumn 2000 (September 15–November 28, mean day/night air temperatures at 30.1/21.5°C, 90 mm rainfall); Spring 2001 (February 7–May 3, mean day/night air temperatures at 27.4/18.1°C, 104 mm rainfall); Autumn 2001 (September 3–December 3, mean day/night air temperatures at 29.8/20.5°C, 523 mm rainfall); and Spring 2002 (February 6–Apr. 29, mean day/night air temperatures at 28.3/18.6°C, 2 mm rainfall). The experimental design was randomized complete block design (RCBD) with four replications. Plot size was 5 m × 3 m, and spacing was 50 cm between rows and 10 cm between plants.

Tested lines showed significant differences in graded pod yields (Table 122). An AVRDC line, GC93032-2-1-1-1 produced the highest yield in Spring 2001 (9.4 kg/ha), and tied another AVRDC line, GC92001-P-25-1, for highest overall mean yield across all seasons (7.0 kg/ha). In some cases the performance of lines varied tremendously from season to season. For example, GC93010-1-1-2-2-6 produced the highest yield in Spring 2002, but the lowest yield in Spring 2001. Similarly, TS87-S4, a Tainan DAIS-developed line, produced the highest yield in Autumn 2000 but the lowest yield in Autumn 2001. Graded pod yields of spring trials were generally higher than those of fall trials. Yields in Autumn 2001 were reduced due to typhoon and heavy rain for two weeks after sowing.

Table 122. *Graded pod yield (t/ha) of vegetable soybean lines tested in regional yield trials at AVRDC*

Lines	Autumn 2000[1]	Spring 2001[2]	Autumn 2001[3]	Spring 2002[4]	Mean
KVS968	4.6	5.9	5.0	6.8	5.6
KVS1027	6.1	5.4	4.9	7.4	6.0
KVS1159	5.1	6.0	4.1	7.1	5.6
TS85-06V	4.6	5.4	3.0	6.3	4.8
TS87-S4	6.9	6.5	2.8	6.2	5.6
TS87-12V	5.8	8.0	5.2	8.4	6.9
GC92001-P-25-1	6.1	7.9	5.0	9.1	7.0
GC93010-1-1-2-2-6	4.8	4.6	7.2	9.3	6.5
GC93032-2-1-1-1	6.2	9.4	4.2	8.3	7.0
KS#1 (ck)	6.7	6.7	3.3	5.9	5.7
KS#2 (ck)	5.7	7.8	5.8	6.5	6.5
KS#5 (ck)	4.4	5.9	3.1	7.0	5.1
Mean	5.6	6.6	4.5	7.4	6.0
LSD (5%)	0.9	1.2	0.9	1.8	

[1] Lines sown on 15 September and harvested 21–28 November 2000
[2] Lines sown on 7 February and harvested 26 April to 3 May 2001
[3] Lines sown on 3 September and harvested 23 November to 3 December 2001
[4] Lines sown on 6 February and harvested 19–29 April 2002

Protein percentages for the various lines ranged from as low as 36.8% for check KS#1 in Spring 2002 to a peak of 50.0% for GC93032-2-1-1-1 in Autumn 2000 (Table 123). Differences of protein content appeared to be greater between seasons than among varieties of the same season. Soluble solids is a key trait for consumer acceptability and KS#1 had the

Table 123. *Quality analysis of vegetable soybean lines tested in regional yield trials at AVRDC*

Lines	Autumn 2000 Protein (%)	Autumn 2000 Sugar (%)	Autumn 2000 Color[1]	Spring 2001 Protein (%)	Spring 2001 Sugar (%)	Spring 2001 Color	Autumn 2001 Protein (%)	Autumn 2001 Sugar (%)	Autumn 2001 Color	Spring 2002 Protein (%)	Spring 2002 Sugar (%)	Spring 2002 Color	Mean Protein (%)	Mean Sugar (%)	Mean Color
KVS968	47.9	12.5	3.9	47.3	13.8	3.5	42.0	10.8	4.5	42.0	9.0	4.6	44.8	11.5	4.1
KVS1027	48.0	10.6	3.7	47.8	12.0	4.0	40.6	12.0	3.4	41.0	8.1	4.0	44.4	10.7	3.8
KVS1159	44.5	10.8	3.8	43.1	12.9	4.0	37.9	11.4	4.7	39.2	8.0	4.9	41.2	10.8	4.4
TS85-06V	49.2	13.5	3.8	47.3	14.4	3.8	40.7	12.4	3.8	42.0	10.0	4.3	44.8	12.6	3.9
TS87-S4	46.4	12.7	3.8	45.1	13.1	3.7	39.3	10.9	3.7	39.6	9.6	3.7	42.6	11.6	3.7
TS87-12V	48.6	11.2	3.8	46.3	13.1	3.6	41.0	12.2	3.5	42.6	9.9	3.4	44.6	11.6	3.6
GC92001-P-25-1	47.1	11.3	4.0	46.7	12.9	4.0	38.3	13.4	4.0	39.2	9.7	4.7	42.8	11.8	4.2
GC93010-1-1-2-2-6	48.4	10.7	3.7	46.3	12.5	3.7	40.7	12.7	3.4	42.5	8.7	4.2	44.5	11.2	3.8
GC93032-2-1-1-1	50.0	12.1	3.6	46.7	13.0	3.8	40.9	12.1	3.4	42.9	9.2	4.7	45.1	11.6	3.9
KS#1 (ck)	45.6	12.3	3.9	43.1	15.0	3.5	35.7	14.7	3.5	36.8	11.0	4.4	40.3	13.3	3.8
KS#2 (ck)	48.2	10.4	3.8	45.1	12.0	3.7	39.8	12.5	2.8	41.2	9.5	3.0	43.6	11.1	3.3
KS#5 (ck)	47.4	11.3	4.0	46.8	12.7	3.6	38.4	13.1	2.8	41.2	10.1	3.9	43.5	11.8	3.6
Mean	47.6	11.6	3.8	46.0	13.1	3.7	39.6	12.3	3.6	40.8	9.4	4.1	43.5	11.6	3.8
LSD (5%)	0.9	0.9	0.2	1.1	0.7	0.2	0.8	0.6	0.4	0.8	0.9	0.4			

[1]Pod color rated on 1–6 scale with 1 = very dark green-yellow, and 6 = pale green-yellow

highest percentage of soluble solids in Spring 2001, Autumn 2001, and Spring 2002.

Another important trait is color value, with lower values signifying darker colored pods and greater consumer acceptability. Line KS#2 produced the darkest green pods, while KVS1159 consistently produced the palest pods. High yielding lines GC920001-P-25-1 and GC93032-2-1-1-1 also produced paler, less attractive pods than check varieties.

The principal criteria for selecting lines for release are higher soluble solids and lower pod color value than the check varieties. Although GC93032-2-1-1-1 produced higher yield in three seasons, it generally had lower soluble solids and paler pods than the check varieties. In fact, none of the experimental lines were superior to the check varieties for these pod quality traits.

In a separate trial, 10 new vegetable soybean lines, including two AVRDC lines, five Kaohsiung DAIS lines, and three Tainan DAIS lines, were evaluated in regional yield trials at AVRDC headquarters in Autumn 2002 (3 September to 21 November, mean day/night air temperatures at 31.9/22.6°C, 84 mm rainfall). A Kaohsiung DAIS-developed line, KVS1175, produced the highest graded pod yield, and significantly outyielded the check varieties, KS#1, KS#2, and KS#5 by 60.9%, 60.1%, and 31.5%, respectively (Table 124). KVS1175 gave significantly higher 100-fresh seeds weight than KS#1. TS88-57V had heavier single pod than other entries. Pod length and width of all tested lines were between 4.4–5.3 cm and 1.3–1.4 cm, respectively. GC95106-6 had significantly longer pods than KS#1, KS#2 and KS#5. Three more RYTs are being planned in 2003–2004.

Table 124. *Regional yield trial of vegetable soybean at AVRDC*

Lines	Days to maturity	Pod no./ 500 g	100-fresh seed wt. (g)	Pod length[1] (cm)	Pod width[1] (cm)	Graded pod yield (t/ha)
KVS1175	73	163.7	74.3	4.4	1.3	10.3
KVS1194	74	164.3	68.0	4.5	1.4	7.6
KVS1209	74	172.0	63.0	4.5	1.4	5.5
KVS1249	73	175.0	63.0	4.6	1.3	8.5
KVS1312	72	171.3	64.3	4.7	1.3	9.4
TS88-04V	72	169.3	69.0	4.8	1.4	8.7
TS88-31V	71	178.0	63.0	5.0	1.3	5.7
TS88-57V	71	157.0	68.3	5.0	1.4	5.7
GC95004-2-3-1-1	67	159.0	67.7	5.2	1.3	8.9
GC95106-6	67	160.0	72.0	5.3	1.4	8.1
KS#1 (ck)	65	166.7	64.7	4.7	1.4	6.4
KS#2 (ck)	65	164.3	72.0	4.8	1.4	6.4
KS#5 (ck)	65	168.3	76.0	4.7	1.3	7.8
Mean	69.9	166.8	68.1	4.8	1.4	7.6
LSD (5%)	1.1	8.4	6.1	0.2	0.1	1.2

Lines sown on 3 September and harvested 12–21 November 2002
[1]Measured from double-seeded pods

Fresh market tomato

This trial was conducted to identify promising fresh market hybrids with late blight resistance for mid elevation (about 500 m above sea level) farms in central Taiwan. This elevation is favorable for summer tomato production because of its relatively cool temperature; however, the high humidity is conducive to late blight infection. Five AVRDC hybrids were evaluated along with check varieties, Taoyuan-ASVEG No. 9, Taichung-ASVEG No. 10, and Farmers 301 (of Known You Seed Co.), during 6 May to 10 July 2002 (mean day/night air temperatures at 32.7/25.0°C, 384 mm rainfall) at AVRDC headquarters. The experimental design was RCBD with four replications. Plants were set in twin rows on raised beds with plants spaced 50 cm apart. Plot size was 5 m × 3 m, and 75 cm between rows. Applications of 90N–38.7P–74.7K–13.7Mg kg/ha of inorganic and 80N–34.4P–66.4K kg/ha of an organic fertilizer with organic matter content of 60% were applied by basal dressing during land preparation. Applications of 30N–12.9P–24.9K inorganic fertilizer were sidedressed two weeks after transplanting, one month after transplanting, and then again every month after that.

Late blight-resistant, large-fruited lines, FMTT792 and FMTT791, gave highest yields at 22.8 t/ha and 22.6 t/ha, respectively; both lines significantly outyielded the check variety Taichung-ASVEG No. 10 (18.3 t/ha) and Farmers 301 (13.4 t/ha) (Table 125). Despite relatively high air temperatures, all entries had high fruit set rates between 45.1 and 49.6%. FMTT795 had higher fruit set rate than FMTT792 and FMTT791, but the yield was lower due to smaller fruit size (54.3 g/fruit). Unfortunately, average yield levels of tested entries in this trial were much lower than expected. This was due to tomato leaf curl virus (ToLCV) infection during the flowering period.

FMTT795 had the highest soluble solids and FMTT793 had the highest color value among all lines tested. Overall, with its high yields and high solids/acidity ratio, FMTT792 was considered as the most promising line. However, lines resistant to both late blight and ToLCV are needed for reliable yields in this region.

High lycopene cherry tomato

Cherry tomatoes, especially those varieties with high lycopene content, are gaining popularity in Taiwan. Three red cherry tomato hybrids were tested at AVRDC headquarters along with check Tainan-ASVEG No. 6. The trial was conducted from 27 February 27 to 10 July 2002 (mean day/night air temperatures at 31.1/22.5°C, 386 mm rainfall). The experimental design was RCBD with four replications, two rows per plot, and 50 cm between plants. Plot size was 5 m × 3 m, and 75 cm between rows. Applications of 90N–38.7P–74.7K–13.7Mg kg/ha of inorganic and 80N–34.4P–66.4K kg/ha of an organic fertilizer with organic matter content of 60% were applied by basal dressing during land preparation. Applications of 30N–12.9P–24.9K inorganic fertilizer were sidedressed two weeks after transplanting, one

Table 125. *Regional yield trial of fresh market tomato hybrids at AVRDC*

Lines	Days to maturity	Fruit set (%)	Fruit wt. (g/fruit)	Marketable yield (t/ha)	Solids °brix	Acid[1] (%)	Solids/ acid	Color[2] (a/b)
FMTT791	81.4	49.2	67.9	22.6	5.75	0.49	11.73	1.00
FMTT792	81.2	45.6	70.5	22.8	5.88	0.49	12.00	1.15
FMTT793	83.2	47.1	52.0	18.5	5.90	0.51	11.57	1.20
FMTT794	83.6	45.1	75.1	18.2	5.38	0.49	10.98	0.96
FMTT795	83.2	49.6	54.3	20.9	6.13	0.57	10.75	0.83
Taoyuan-ASVEG No. 9	82.8	45.6	78.7	22.0	5.60	0.49	11.42	0.74
Taichung-ASVEG No. 10	83.3	45.8	68.5	18.3	5.53	0.48	11.52	1.13
Farmers 301	87.2	45.9	45.4	13.4	5.93	0.551	10.78	1.10
Mean	83.2	46.7	64.1	19.6	5.76	0.51	11.29	1.01
LSD (5%)	2.3	4.6	21.9	2.8	0.42	0.03	0.16	

Lines sown on 6 March, transplanted on 29 March, and harvested from 30 May to 10 July 2002

[1]Equivalent of citric acid

[2]Values for a and b were measured with a chromometer using red standard surface. Immature green tomatoes have a/b ratio less than zero. The a/b ratio increases to zero and above as fruits ripen toward dark red.

month after transplanting, and then again every month after that.

The AVRDC hybrids selected for this trial set fruit under high temperatures, resist cracking, and have good flavor. CHT1127 matured earlier, produced significantly higher yields, and had significantly larger fruit weight, soluble solids, and color values than check Tainan ASVEG-No. 6 (Table 126). It is resistant to tomato mosaic virus and fusarium wilt races 1 and 2. On 3 December 2002, the ROC Council of Agriculture released CHT1127 as "Tainan ASVEG-No. 11."

ToLCV-resistant cherry tomato

Overall yield of the above trial was depressed due to ToLCV incidence during the flowering period. Thus, a second trial was conducted to evaluate lines with ToLCV resistance. Five ToLCV-resistant red cherry tomato hybrids, namely, CHT1312, CHT1313, CHT1372, CHT1374, and CHT1358, and check variety Tainan-ASVEG No. 6 were evaluated at four locations (AVRDC, Annan, Luenbey, and Sueishan; the latter three are within a 30-kilometer radius from AVRDC) from 9 August 2002 to 10 February 2003 (mean day/night air temperatures at 29.1/19.7°C, 211 mm rainfall). The experimental design was RCBD with four replications, two rows per plot, and 50 cm between plants. Plot size was 5 m × 3 m, and 75 cm between rows. Applications of 90N–38.7P–74.7K–13.7Mg kg/ha of inorganic and 80N–34.4P–66.4K kg/ha of an organic fertilizer with organic matter content of 60% were applied by basal dressing during land preparation. Applications of 30N–12.9P–24.9K inorganic fertilizer were sidedressed two weeks after transplanting, one month after transplanting, and then again every month after that.

The incidence of ToLCV for the CHT lines was very low (below 5%) at all four locations, whereas 74–100% of check variety plants were infected (Table 127). The CHT lines outyielded the check variety by 22–40% at AVRDC, 38–54% at Annan, and 162–194%

Table 126. *Regional yield trial of cherry tomato hybrids at AVRDC*

Lines	Days to maturity	Fruit set (%)	Fruit weight (g)	Marketable yield (t/ha)	Solids (°brix)	Acid[1] (%)	Solids/ acid	Color[2] (a/b)
CHT1126	84.1	71.9	11.1	19.6	6.55	0.41	15.98	0.66
CHT1127	80.2	74.0	12.4	29.1	7.00	0.40	17.50	0.83
CHT1130	79.3	73.0	13.6	28.9	6.23	0.37	16.83	0.77
Tainan-ASVEG No. 6	83.6	72.6	10.5	17.8	6.63	0.41	16.17	0.74
LSD (5%)	1.2	4.7	1.4	3.2	0.47	0.03		0.16

Lines were sown on 27 February, transplanted on 20 March, and harvested from 20 May to 10 July 2002
[1]Equivalent of citric acid
[2]Values for a and b were measured with a chromometer using red standard surface. Immature green tomatoes have a/b ratio less than zero. The a/b ratio increases to zero and above as fruits ripen toward dark red.

Table 127. *Incidence of tomato leaf curl virus and fruit yields of cherry tomato hybrids evaluated at locations in southern Taiwan*

	AVRDC		Annan		Luenbey		Sueishan	
Lines	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)
CHT1312	0.0	78.9	0.5	79.7	3.7	-[2]	2.1	43.7
CHT1313	0.0	73.4	2.1	73.8	2.1	-	3.1	40.6
CHT1372	0.0	71.0	2.6	71.9	1.6	-	0.5	43.4
CHT1374	0.0	72.8	1.0	71.5	4.7	-	2.1	41.0
CHT1358	0.0	81.5	2.6	71.9	1.6	-	2.6	45.5
Tainan-ASVEG No. 6	74.0	58.2	100.0	51.9	100.0	-	100.0	15.5
LSD (5%)	19.2	7.5	3.3	14.9	4.2	-	3.6	7.2

[1]Lines were transplanted on 2 September at AVRDC, 11 September at Anna, 12 September in Sueishan, and 13 September 2002 in Luenbey. All lines were harvested during 30 October 2002 to 10 February 2003 across four locations.
[2]Yield data were unreliable.

at Sueishan. Yield data of Luenbey were not reliable due to recording errors by the collaborating farmer. Tainan-ASVEG No. 6 had higher soluble solids and lower acidity across four locations than five CHT lines, whereas CHT1372 had significantly higher color value than the check (Table 128). RYTs of these five CHT lines will be further conducted at same four locations at different seasons in 2003 to verify this observation.

Table 128. *Quality analysis of cherry tomato hybrids tested in regional yield trials across four locations in southern Taiwan during summer of 2002*

Lines	pH	Solids (°Brix)	Acid[1] (%)	Solids/ acid	Color[2] (a/b)
CHT1312	4.09	6.09	0.59	10.32	1.61
CHT1313	4.11	6.01	0.54	11.13	1.68
CHT1372	4.10	6.20	0.54	11.48	1.71
CHT1374	4.11	6.03	0.55	10.96	1.66
CHT1358	4.07	6.08	0.59	10.31	1.65
Tainan-ASVEG No. 6 (ck)	4.10	6.13	0.49	12.51	1.48
LSD (5%)	0.02	0.41	0.02		0.07

[1]Equivalent of citric acid

[2]Values for a and b were measured with a chromometer using red standard surface. Immature green tomatoes have a/b ratio less than zero. The a/b ratio increases to zero and above as fruits ripen toward dark red.

Evaluation of indigenous vegetables

As one of the largest depositories of vegetable germplasm in the world, the host NARES is keen on possible utilization of AVRDC's collection, especially indigenous vegetables of tropical origin. Thus, the ROC Council of Agriculture supported a project in complementing collection efforts of AVRDC Genetic Resources and Seed Unit (GRSU) on indigenous vegetables from South and Southeast Asia. The objective of this project was to observe utilization potentials of indigenous vegetables as new vegetables in Taiwan. The effort in 2002 entails: collection of information, field testing to observe for botanical and horticultural traits, testing for adaptability and production potential, observation of potential diseases and insect pests, testing for tolerance to heat and flooding, analyses of nutrient contents and health-related factors, and evaluation of consumer acceptance.

Observational trials of indigenous vegetables

The objectives of this trial was to investigate adaptability and acceptability of lesser-known vegetables indigenous to the tropics, and to identify promising materials in overcoming hot-wet constraints and in diversifying cropping systems and diets. An observational plot with 0.63 ha for indigenous vegetables was established in 2001–2002 at AVRDC. Materials (647 accessions, 196 species of indigenous vegetables) were obtained from GRSU and other collaborators. The promising materials were selected based on the following criteria: 1) profuse growth under hot-wet conditions; 2) less disease and insect pest infections; 3) special nutrient contribution; and 4) acceptability to taste panels.

Two hundred eighty-three of these accessions (170 species) were planted and investigated at observational plot without replication in 2001–2002. Among them, 117 accessions from 59 genera (70 species) were characterized horticulturally, and 84 accessions from 55 species were multiplied.

Eighteen species grew well during the hot-wet season: *Anredera cordifolia, Asystasia gangetica, Basella alba, Cassia occidentalis, Celosia argentea, Coccinia grandis, Corchorus olitorius, Curcuma longa, Eryngium foetidum, Gynura bicolor, Gynura crepidioides, Gynura oralis, Lablab purpureus, Lycium chinense, Momordica cochinchinensis, Monochoria vaginalis, Perilla frutescens,* and *Telosma cordata.* Among them, six species with fine taste and high nutrient content or antioxidant activity were selected for replicated yield trials (Table 129).

Table 129. *Promising species with desirable nutritional properties*

Species (part used)	Nutrient or functional property
Cassia occidentalis (shoot)	antioxidant , Vit. C, β-carotene
Coccinia grandis (shoot)	Ca, Fe, fiber, good texture
Corchorus olitorius (shoot)	Ca, Fe, β-carotene, fiber
Lablab purpureus (pod)	antioxidant
Momordica cochinchinensis (fruit)	Ca, Vit. C, fiber, sugar
Telosma cordata (flower bud)	Ca, Fe, fiber, sugar

Special attention was directed toward *Abelmoschus* and *Hibiscus* due to available germplasm and their promising potential for hot-wet conditions. Three hundred and thirty-seven accessions of *Abelmoschus* and 27 accessions of *Hibiscus* were planted at the AVRDC experimental farm without replication in 2001–2002. Plot size was 3 m × 1.5 m. There were five plants per accession per plot and 50 cm between plants. Seeds were sown on 13 March and transplanted on 3 April 2002. Fully-grown immature pods of *Abelmoschus* were harvested twice a week from three plants per plot during May to December. Three immature pods per plant were sampled during peak harvesting period for measurements of pod length and width, and ridge number. Extent of pubescence on the sampled pods was also investigated. Edible young shoots of *Hibiscus* were harvested once a week from three plants per plot from June to November.

Desirable *Abelmoschus* pod characteristics were 10–15 cm length and 1.5–2.0 cm width, five ridges, and smooth hair. Thirteen promising accessions were identified, namely TOT0581 (fully grown immature pod length of 11.4), TOT1496 (13.1), TOT1514 (12.4), TOT1767 (11.1), TOT2191 (12.4), TOT2202 (10.3), TOT2749 (12.0), TOT3133 (13.2), TOT4115 (10.5), TOT4242 (12.0), TOT4641 (12.8), TOT4719 (13.4), and TOT5864 (14.3). Five accessions (TOT1496, TOT1514, TOT2191, TOT2202 and TOT3133) produced round-shaped pods, which may generate interest in markets. Accessions TOT0581, TOT1496, TOT2191, TOT2202, TOT4242, and TOT5864 were multiplied for future trials.

For *Hibiscus*, 16 accessions were characterized and three promising accessions (TOT0534, TOT4178, and TOT4423) were identified and selected for future trials. These promising accessions possessed colorful leaves and a sour flavor preferred by an organoleptic panel.

A panel of 33 persons evaluated cooking methods, appearance before and after cooking, and taste after cooking. Nineteen promising species were investigated in 2002. Among these, *Anredera cordifolia, Coccinia grandis, Lycium chinense, Monochoria vaginalis,* and *Perilla frutescens*, were well accepted. Stir-frying was the preferred way to prepare the vegetables, followed by boiling. Additional studies with consumers and farmers will be implemented in 2003 to identify the most promising species for Taiwan.

Nutrient values of indigenous vegetables

Twenty-eight samples of 25 species from the aforementioned observational trials were collected. Raw materials of 1–2 kg edible portions were analyzed by the AVRDC Nutrition and Analytical Lab. Contents of protein, β-carotene, vitamin C, iron, and calcium were measured to evaluate nutritional quality while contents of dry matter, fiber, and sugar were measured to evaluate eating quality.

Variations of nutrient values were wide, likely due to age, variety, texture and part of plant (Table 130). The rhizomes of *Curcuma longa* and leaves of *Cassia sophera* contained the highest amounts of protein (about 7.3% on a fresh weight basis). Leaves of *Cassia sophera* and young shoots of *Coccinia grandis* and *Clitoria ternatea* had the highest protein densities, over 35% on a dry weight basis, which is comparable to the protein content of soybean.

For β-carotene, *Cassia sophera* had the highest value (19.8 mg/100 g fresh weight). *Cassia tora* and *Corchorus olitorius* were also high, with values equivalent to that of carrot (about 11.5 mg). Stem and fruit types of vegetables such as eggplant, Indian nightshade, ivy gourd fruits, taro stalk, and aromatic turmeric rhizomes were relatively low in β-carotene.

Vitamin C contents were mostly below 100 mg/100 g edible portion, with the exceptions of *Cassia sophera* and *Zanthoxylum ailantoides*. Vitamin C contents of these two vegetables were outstanding in comparison to other vegetables and similar to that of chili pepper. *Cassia tora* and *Echeveria* sp. showed calcium values exceeding 300 mg/100g fresh weight, which are very high compared to vegetables commonly listed in food composition tables. In contrast to species in last year's collection, in which 7 samples out of 40 had iron content higher than 4 mg/100 fresh, this year only *Oenanthe javanica* had an iron content exceeding such level. Overall, *Cassia sophera* and *Cassia tora* were superior to other tested vegetables in nutritional quality.

With regard to eating quality, fruit and stem types of vegetables showed higher sugar densities than young shoots and leafy forms. On the other hand, fruit and leafy types showed higher fiber content on average. Regarding eating quality, sugar was considered as a positive factor, while higher dry matter and fiber were deemed as negative factors. Hence we scored overall eating quality as a value calculated as sugar divided by fiber and dry matter, with higher values indicating better eating quality. The top three vegetables based on eating values were *Colocasia esculenta* and fruit of *Lagenaria siceraria* and *Solanum mammosum*; while the worst three were fruit of *Solanum indicum and Solanum melongena*, and young shoots of *Hibiscus sabdariffa*. Leaves of *Cassia tora* and *Cassia sophera*, the most nutritious vegetables, rated relatively poor in eating quality, ranking 19 and 20 out of 28 types, respectively.

Table 130. Nutrient contents of indigenous vegetables collected from AVRDC Indigenous Vegetable Observational Plot in 2002

Common name	Scientific name	Portion[1]	Dry matter (g)	Fiber (g)	Sugar (g)	Protein (g)	Vit.C (mg)	β-caro. (mg)	Ca (mg)	Fe (mg)
African eggplant	*Solanum macrocarpon*	fruit	9	1.14	2.07	1.23	0.03	11	7	0.36
Ailanthus prickly-ash	*Zanthoxylum ailantoides*	leaf	26	2.13	2.67	5.69	8.43	138	95	2.41
Anisomeles	*Anisomeles indica*	leaf	20	2.20	2.08	5.16	9.21	31	21	2.43
Aromatic turmeric	*Curcuma longa*	rhizome	30	0.70	1.38	7.39	0.02	0	20	1.85
Bamboong	*Oenanthe javanica*	young shoot	8	0.96	0.86	1.81	3.52	19	194	4.23
Bottle gourd	*Lagenaria siceraria*	fruit	5	0.69	2.36	0.58	0.02	5	7	0.30
Butterfly pea	*Clitoria ternatea*	young shoot	12	2.05	0.94	4.51	8.52	117	23	1.34
Chard, dark green leaf	*Beta vulgaris*	leaf	7	0.74	1.23	1.85	2.72	17	54	0.55
Chard, light green leaf	*Beta vulgaris*	leaf	6	0.88	0.62	1.29	1.38	6	52	0.55
Chive	*Allium schoenoprasum*	leaf	10	1.46	3.12	2.46	1.51	21	92	0.50
Echeveria	*Echeveria* sp.	leaf	4	0.22	0.42	0.32	0.46	10	338	0.20
Eggplant	*Solanum melongena*	fruit	16	5.57	2.17	2.24	0.07	20	11	0.65
Estragon	*Artemiscus dracunculus*	young shoot	12	1.23	0.49	3.70	5.36	23	95	1.76
Indian nightshade	*Solanum indicum*	fruit	17	5.23	1.91	2.39	0.60	1	135	1.18
Ivy gourd	*Coccinia grandis*	young shoot	8	0.97	0.41	3.14	1.60	26	15	0.91
Ivy gourd	*Coccinia grandis*	mature fruit	32	5.37	10.42	5.44	1.40	5	105	2.06
Ivy gourd	*Coccinia grandis*	young fruit	25	4.92	4.36	4.43	0.40	17	60	1.55
Jute mallow	*Corchorus olitorius*	young shoot	18	1.52	2.03	5.96	11.94	72	198	2.36
Nipple fruit	*Solanum mammosum*	fruit	7	0.78	3.23	0.96	0.05	4	7	0.30
Oriental senna	*Cassia tora*	young shoot	16	1.44	1.02	4.97	11.43	105	346	1.39
Pong-hu senna	*Cassia sophera*	young shoot	18	1.45	1.17	7.17	19.83	291	273	2.88
Potherb fameflower	*Talinum triangulare*	young shoot	9	0.89	0.31	2.77	6.07	74	106	1.50
Roselle	*Hibiscus sabdariffa*	young shoot	11	1.30	0.42	2.62	4.40	25	217	1.26
Spiny bitter cucumber	*Momordica cochinchinensis*	young fruit	7	1.03	1.80	0.94	0.04	91	23	0.34
Taro	*Colocasia esculenta*	stalk	7	0.80	4.11	0.32	0.20	5	79	0.36
Telosma	*Telosma cordata*	flower bud	11	1.18	2.62	3.13	0.74	52	19	0.92
Tree of damocles	*Oroxylum indicum*	young shoot	20	1.29	0.92	5.92	3.48	97	26	1.26
Wedge fruit grass	*Sphenoclea zeylanica*	young shoot	10	1.08	1.65	2.72	5.36	65	115	1.61
Average			14	1.76	2.03	3.25	3.89	48	98	1.32
Standard deviation			8	1.53	1.98	2.09	4.82	62	99	0.95
Minimum			4	0.22	0.31	0.32	0.02	0	7	0.20
Maximum			32	5.57	10.42	7.39	19.83	291	346	4.23

[1]100 g fresh weight of edible portion

Project 10. Information exchange on tropical vegetables

Project 10 focuses on collecting, managing, and sharing information for vegetable research and development. Innovative approaches are used to extend information to AVRDC partners with the ultimate goal of informing and empowering small-scale farmers in developing countries.

Project Coordinator: T Kalb

Multimedia, electronic, and print publications

The most extensive publication in 2002 was *AVRDC Report 2001*, which reported the research and development activities of the Center for that year. Another major publication was AVRDC's new long-term strategy plan, *Empowering Small-Scale Farmers for Knowledge-Based Agriculture: AVRDC Strategy 2010.* This document described trends in vegetable production, constraints for farmers, the need for new research and development strategies, AVRDC's new platform for action, regional strategies, and management considerations.

The booklet, *Vegetables are Vital: healthy diets, productive farmers, strong economies*, was produced for dissemination at the Annual General Meeting of the Consultative Group of International Agricultural Research. This booklet used an easy-to-read and illustrative format to describe the importance of vegetables in the developing world and the core expertise of AVRDC related to the increased production and consumption of vegetables.

AVRDC compiled the above three publications, a Powerpoint slide show on AVRDC, and the entire online Learning Center to develop an interactive CD-ROM, which was distributed to the participants at the Annual General Meeting.

Books published at AVRDC in 2002 included the proceedings of a newly formed research network, entitled *Perspectives on ASEAN Cooperation in Vegetable and Development: Proceedings of the Forum on the ASEAN-AVRDC Regional Network on Vegetable Research and Development (AARNET).* A socio-economic study involving vegetable production in Cambodia, Laos and Vietnam was also published, entitled *The Vegetable Sector in Indochina Countries: farm and household perspectives on poverty alleviation.*

Numerous scientific findings were published in refereed scientific journals. Topics of these reports included molecular characterization of tomato and chili leaf begomoviruses and evaluation of onion cultivars for resistance.

International Cooperators' Guides were published on controlling eggplant fruit and shoot borer, and suggested cultural practices for kangkong and basella.

A brochure on controlling eggplant fruit and shoot borer was published and distributed to researchers and extension specialists throughout South Asia. The AVRDC international newsletter *Centerpoin*t was published and distributed. All AVRDC publications in 2002 are listed at the end of this Annual Report.

The Communications and Training Office mailed 8,876 publications in 2002. The Center's mailing list now contains 1,896 entries, including 623 libraries in 163 countries. The office printed more than a quarter of a million pages and handled more than 325 art requests from Center scientists. Over 10,000 photos were shot and processed.

AVRDC web site

More than 40,000 domain addresses (organizations or persons) from 130 countries accessed the AVRDC web site. This represents a 15% increase in the number of users of the site from the previous year. The numbers of users from developing countries accessing the web site each year has increased over 100% since 2000, a reflection of the improved availability of the internet to scientists in these countries.

Users were most interested in accessing educational resources from the web site. Users downloaded over 14,000 educational documents; these persons received these educational documents instantly and without need of paying postage. Over 18,000 web pages of *Centerpoint On-line* were read in 2002. Several new educational documents and tutorials on vegetable production were placed into the AVRDC on-line Learning Center (see Project 11 for more information).

To improve the ability of users to access the web site, AVRDC upgraded the main access line, which increased the web site's delivery speed from a 64k connection to a much faster T1 connection. This substantially improved speed of delivery, meaning users around the world can now log on to the AVRDC web site and download information more quickly than ever.

Open House

AVRDC held its first-ever Open House, co-sponsored by the Council of Agriculture of the host country. Nearly 100 visitors from government, scientific research institutions, universities, private sector, foreign diplomatic community, and the media participated in the event. The focus of the Open House was to show the global impact of the Center and display its current research activities. AVRDC staff presented 22 demonstrations to participants.

Collecting and sharing tropical vegetable information

This subproject is handled by the Center's library. In 2002, the library acquired over 262 new books and over 1805 serial publications. Subscriptions to 101 journals were renewed.

The library updated the Center's bibliographic databases to facilitate information storage and retrieval. A total of 180 books, 2090 crop documents, and 28 new serial titles were indexed and added to the library database. This in-house database, which now holds 40,001 bibliographic records and 3891 journal records, was placed on-line in 2002 and can be readily retrieved by staff and collaborators via computer. A total of 267 journal issues were bound; this hard-copy collection of journals now totals 15,432 volumes.

The library conducts regular searches of literature for vegetable researchers. The results of these searches are categorized by vegetable crop and published as Selective Dissemination of Information (SDI) bulletins. The SDI system was expanded and updated in 2002. Fifteen issues of SDI bulletins and five issues of recent AVRDC Library acquisitions were established on the library web site in 2002. A total of 551 users from 35 countries accessed the SDI services via the internet.

Library staff conducted 20 literature searches of CD-ROM databases and Tropical Vegetable Information Services databases for internal and external users. A total of 1094 documents were photocopied and delivered to 80 users in 71 libraries in 15 countries.

Project 11. Training for research and development

The main goal of this project is to increase skills among vegetable researchers throughout the world, especially in developing countries. In 2002, a record number of trainees, 117 scholars from 18 countries, received training in vegetable research and development at AVRDC headquarters in Taiwan. A list of trainees can be found in the back of this document.

These trainees experienced productive and useful trainings at AVRDC. All (100%) of the scholars reported that their training would be useful for their work. A total of 92% stated that they would like to come to AVRDC again for further training and (100%) reported that they would recommend training at AVRDC to their colleagues.

When rating their training experience at AVRDC, using a 1–5 scale with 1 = poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent, students rated the success of their training at 3.84, the quality of their instruction from trainers at 4.42, and the assistance from the Communications and Training Office at 4.34.

Project Coordinator: T Kalb

Internships

ASEAN scholarship training

A multi-year scholarship program was established in 2001 to support the training of young scholars from Cambodia, Laos, Myanmar and Vietnam. The Japanese government, through the Association of Southeast Asian Nations (ASEAN), sponsors this program. Four scholars completed 12-month training programs at AVRDC headquarters during 2002. The following information in this section is provided, in detail, to highlight examples of AVRDC training programs and their immediate impact:

Bounchanh Komboungnasith, agricultural technician from the Department of Agriculture in Laos, received training on hot-wet season vegetable production technologies. He learned tomato grafting procedures, constructing grafting chambers, and screening tomato and eggplant rootstocks for diseases. After his training was completed, he returned to Laos and assisted AVRDC staff in teaching grafting technologies to entrepreneur farmers.

Heang Dany, researcher at the Cambodian Agricultural Research and Development Institute (CARDI), was trained on tomato breeding strategies and evaluation procedures. His work focused on the evaluation of hybrid vigor for yield, fruit quality, and disease resistance traits. Mr. Dany is currently assisting AVRDC in establishing a tomato breeding program at CARDI.

Nguyen Ngoc Bau Chau, researcher from the National Center for Natural Science and Technology in Ho Chi Minh City, Vietnam, developed skills in gene transformation techniques. Specifically she learned *Agrobacterium*-mediated transformation of tomato with pest resistance protein-VrCRP. Ms. Nguyen is currently teaching gene transformation techniques to colleagues and students in her institute.

Nguyen Huy Chung from the Vietnam Agricultural Science Institute in Hanoi, evaluated phytochemical attractants that attract pest insects. The ultimate objective of this research is to breed crops that are less attractive to pests. He is currently using these techniques to develop new integrated pest management protocols in Vietnam.

These four students evaluated their training programs. All four students reported that their training was "useful" for their work in the future. On a scale of 1–5, where 1 = poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent, students rated the success of their training at an impressive 4.25. Similarly, the quality of their training from their instructors was rated at 4.25; the assistance from the Communications and Training Office was rated at 5.00; and the research facilities were rated at 4.25. All four trainees stated they would recommend this training program to their colleagues and would like to continue their training at AVRDC if given the opportunity in the future.

Other interns and fellows

Twenty-three additional researchers from Bhutan, Cambodia, China, Ethiopia, Indonesia, Japan, Korea, Laos, and Thailand studied as interns at AVRDC headquarters. In these 1 to 12-month training programs, researchers developed skills within the fields of entomology, genetic resource management, plant pathology, plant physiology, tomato breeding, legume breeding, and nutrition. It was the first time in several years that trainees from Bhutan and China came to AVRDC in Taiwan.

Four research fellows, two each from India and Bangladesh, learned molecular marker-assisted selection techniques in mungbean. Another research fellow from Bangladesh learned techniques in conservation of indigenous vegetable germplasm. A fellow from Korea learned polymerase chain reaction techniques for screening peppers against bacteria, while another learned techniques for characterizing *Capsicum* spp. germplasm. A fellow from India studied socio-economic impact analysis procedures.

Graduate degree-oriented training

AVRDC collaborated with National Pingtung University of Science and Technology (NPUST) in Taiwan; University of Bonn, Technical University of Munich (TUM), and Rheinisce Friedrich-Wilhelms-Universitat in Germany; Wye University in the United Kingdom; and Kasetsart University in Thailand to make its facilities and expertise available to graduate students conducting thesis research on vegetables.

In 2002, seven graduate students studied at AVRDC under this program. Among the NPUST scholars, a student from Senegal studied integrated pest management topics, and a student from Dominica received training in socio-economic impact analysis. A Vietnamese scholar from the University of Bonn received training on the control of *Pythium* during off-season tomato production. The graduate student from TUM received training in biological control of tropical crucifer insects while the other German scholar studied the perceptions of farmers and consumers toward genetically modified food crops. The student from Wye evaluated fresh food wholesale marketing systems in Hanoi and Ho Chi Minh City. A Thai graduate student from Katsetsart University studied the control of bruchids in the storage of legume seeds.

Summer program for undergraduates

A record number of undergraduate students were trained at AVRDC in 2002. Fifteen students from the University of the Philippines at Los Baños and 32 students from 11 universities in Taiwan received training. The students conducted research in a wide range of topics, including plant breeding, plant pathology, entomology, plant physiology, and plant production. They gained experiences in conducting experiments and writing technical reports. This training provided a valuable experience to students who are deciding their futures in agricultural science.

AVRDC on-line Learning Center

On-line education is recognized as the one of the most cost-effective, accessible, and convenient means for higher education in developing countries. AVRDC's on-line Learning Center was launched in 2001. This worldwide internet site instantly provides researchers, extension workers, and farmers with a vast source of information on tropical vegetable production. The Learning Center currently holds 20 publications on crop and seed production, 51 fact sheets on managing vegetable disorders, and 46 fact sheets on managing vegetable pests.

The Learning Center is the most widely used section of the AVRDC web site. Over 10,000 persons from over 50 countries entered the Learning Center in 2002. Approximately 60,000 web pages of materials were accessed. Fourteen computer-based tutorials were developed on major vegetable production topics. Over 3000 persons completed these tutorials in 2002; this number exceeds the number of trainees AVRDC has trained in its previous 29 years combined. Responses from users have been very positive. The site is located at <www.avrdc.org/LC/home.html>.

English language training

Twenty-seven international trainees, 24 AVRDC staff, and 46 university students developed greater fluency in the English language through weekly classes. The focus of these classes was to improve the students' abilities in English conversation. Students demonstrated improved communication skills that assisted them in their work at AVRDC.

Dissemination of training materials

Over 14,000 educational documents in Adobe Portable Document Format (PDF) format were downloaded for printing from the AVRDC web site. Thousands of more documents in Hypertext Markup Language (HTML) were accessed and printed. HTML is the publishing language of the World Wide Web and the principal format used in the AVRDC Learning Center.

One hundred forty slide sets, eight videos, and over 200 vegetable production training manuals were sold and disseminated upon request.

Project 12. Technical services

Offering of technical services

AVRDC provided technical services to two private companies and five public institutions in 2002. The services included screening of bacterial wilt resistance in eggplant and screening of resistance to tomato mosaic virus (ToMV) strain 1, tomato leaf curl virus (ToLCV) and fusarium wilt in tomato. Seed were produced of processing tomato lines (PT4732, PT434), cherry tomato line (Tainan-ASVEG No. 6), fresh market tomato lines (Taichung-ASVEG No. 4, Hualien-ASVEG No. 5, Taoyuan-ASVEG No. 9, Taichung-ASVEG No. 10), and mungbean line (Tainan No. 5). In total, 419 kg of seeds were produced and distributed.

Contract research projects

In 2002, AVRDC was granted US$735,676 for 22 contract research projects from the ROC (Republic of China) Council of Agriculture and one from the National Science Council. In addition, AVRDC tomato and pepper units implemented two research contracts with Kagome Company and Seminis Vegetable Seeds. Under the contract agreements, processing tomato hybrids and the cytoplasmic male sterile (CMS) pepper materials developed at AVRDC were provided to Kagome and Seminis, respectively, for further evaluation. One processing tomato line (PT4723) is being registered in Japan as KGM012.

Increasing public awareness

AVRDC received 1364 visitors, consisting of 1022 from Taiwan, 133 from China, and 209 from other nations. AVRDC also helped arrange trips to introduce international visitors to small-scale farming and intensive crop production systems in Taiwan.

Manila peri-urban vegetable project

Asian cities face the enormous challenge of increasing the poor's access to nutritious food while at the same time recycling solid wastes and reversing enviornmental degradation. The AVRDC peri-urban vegetable project in the Philippines, sponsored by BMZ/GTZ, is designed to stabilize the supply of nutritious vegetables to metro Manila and to develop an approach for the acquisition, testing, and dissemination of information related to peri-urban vegetable production and consumption. Year 2002 activities focused on the transfer of technologies developed in the previous four years of the project. These technologies involved improved practices for the production of safe leafy vegetables and off-season tomato.

Project Coordinator: JR Burleigh

Socio-economic studies

Evaluation of technology transfer methods

Over the five-year life of the Manila peri-urban vegetable project we introduced resource-poor farmers in four provinces of Luzon (Nueva Ecija, Quezon, Laguna, and Batangas) to a five-component improvement package for pak-choi cultivation using two extension methods: on-farm demonstrations and farmer field schools (FFS). Demonstrations and FFS were not treatments in a designed trial; rather, FFS evolved from the perceived failure of on-farm demonstrations to efficiently and effectively promote adoption of improved practices among farmers. Percent adoption among farmers trained by demonstration trials or by FFS can be used to compare success of the two methods. In addition, adoption by neighbors of farmer-cooperators enabled us to assess the effect of observation as a means to promote adoption.

Through on-farm demonstrations individual farmers learned from researchers to: 1) sow pak-choi on raised beds rather than on flat ground to reduce plant damage by flooding; 2) use net tunnels erected over beds to reduce insect pest damage rather than rely solely on insecticides for pest management; 3) sow seeds in rows rather than broadcast to produce a stand uniform in age and plant distribution; 4) use organic fertilizer as partial replacement for inorganic rather than use inorganic alone; and 5) monitor pest and disease populations before applying pesticides rather than follow the standard practice of frequent pesticide treatments regardless of pest and disease intensities. In contrast, FFS were conducted with groups of 20 to 35 farmers at a single site. Farmers organized themselves into subgroups of three to five with each subgroup responsible to determine the response of pak-choi when different combinations of two or more components were applied simultaneously. Farmer participants attended lectures given by researchers, conducted self-taught sessions, and shared results among subgroups.

Both demonstration and FFS were designed to promote adoption of the improvement package among farmers or if some improved practices were being used before training, then adoption of components of the package. Data on adoption were acquired by interviewing farmers in each training category.

A total of 92 FFS trainees, 14 on-farm research farmer-cooperators, and 47 neighbor-farmers of farmer-cooperators were interviewed to determine the direct impact of AVRDC introduced technologies on pak-choi production.

Thirty-three of the 92 (36%) FFS trainees and 2 of the 14 (14%) on-farm research cooperators did not plant pak-choi after the FFS training and farm demonstrations. The primary reasons identified by FFS trainees who stopped growing the crop were lack of water supply, lack of capital, low price of pak-choi in the market, lack of land ownership, and old age. The two farmer-cooperators stopped growing pak-choi because one chose to get a new job and the other farmer shifted into planting string beans instead.

Adoption by FFS trainees

Even before the FFS began, some of the trainees used raised beds and organic fertilizer (Table 131). Raised beds were used because farmers believed the technology provided better drainage during the rainy season and enabled easy irrigation of plants during the dry season. There was a slight increase in adoption after training, but this quickly dropped off due to the additional labor required.

Organic fertilizer, mainly chicken manure and burned rice hull, was used because farmers believed it neutralized the acidity of the soil and reduced expenses for inorganic fertilizer. However, there was a decline in the use of organic fertilizer after the FFS training because farmers could not find sources of chicken manure or other organic materials in the market (Table 131).

Eight of the 59 (14%) FFS farmers had monitored for pests before the training and 33 (56%) of the trainees utilized pest monitoring techniques after training was completed. But all soon stopped monitoring for pests because it was too laborious (Table 131).

Table 131. *Percentages of pak-choi farmers adopting production technologies among 59 FFS trainees in Nueva Ecija, Batangas, Laguna and Quezon[1]*

Technology	Before training (% adopters)	Growing seasons after training (% adopters) 1	2	3	>3
Pest monitoring	14	56	10	0	0
Organic fertilizer	42	37	31	2	7
Raised bed	24	29	14	2	0
Net tunnel	0	2	0	0	0
Line sowing	12	15	5	0	0

[1] Percentages do not include 36 FFS trainees who did not grow pak-choi after training

The use of line sowing and net tunnel showed low adoption among FFS trainees due to the high degree of labor and capital required for both technologies (Table 131).

Adoption by on-farm research cooperators

All five technologies showed positive adoption rates in the first season after the on-farm demonstration, but levels of adoption rapidly declined for all technologies in subsequent growing seasons (Table 132). Reasons for this decline varied depending on the technology. The most common reasons mentioned by non-adopters were they were "not used to" monitoring for pests, organic fertilizer was not available, net tunnels were too expensive, and net tunnels, raised beds, and line sowing all required too much labor.

Adoption by neighboring farmers

There was very little transfer of technology to farmers living next to the on-farm demonstration sites. There were no positive gains for the organic fertilizer, net tunnel and line sowing technologies (Table 133). A few farmers adopted pest monitoring techniques and raised beds, but the use of these technologies declined after the initial season.

In Nueva Ecija, an additional sample of 33 neighbors of farm cooperators in Castellano and Nieves were interviewed to determine if the AVRDC on-farm demonstrations held in the area have improved their pak-choi farming. However, results showed that 16 (48%) of these farmers already shifted in producing other crops, such as bitter gourd, eggplant and okra, instead of planting pak-choi. Low price of pak-choi is the primary reason why they stopped planting the crop.

Conclusions

Very few farmers adopted the introduced technologies, no matter the approach used for technology transfer. Capital and labor demands were too high, the organic

Table 132. *Percentages of pak-choi farmers adopting production technologies among 12 on-farm farmer-cooperators in Nueva Ecija, Batangas, Laguna and Quezon[1]*

Technology	Before demo (% adopters)	Growing seasons after demo (% adopters) 1	2	3	>3
Pest monitoring	17	50	25	17	–[2]
Organic fertilizer	67	83	33	8	–
Raised bed	42	100	25	0	–
Net tunnel	0	25	8	0	–
Line sowing	25	50	17	0	–

[1] Percentages do not include two farmer-cooperators who did not grow pak-choi after demos
[2] Data not available

Table 133. *Percentages of pak-choi farmers adopting production technologies among 47 neighbors of farmer-cooperators*

Technology	Before demo (% adopters)	Growing seasons after demo (% adopters) 1	2	3	>3
Pest monitoring	0	6	0	0	0
Organic fertilizer	32	30	15	0	0
Raised bed	28	32	19	4	4
Net tunnel	0	0	0	0	0
Line sowing	4	4	0	0	0

fertilizer was not available, and pak-choi prices at the market were not attractive. The project formulated a credit program for pak-choi producers to overcome the limitation of capital in adopting the technologies, but only five farmers participated in the program. Farmers who chose to not participate in the credit program cited the inappropriateness and high labor demands of the technologies, and lack of land ownership as reasons.

A closer look at the technology transfer methods themselves shows that higher percentage of farmer-cooperators adopted elements of the technology package than did FFS trainees, but this is the most expensive method of technology transfer and there was minimal transfer of technologies to neighboring farmers.

Differences in percent adoption among methods may be due to the manner used to select participants. Farmer-cooperators were pak-choi growers and known to project researchers, whereas FFS trainees were nominated by municipal agricultural technicians. In addition, farmer-cooperators worked with project researchers on their own farms. FFS trainees also worked with project researchers but on municipal land. Therefore, land ownership and participant selection may be key factors to consider in efforts designed to promote adoption. That is, when training is conducted on a participant's land there may be heightened awareness that results apply to his land. In contrast, the linkage between lessons learned from training conducted on municipal land or on the land of a FFS participant and the relevance of those lessons to land owned by each participant might not be apparent. Conceivably, selection of FFS trainees based on their prior knowledge of pak-choi cultivation might increase percent adoption among them.

Broadening our discussions to include our work with grafted tomato technology, in which both on-farm demonstrations and FFS were also used, we do not propose to abandon FFS as a means to promote adoption of improved practices for vegetable production. However, we do emphasize that those conducting the training must select trainees assiduously. Also, we propose that FFS trials be placed on farm fields rather than on municipal land.

A major constraint to technology adoption by the FFS approach was that local municipalities selected participants, and then only on the basis of interest expressed. That is, farmer selection was not based on previous experience in vegetable culture and ready access to capital (needed to invest in rain shelters or net tunnels, for example). Consequently, many trainees are unable to adopt the grafted tomato technology package because they lack confidence and capital.

Selection of FFS participants is another key to adoption of peri-urban technologies, particularly the grafted tomato package. Farmer-cooperators with little or no experience with tomato may express interest but lack the confidence to tackle the subtleties of growing grafted tomato under shelter. Consequently, participants should have experience with tomato culture as well as access to capital.

A reassessment of the technology packages is called for. Some farmers report using improved practices for pak-choi after receiving training in FFS, but no FFS participant is using the grafted tomato technology. The appropriateness of capital-intensive technologies needs to be considered. The optimization model suggests that 200,000 PHP (US$4000) per ha is needed to maximize net income from peri-urban technologies that include the grafted tomato package. That level of investment is beyond the capacity of most Filipino farmers. Clearly, cost reduction is a prerequisite to adoption among resource-poor farmers. We should also approach farmer-investors who have the capital to purchase materials required to produce grafted tomato during the rainy season.

It is further recommended that the project investigate the possibility of reducing the labor demands of these technologies through the introduction of mechanical seeders and bed shapers. In addition, the market for pak-choi should be continuously analyzed to determine the most appropriate time to sow and best markets to sell the crop.

Consumer preferences for qualities of selected leafy vegetables

It is important to understand the preferences of consumers when evaluating cultivars and types of vegetables. The objectives of this study were to determine consumer preferences for qualities of selected leafy vegetables and to calculate the price and income elasticities of these crops.

Trader and consumer preferences

A total of 101 traders and 96 consumers buying in the market were interviewed to determine their preferences when purchasing pak-choi, mustard, kangkong, sweet potato vine tips, bitter gourd vine tips, and jute mallow. Preferences across the survey sites (Nueva Ecija, Laguna, Batangas and Metro Manila) were generally similar. Freshness (within one day of harvest) was most highly valued for all vegetables.

Consumers preferred white-stem types of pak-choi, light-green leaf types of mustard, heart-shaped leaf types of kangkong, large-leaf types of bitter gourd vine tips, and smooth-leaf types of jute mallow. Regional differences were detected for kangkong and sweet potato vine tips: Laguna and Batangas consumers preferred violet types while Nueva Ecija consumers preferred green types.

A total of 117 consumers of leafy vegetables were interviewed in their homes to evaluate their preferences. Freshness was again the most desired quality for all leafy vegetables. For pak-choi, its cleanliness, amount of leaf damage, and size of leaves significantly affected its price. In other words, consumers would pay more for pak-choi that was clean, undamaged, and large-leaved.

The value of kangkong is significantly affected by the characteristics of its stem. Darker green stem color, short stem length (24–34 cm), and short stem diameter (0.4–0.6 cm) was preferred.

For sweet potato vine tips, four factors influenced its value: freshness, leaf shape, stem length and color. Consumers would pay more for fresh tips with heart-shaped leaves, short stem length, and light green or light violet stem color.

No significant attributes explained the price variations of mustard, bitter gourd vine tips, or jute mallow.

Price and income elasticities of vegetables

Price and income elasticity coefficients were calculated using linear regression functions. The data used were from the survey of 117 consumers interviewed in their homes. The vegetables studied as a whole manifested moderate price elasticity. It is projected that a price increase of 10% would reduce consumption of these leafy vegetables by 5%.

These vegetables have low income elasticity, suggesting that changes in consumer incomes will not affect their consumption of leafy vegetables. It is projected that a 10% rise in income would lead to only 1.2% more leafy vegetables in the diet.

Since higher income levels are not likely to lead to significant gains in consumption of leafy vegetables, there is an urgent need to educate Filipinos on the importance of vegetables in the diet. Currently Filipinos eat less than 40% of the amount of vegetables recommended for healthy diets.

Crop and soil management

Promising leafy vegetable cultivars

Trials were conducted on farms in central and southern Luzon and at the research station at Manila to identify superior cultivars of leafy vegetables.

BPI-LBNCDC on-station trials

The same 20 cultivars were planted monthly from March to December 2002. The cultivars were set in 1 × 2 m raised beds, distributed in RCBD with four replications. Net tunnel structures were installed immediately after planting and were lifted during weeding, sidedressing and spraying of fungicides/insecticides. Plants were maintained using recommended fertilization and other cultural practices.

Results are presented in Table 134. The yields of pak-choi peaked in December. The top performers were Bp 03 and check Black Behi. Bp 03 was the highest yielder in four of the six monthly trials.

Recommendations are more difficult with the non-heading Chinese cabbage trials since not all cultivars were planted each month. But the data clearly show that this leafy vegetable struggles in the summer heat of June and July.

Choysum also grew best in autumn. Cultivar Bc 13 gave the highest yield in June and November while Bc 36 was superior in August and December.

Indian mustard performed best in December. Significant yield differences were observed in July and September. Bj 03 significantly outyielded both other cultivars in July and was comparable with the check cultivar Excell in September cropping. Overall, Bj 03 was judged as the top performer.

Yields of Chinese kale peaked in December; Ba 24 was the top yielder across six planting dates.

Yields of kangkong peaked in September. Ia 18 significantly outyielded other cultivars in November, while Ia 02 produced significantly higher yields in December. Overall across six plantings, both Ia 02 and Ia 18 outyielded the check line by approximately 10%.

Table 134. *Yields (t/ha) of leafy vegetable types and entries evaluated at Bureau of Plant Industry, Manila, Philippines, 2002.*

Type/entry	Month sown						
	June	July	August	September	November	December	Mean
Pak-choi							
Bp 03	2.1 a[1]	5.1 c	5.9	3.3 a	7.1 ab	19.0 a	7.1
Bp 09	1.7 b	7.7 ab	5.7	–[2]	–	–	5.0
Bp 21	1.6 b	6.6 b	4.8	1.6 b	8.7 a	13.0 b	6.0
Black Behi (ck)	1.4 b	8.7 a	4.8	2.6 a	5.8 b	17.0 a	6.7
Mean	1.7	7.0	5.3	2.5	7.2	16.3	6.7
CV (%)	12.6	9.7	14.5	21.9	14.0	12.7	
Non-heading Chinese cabbage							
Bcc 02	1.1 b	1.2	–	–	–	–	1.1
Bcc 04	1.8 a	1.3	7.5 b	4.9	7.8	7.8 b	5.2
Bcc 12	–	–	6.6 b	4.3	7.8	8.7 b	6.8
Bcc 23	1.8 a	1.2	10.4 a	4.7	7.3	13.2 a	6.4
Mean	1.6	1.2	8.1	4.6	7.6	10.0	5.5
CV (%)	15.1		13.6			11.4	
Choysum							
Bc 12	2.1 b	1.8	4.7 b	8.0	9.4 b	10.6	6.1
Bc 13	3.2 a	1.8	2.5 c	8. 5	12.1 a	10.6	6.4
Bc 36	2.3 b	1.5	7.2 a	6.1	6.6 c	13.0	6.1
Mean	2.5	1.7	4.8	7.5	9.4	11.4	6.2
CV (%)	16.2	16.4	11.6	17.1	15.0	15.0	
Indian mustard							
Bj 03	4.1	4.1 a	7.1	6.2 ab	6.5	12.4	6.7
Bj 11	3.0	2.8 b	6.3	5.3 b	6.3	11.3	5.8
Excell (ck)	3.5	3.3 b	6.2	7.3 a	6.7	11.0	6.3
Mean	3.5	3.4	6.5	6.3	6.5	11.6	6.3
CV (%)	18.8	13.7	10.8	12.9	15.6	11.9	
Chinese kale							
Ba 11	1.6	1.1	3.0 b	2.4	2.6	8.2	3.1
Ba 17	1.5	1.3	2.0 c	2.6	3.2	8.4	3.1
Ba 24	1.7	1.2	4.0 a	2.4	2.9	9.0	3.5
Mean	1.6	1.2	3.0	2.4	2.9	8.5	3.2
CV (%)	15.1	9.5	13.6	11.1	20.1	6.8	
Kangkong							
Ia 02	9.5	7.4	14.6 a	20.0	10.8 b	10.9 a	12.2
Ia 18	9.0	8.2	15.7 a	17.6	13.5 a	8.2 b	12.0
Kaneko (ck)	9.1	8.3	12.3 b	19.2	9.7 b	7.9 b	11.1
Mean	9.2	8.0	14.2	19.0	11.3	9.0	11.8
CV (%)	11.1	12.4	6.9	18.5	12. 8	12.6	

[1] Mean separation within columns of vegetable species by Duncan's multiple range test, $P \leq 0.05$
[2] Not planted

In conclusion, these trials show that kangkong yields are relatively stable through the summer and autumn, whereas the other leafy vegetables (all Brassicas) grow much better during the autumn. Differences were noted among the cultivars for each species and superior cultivars were identified.

BPI-LBNCDC on-farm trials

Twenty cultivars of six leafy vegetable types were planted in five to six locations. Plants were grown in 1 × 2 m sub-plots, using the project's recommended production practices and net tunnels. At each location, plots were established using randomized complete block design (RCBD) and four replications. Locations were planted on different dates ranging from 8 May to 22

November 2002. Data were taken from 2 m^2 plots and analyzed statistically.

The performance of the cultivars varied due to the differences in time of planting, soil conditions, and crop management (Table 135). Among sites, crops performed best at the Santa Cruz farm, because the trial was set in November when rain was not as frequent and the site had been fallow for a long time.

Across locations, the best yielding entries were: Ia 02 kangkong with potential yield of 15.6 t/ha; Bj 11 Indian mustard, 10.6 t/ha; Bcc 12 non-heading Chinese cabbage, 10.1 t/ha; Bc 12 choysum, 15.2 t/ha; Bp 03 pak-choi, 13.1 t/ha; and Ba 17 Chinese kale 3.8 t/ha. These entries have all performed well in previous trials and are recommended for commercial production.

Table 135. *Yields of leafy vegetable entries grown in on-farm trials in Luzon, Philippines*

	Yield (t/ha)						
Type/entry	Tiaong, Quezon 8 May	Tanauan, Batangas 30 July	Bagong Silang, San Pablo City 4 Sept.	Lumban, Laguna 2 Oct.	Sto. Angel, San Pablo City 20 Nov.	Sta. Cruz, Laguna 22 Nov.	Mean
Pak-choi							
Bp 03	15.5 a[1]	14.3	7.2 a	12.6	9.6 a	19.3 b	13.1
Bp 09	1.75 c	–[2]	–	10.7	–	–	6.2
Bp 21	6.7 b	17.2	5.8 b	11.3	8.4 ab	26.2 a	12.6
Black Behi (ck)	8.1 b	17.2	6.9 a	10.5	6.7 b	28.4 a	13.0
Mean	8.0	16.2	6.6	11.3	8.3	24.6	11.2
CV (%)	18.6	5.5	4.3	21.4	12.4	14.9	
Non-heading Chinese cabbage							
Bcc 04	6.2 b	8.3	7.8 a	–	3.9 b	21.5 b	9.5
Bcc 12	6.8 b	7.8	6.5 a	–	5.2 b	24.3 a	10.1
Bcc 23	7.8 a	9.2	3.2 b	–	7.2 a	22.1 b	9.9
Mean	6.9	8.4	5.8	–	5.4	22.6	9.8
CV (%)	18.2	11.8	21.9		15.7	10.4	
Choysum							
Bc 12	12.2 a	15.4 a	17.1 a	–	8.4 a	23.0 a	15.2
Bc 13	6.8 b	15.8 a	17.0 a	–	5.6 b	18.9 b	13.0
Bc 36	7.6 b	9.2 b	11.6 b	–	6.1 b	14.7 c	9.8
Mean	8.8	13.5	15.2	–	6.7	18.9	12.7
CV (%)	17.4	13.0	10.0		9.0	8.0	
Indian mustard							
Bj 03	13.5	9.6 ab	8.3	6.5 b	8.6	16.5	10.5
Bj 11	13.1	11.9 a	5.9	8.4 a	9.5	15.0	10.6
Excell (ck)	12.7	7.1 b	6.4	6.7 b	8.6	17.4	9.8
Mean	13.1	9.5	6.8	7.2	8.9	16.3	10.3
CV (%)	19. 9	15.7	13.9	23.3	9.7	13.2	
Chinese kale							
Ba 11	1.0 b	3.4 a	2.1 b	–	3.4 a	6.5	3.3
Ba 17	1.5 a	3.4 a	3.3 a	–	3.3 a	7.6	3.8
Ba 24	1.9 a	2.2 b	2.6 ab	–	2.5 b	6.3	3.1
Mean	1.5	3.0	2.7	–	3.1	6.8	3.4
CV (%)	19.8	19.9	17.3		9.5	12.9	
Kangkong							
Ia 02	16.1	11.4	6.6 a	20.0 ab	14.5 a	25.8 a	15.7
Ia 18	14.3	11.1	4.0 b	16.9 b	12.8 b	16.9 b	12.7
Taniya (ck)	14.5	14.0	4.8 b	21.9 a	12.9 b	17.5 b	14.3
Mean	14.9	12.2	5.1	19.6	13.4	20.1	14.2
CV (%)	10.3	17. 9	10.4	16.3	3.1	10.4	

[1] Mean separation within columns for individual vegetable species by Duncan's multiple range test, $P \leq 0.05$
[2] Not planted

Introduction to CLSU trials

The objective of his research was to identify the superior cultivars of leafy vegetables for year-round production in metro Manila. Cultivars of four leafy vegetables, namely: pak-choi (Bp 22, Bp 23, and Black Behi as check variety); Indian mustard (Bj 03, Bj 14 and native check), Chinese kale (Ba 11, Ba 17, and Ba 24) and upland kangkong (Ia 02 and Ia 07) were planted in non-replicated trials at five farms to evaluate their adaptability. These accessions were the highest yielding performers in yield trials conducted at Central Luzon State University (CLSU) from 1998 to 2001. The on-farm trials were situated in San Miguel, San Jose del Monte, and Doña Remedios Trinidad of Bulacan province, and in San Leonardo and San Jose City of Nueva Ecija province. For each plot, four rows were planted in a space of 1 × 3 m on 30-cm-high raised beds. Pak-choi, Indian mustard, and Chinese kale were provided with net tunnels after planting to protect plants from insect pest damage and impact of rainfall during the late summer (July to September 2002) crop and from insect pest damage during the winter (November 2002 to January 2003) crop. The same accessions were evaluated at CLSU in replicated trials (seven replications) both in open field and nethouse. Analyses of yield data were done within species. Mean monthly rainfall amounts from the months of July to December in Nueva Ecija were 605, 300, 362, 159, 38, and 12 mm.

CLSU on-station trial

Damaging rainfall and *Rhizoctonia* rot caused 6 of the 11 accessions to fail to produce marketable yields in the open field planting sown in July. Only kangkong produced reliable yields.

In several cases, the effects of net tunnels were dramatic during this rainy season trial. For example, Bp 23 failed to produce any yield in the open field, but it was the highest yielding pak-choi accession under the net. Similarly, Bj 03 and the native mustard check failed to produce marketable yields in the open field, but both outperformed Bj 14 under the net. None of the Chinese kale accessions produced marketable yields in the open field, but all of them produced crops under the net. Finally, Ia 02 was relatively low yielding in the open field, but it produced a remarkable 79.2 t/ha of yield under the net. The net tunnel, therefore, may be a profitable technology to produce reliable yields during this wet season when leafy vegetable supplies are low and prices are highest. A comparison among the leafy vegetables grown in this season's trial shows that Chinese kale yields were relatively low and kangkong yields were very high. So high, in fact, that even the lowest yielding kangkong accession produced at least five times more yield than the best of any other accession of any leafy vegetable grown under similar conditions.

The yields of pak-choi, Indian mustard, and kale varieties increased tremendously under nethouse during the cool-dry winter (Table 136). This is attributed to cooler temperatures and higher plant survival. Kangkong yield however, decreased due to lower temperatures and less available water compared to the wet season trial. Similar trend in yield was observed under open field, but the yields were slightly lower due to higher pest pressure particularly flea beetle and diamondback moth on the crucifers.

In conclusion, the net tunnel contributed to higher marketable yields in both seasons. The benefit of the tunnel was evident for all accessions but to differing degrees. Kangkong was the only productive leafy vegetable in the rainy season trial and crucifer yields dramatically increased in the cool season.

Table 136. *Yields (t/ha) of cultivars grown with and without net tunnels during the rainy season (July) and cool-dry season (November) at CLSU, Muñoz, Philippines*

	July		November	
Crop/entry	Net	Open	Net	Open
Pak-choi				
Bp 22	5.9 b[1]	5.0 a	37.4	25.4
Bp 23	9.2 a	0.0 b	28.7	22.5
Black Behi (ck)	8.9 a	3.4 ab	29.1	25.0
Submean	8.0	2.8	31.7	24.3
Indian mustard				
Bj 03	8.7	0.0 b	40.4 a	25.8
Bj 14	7.4	5.9 a	28.7 b	21.0
Native (ck)	9.2	0.0 b	38.0 a	25.2
Submean	8.4	2.0	35.7	24.0
Chinese kale				
Ba 11	3.7	0.0	13.9 a	10.1
Ba 17	3.9	0.0	8.1 b	7.9
Ba 24	4.3	0.0	16.8 a	10.1
Submean	4.0	0.0	12.9	9.4
Kangkong				
Ia 02	79.2 a	37.0 b	29.2	24.5
Ia 07	51.2 b	50.8 a	27.2	23.4
Submean	65.2	43.9	28.2	24.0

[1] Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

CLSU on-farm trials

During the rainy season trial (July to September) marketable yield of pak-choi variety Bp 22 was highest on four of five farms (Table 137). Yields ranged from 6.5 to 30.0 t/ha, with differences due to different levels of soil fertility and farm management skills. Yields slightly declined in the next cropping season but rose again in the cool-dry winter. All lines performed satisfactorily. Bp 22 had the highest yields overall but its green stems were less desirable to consumers. Black Behi was a reliable performer and has white stems, which consumers preferred.

For Indian mustard, the check variety was the highest yielder for the first two cropping seasons. The yield of Bj 14 was highest in the third season, due in large part to a whopping yield of 60.6 t/ha at one farm. All three lines performed well, usually producing yields in the range of 15 to 20 t/ha.

Chinese kale yields were low due to poor seed quality for all accessions. Yields ranged from 0 to 13.5 t/ha. When data were pooled across all farms, yields for this vegetable were low but fairly steady through the three seasons.

Kangkong yields were consistently the highest among all the leafy vegetables tested. Both accessions produced high yields at all locations during all seasons.

Table 137. *Yields (t/ha) of leafy vegetables entries tested on five farms in Luzon, Philippines*

Crop	Date sown			
	July	September	November	Mean
Pak-choi				
Bp 22	19.8	15.3	17.8	17.6
Bp 23	14.0	14.6	17.8	15.5
Black Behi (ck)	17.3	15.6	18.5	17.1
Submean	17.0	15.2	18.0	16.7
Indian mustard				
Bj 03	16.5	15.1	21.7	17.8
Bj 14	18.3	15.0	24.6	19.3
Native	20.8	15.6	19.1	18.5
Submean	18.5	15.2	21.8	18.5
Chinese kale				
Ba 11	6.2	6.9	7.0	6.7
Ba 17	6.4	7.5	6.9	6.9
Ba 24	7.4	7.6	7.3	7.4
Submean	6.7	7.3	7.1	7.0
Kangkong				
Ia 02	24.0	23.0	27.8	24.9
Ia 07	28.4	22.3	27.0	25.9
Submean	26.2	22.7	27.4	25.4

In conclusion, these on-farm trials showed that all these entries could be grown successfully throughout the year under net tunnels, and in the case of kangkong, without net tunnels. Although yields were satisfactory, growers would be advised to consider consumer preferences when selecting cultivars to plant. As stated earlier, Bp 22 may be high yielding, but its green stems are undesirable. The upland kangkong accessions Ia 02 and Ia 07 were very productive, but their narrow leaf shapes are less desirable compared to the heart-shaped leaves of other kangkong types.

Grafted and non-grafted tomato production under rain shelters

BPI-LBNCRDC on-station trial

The trial at the BPI-LBNCRDC station in Manila consisted of four lines (CHT501, CL5915, CLN2026D and PSB Tm9) grafted onto EG203 eggplant rootstocks. Grafted and non-grafted plants were transplanted into beds with and without rain shelters. Beds were 2.5-m-wide and mulched with polyethylene. Seedlings were transplanted in 3 rows, 0.5 m between rows and 0.4 m between hills. Each sub-plot had 3.75 m^2 area and a 15-plant population. Entries were distributed in RCBD with three replications.

The yield performance of grafted and non-grafted seedlings significantly varied under shelter and open conditions (Table 138). PSB Tm9 produced the highest yields under shelter and CHT501 produced the highest yields in the open field. Both of these lines are tolerant to heat.

Grafted plants, in general, outyielded non-grafted plants by a significant margin, 41% under shelter and 20% in the open field. Grafted plants had higher levels of plant survival, contributing to higher yields. There was no interaction between the lines and grafting.

BPI-LBNCRDC on-farm trials

Five demonstration trials were set in October 2002. Grafted and non-grafted plants of one to two tomato lines at each site were grown under three regimes: 1) 2.5-m-wide, 10-m-long raised bed, provided with polyethylene mulch and open-side rain shelter; 2) same bed size with polyethylene mulch without rain shelter; and 3) farmers' practice of planting in flat-bed rows spaced 1 m apart and 0.5 m between plants.

Grafted plants, whether under rain shelters or in the open field, gave higher yields at all sites (Table

Table 138. *Yield (t/ha) of grafted and non-grafted tomato varieties under rain shelter and in open field conditions at Bureau of Plant Industry, Manila, Philippines*

	Yield (t/ha)					
	With shelter			Open field		
Line	Grafted	Non-grafted	Mean	Grafted	Non-grafted	Mean
CHT501	17.1	11.4	14.2 b	14.9	14.0	14.5 a
CL5915	18.0	12.9	15.4 b	12.8	10.0	11.4 ab
CLN2026D	18.6	16.5	17.3 b	8.2	6.8	7.5 b
PSB Tm9	26.3	14.2	21.4 a	12.9	9.9	11.4 ab
Mean	20.0 a	14.2 b	17.1	12.2 a	10.2 b	11.2
CV (%)			20.7			17.1

Grown in Summer 2002
[1]Mean sepearation in columns by LSD at 5% level

139). The tomato lines grown under rain shelters produced higher yields than the open field practices of BPI-LBNCRDC and farmers. The Santa Cruz site produced the highest yields peaking at 41.5 t/ha for grafted plants grown under rain shelters. Yields of "farmer-practice" plots were only about one-third the yield of plots managed using researcher practices.

BPI-LBNCRDC Batangas trial

In Tanauan, Batangas, grafted and non-grafted seedlings of four tomato lines were transplanted in a non-replicated trial under two growing regimes (with and without rain shelter). Each regime had two plots, 1-m-wide, 25-m-long with 0.5 m distance between plots. One plot in each regime was planted with grafted plants and the other plot with non-grafted plants. All plots were mulched with polyethylene. Transplanting was done on 5 September 2002 and harvesting was done from 8 November to 1 December.

PSB Tm9 produced the highest mean yield (22.2 t/ha)(Table 140). Following the same trend as the BPI-LBNCRDC trial, PSB Tm9 gave the highest yield under shelter and CHT501 in the open field. Grafting improved the yield of the lines by 22% under shelter and 29% in the open field. Rain shelters provided 37% higher yields compared to the plants grown under open field conditions despite the fact that the trial was not planted in the rainy season. Monthly rain totals in Nueva Ecija for September, October, and November were 362, 159, and 38 mm, respectively.

Table 140. *Yields (t/ha) of grafted and non-grafted tomato lines under shelter and open field conditions in Tanauan, Batangas, Philippines*

	With shelter		Open field		
Line	Grafted	Non-grafted	Grafted	Non-grafted	Mean
CHT501	20.1	16.6	22.3	20.3	19.8
CL5915	22.3	19.4	16.58	11.1	17.3
CLN2026D	23.0	18.3	16.0	9.9	16.8
PSB Tm9	31.8	25.3	18.4	13.2	22.2
Mean	24.3	19.9	18.3	14.0	19.0

Transplanted 5 September 2002

Table 139. *Mean yield (t/ha) of tomato lines in on-farm demonstration trials in Luzon, Philippines*

		With shelter		Open field		Farmer's practice		
Site	Line(s)	Grafted	Non-grafted	Grafted	Non-grafted	Grafted	Non-grafted	Mean
San Pablo City	CHT501, CLN2026D	10.9	7.2	6.4	5.4	3.2	1.8	5.8
San Pablo City	CHT501, PSB Tm9	17.7	14.3	14.7	13.3	3.3	2.3	10.9
Laguna	CLN2026D	13.4	11.0	9.3	6.2	1.5	1.0	7.1
Laguna	PSB Tm9, CLN2026D	41.5	28.5	35.2	25.8	14.4	9.6	25.8
Batangas	CL5915, Floradade	9.2	6.7	4.5	3.2	1.8	1.7	4.5
Mean		18.5	13.5	14.0	10.8	4.8	3.3	–

Transplanted October 2002

CLSU on-station trials

The use of grafted tomato has shown promise as a technology that can stabilize yields in the hot-wet season. This trial evaluated the performance of four promising scions (Apollo, CHT501, CL5915, and CLN2026D) all grafted onto the recommended rootstock, eggplant EG203.

A field was divided into three blocks representing replications with each block. Blocks were subdivided into two main plots (with and without shelter) and each main plot further divided into four subplots (tomato lines). The four subplots were further subdivided into two sub-sub plots (non-grafted and grafted).

Plant survival was markedly influenced by line and graft level, but no interaction effects were noted among the factors evaluated. The non-grafted plants obtained a percent survival of 24% while the grafted plants obtained 74%, a difference of 208%. Among the four lines of tomatoes, the survival rate of CLN2026D was highest (62%), followed by CHT501 (54%), both of which were statistically superior to the survival rates of Apollo (41%) and CL5915 (40%).

The differences in percent survival of the lines may be viewed from their resistance to flooding and wilt diseases. While the rootstock EG203 is resistant to the above conditions, floodwater in the experimental plots often rose above the graft union. Therefore, scions with greater tolerance to flooding and bacterial wilt survived better.

Yields differed among varieties between grafting treatments, rainshelter × line, and line × graft level (Table 141). CHT501 grown under shelter had the highest yield of 7.0 t/ha. The same line obtained the highest yield under open field conditions, 3.3 t/ha. While CLN2026D had the highest percent survival, it was a low yielder.

Table 141. *Effects of grafting and rain shelter on yields (t/ha) of lines grafted onto eggplant rootstock, evaluated at CLSU, Philippines*

	Grafting		Rain shelter	
Line	Grafted	Non-grafted	With	Without
Apollo	2.4 d[1]	0.1 c	1.4 d	1.1 c
CHT501	8.3 a	2.0 a	7.0 a	3.3 a
CL5915	3.7 c	1.0 b	2.7 c	2.1 b
CLN2026D	4.8 b	1.5 ab	4.0 b	2.2 b

Grown in Summer 2002

[1] Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$

CHT501 was the highest yielding line, whether grafted or non-grafted. When grafted it had a yield advantage of 250, 121 and 74% over Apollo, CL5915 and CLN2026D, respectively.

From the results of study, grafting again provided a significant yield advantage in the hot-wet season. Rain shelters also provided an advantage, although less pronounced. CHT501 was the top scion and is recommended to growers.

CLSU on-farm trials

On-farm trials were conducted to evaluate the yield potential of grafted tomato in farmers' fields. Seedlings of CL5915 and CHT501 were grafted onto rootstocks of EG203 and tested on six farms, with and without rain shelters, using the standard cultural management practices adopted in on-station trials. The trial was transplanted in Guimba on 19 July, the recommended time to use grafted plants in order to gain the fullest advantage from the rootstock's tolerance to flooding, water-logged soils, and bacterial wilt. Plantings at other sites were delayed until September.

The rain shelter led to a higher rate of plant survival for both lines at all sites. Survival of CHT501 ranged from 85.0 to 97.5% under shelter and 77.5 to 92.5% in the open field. Survival of CL5915 had percent survival ranged from 87.5 to 100.0% under shelter and 62.5 to 95.0% in the open field. The differences in plant survival among sites can be attributed to the incidence of wilt-causing organisms.

The highest fruit yield of CHT501 under shelter was obtained from the farm in San Jose City (25.4 t/ha) followed by the trial in San Leonardo 23.9 t/ha (Table 142). The lowest yield was obtained from the farm in Llanera, which was highly prone to flooding.

Table 142. *Yields (t/ha) of grafted tomatoes, grown with and without shelter, in on-farm trials in Luzon, Philippines*

Date		With shelter		Open field	
trans.	Location	CHT501	CL5915	CHT501	CL5915
19 July	Guimba	22.7	10.1	13.4	3.6
02 Sept.	Llanera	18.0	9.0	12.7	6.7
13 Sept.	Florida Pamp.	19.2	15.0	15.1	11.5
17 Sept.	San Jose City	25.4	16.5	23.5	13.2
19 Sept.	Muñoz	21.5	15.2	18.3	13.3
30 Sept.	San Leonardo	23.9	15.0	10. 6	9.3
Mean		21.8	13. 5	15.6	9.6
CLSU (4-year avg)		17.2	13.1	7.4	3.1

Guimba trial transplanted 19 July 2002; others transplanted in September

The beneficial effects of rain shelter on CHT501 was seen in Guimba where planting was done during the rainy season (Table 142). It was also dramatically observed in San Leonardo. Moderate effect of rain shelter was seen in Muñoz and Llanera and in Florida Pampanga where the farms are laden with *lahar* (mudflow from volcanic debris).

Yields were higher under shelters compared to the open field for both scions at all sites. Fruit yield of CHT501 from the six farms under rain shelter averaged 21.8 t/ha while the yield of CL5915 averaged 13.5 t/ha, a difference of 62%. CHT 501 in the open field yielded 15.6 t/ha as against 9.6 t/ha for CL5915, again a yield difference of 62%. On-farm yields were higher than the average yield of four years of testing at CLSU, an encouraging sign that the technology is adaptable to on-farm conditions.

Tarlac College of Agriculture

In a non-replicated trial on the campus of Tarlac College of Agriculture, CHT501 yielded 27.4 t/ha when grafted onto eggplant rootstock and transplanted under a rain shelter, but only 11.57 t/ha when not grafted. In contrast, yields were 18.6 and 8.8 t/ha for grafted and non-grafted CHT501, respectively, in the open field. The trial was not unbiased, but data support conclusions from other locations and past seasons that yields from grafted tomato raised under shelters are greater than yields from non-grafted tomato raised in the open field during the hot-wet season. CHT501 consistently yielded more than CLN5915.

Mass production of grafted tomato seedlings

Adoption of the grafted tomato technology depends, in part, on the availability of grafted seedlings to participants in FFS, farmer-cooperators, and growers. A temperature and humidity-controlled grafting chamber was constructed on the campus of CLSU in 2001 to provide grafted transplants. In 2002, 5000 seedlings were distributed among 10 FFS, 1500 seedlings were used in six on-farm trials, and 2000 seedlings were used in three farm demonstration sites. These seedlings consisted of scions of CHT501 and CL5915 grafted onto EG203 rootstocks.

A potential constraint to adoption of the grafted technology among growers is that the number of transplants dispersed in 2002 would meet only 5% of the demand indicated by interested farmers in 2003 (159 trainees expressed interest and requested a total of 167,000 seedlings). Increased efficiency of the graft chamber at CLSU is necessary but increased efficiency alone will not meet the projected demand. Therefore, the project has proposed to construct a second graft chamber in the province of Bulacan where the projected demand for grafted seedlings in 2003 is greatest.

Planting media for grafting tomatoes

An inexpensive but effective planting medium is required for large-scale production of tomato and eggplant seedlings for grafting purposes. The standard rootstock, eggplant line EG203, and two productive scions, tomato lines CHT501 and CL5915, were seeded in decomposed sawdust, coconut coir, and carbonized rice hulls mixed with organic fertilizer. To each of the media were added either a controlled release fertilizer, a complete fertilizer (14N–6P–11.6K), a controlled release fertilizer + 2% urea, or the complete fertilizer + 2% urea in similar, but unspecified amounts. Media were evaluated based on percent seedlings with matching stem diameters fitting the latex sleeve used for grafting.

Generally, the highest percentage of seedlings with uniform stem diameter came from coconut coir. Fertilizer effects were not measured and fertilizer types did not appear to make a significant difference.

Integrated pest management

Infection of grafted tomato plants by black leaf mold disease

Black leaf mold (*Pseudocercospora fuligena*) is the dominant foliar disease of grafted tomato during the hot-wet season. Whether in open field or under rain shelter, tomato cultivars reacted similarly and there was no difference in disease intensity among scions tested (Apollo, CHT501, CL5915 and CLN2026D); all were susceptible. We did not analyze the yield loss due to black leaf mold, but the disease merits scrutiny since it is ubiquitous during the hot-wet season.

Efficacy of insecticides for control of striped flea beetle

Striped flea beetle is a major pest of pak-choi that has the capacity to destroy entire crops. Studies were conducted at CLSU in the rainy season (September to October 2002) and cool-dry season (November to December 2002) to identify superior insecticides for control of the pest. Five commercial insecticides, namely Pennant (phenthoate), Mimic (tebufenozide), Ascend (fipronil), Success (spinosad), and Brodan (chlorpyrifos + BPMC) were tested along with an untreated control. Treatments were evaluated using four replications. Individual plot size was 2 × 5 m with 1-m distance between plots. Plants were managed using recommended cultural practices.

In the rainy season, plots sprayed with insecticides suffered less damage by striped flea beetle in comparison to untreated plots, but there were no significant differences among the insecticides. In the cool-dry season, none of the insecticides could control the pest and marketable yields were minimal.

Chlorpyrifos is not registered for use on pak-choi in the Philippines; however, it is the insecticide of choice by many farmers because it is inexpensive. Spinosad is an organic fermentation product from bacteria. Our results suggest that Spinosad is as effective as other pesticides (all synthetic) tested.

Effect of rainfall on cabbage webworm populations

Cabbage webworm (*Hellula undalis*) is a major insect pest of pak-choi in Central Luzon. Larvae can be found year-round but populations vary among months. When we regressed plant density and rainfall on numbers of larvae, total monthly rainfall explained 81% of the variation in numbers, whereas plant density was not significant. The regression coefficient was negative as expected, indicating that as rainfall increases, numbers decrease. Rainfall, therefore, may be a good predictor of larval numbers and perhaps of larval activity.

Hellula undalis sex pheromone studies

Experiments were conducted to determine how to use pheromone traps in the field. Studies were done on trap heights, trap designs, pheromone concentrations, and trap longevity. Dr. Griepink from the Netherlands provided the sex pheromone. Dosages used were from 1 µg to 500 µg active substance dispensed in red rubber septae. Trials were conducted on farms in San Leonardo and the CLSU experimental area in Muñoz.

A total of eight separate fields were used to set up traps. The sizes of the field for the trap height and concentration trials were 3000 m^2 for Block A, 5000 m^2 for Block B, and 8000 m^2 for Block C. The field for the longevity trial was 5500 m^2 and for the trap design trial, one ha. The field size inside CLSU was 1200 m^2. Control traps without lures were included in all trials, but the number of males caught in the control traps was so little that the numbers are not included in the results. The experiments were conducted using either RCBD or completely randomized design (CRD). Data were transformed to $\log_{10}$ scale and analyzed using the analysis of variance (ANOVA).

Except for the trap design trial, the traps used in this research were handmade using corrugated plastic. A 25 × 25 cm section was folded in the middle and a triangle of two opposite sides were pressed in the plastic with a ball pen to be able to fold these parts upward or downward. Holes were made in the middle line 1.5 and 4 cm from the edge to connect the upper and lower parts with wire. Yellow sticky paper was attached with double-sided tape on the bottom part. The lures were attached with a steel pin through the upper part. The traps were tied to bamboo sticks with two attachment threads to stabilize the traps from wind.

Trap height

Eight traps were placed at random within each of three blocks in a field planted in radish. Each trap had a 10 µg lure placed at heights of either 10 cm, 50 cm, 100 cm or 200 cm above ground. The minimum distance between traps was 15 m. The trial in San Leonardo was conducted from 25 October to 1 November. The trial was repeated at CLSU in January 2003 in a field planted to radish, mustard, and pak-choi. The height of 200 cm was excluded in the CLSU trial due to the smaller size of the area.

No significant differences were found among the numbers of male moths caught daily from traps of different heights in San Leonardo. In CLSU, traps at heights of 25 and 50 cm caught significantly more moths than the traps at the height of 100 cm; no significant differences were detected between the 25 and 50 cm heights at this location. The results support previous findings and the height of 50 cm is recommended.

Pheromone concentration

Traps were loaded with 1, 5, 10, 20, 50, 100, 200, and 500 µg lures. Concentrations were distributed using a RCBD with three replications. Traps were placed 50 cm aboveground. The trial started on 2 November 2002 and completed on 15 January 2003. The fields were monitored several times and sticky traps replaced when needed. The number of trapped males was 957 per night for traps with the 1-μg treatment, rose steadily as pheromone concentrations increased, and peaked at 1210 for the 500-μg treatment; however, differences were not statistically different. In a related study, it was shown that the effects of higher pheromone concentrations persist longer, albeit by nonsignificant margins (with the exception of the extreme 500 vs. 1 μg treatments). Due to the high costs of the pheromone (1 g costs US$418), the lowest concentration is recommended.

Trap design

Traps were arranged in two adjacent radish fields, each 2000 m² in size. The traps were set up in a complete randomized design with three replicates. Trap designs tested were wing traps, delta traps, water bowl traps, plastic bottle traps, and tube traps. All traps were handmade. Yellow sticky paper was used in wing, delta, and tube traps. The water bowl and the plastic bottle traps were filled with a mix of water and either motor oil or a soap solution. Tube traps were made of plastic pitchers with the bottom removed, i.e. they were open on two sides. The wing and the delta traps were made of corrugated plastic. The plastic bottle traps had four openings in the upper third of the bottle, bent to the top such that the cut parts could protect the openings from rain; for this trap, lures were hung from the lid 3 cm above the water level. The water bowl traps were made of plastic bowls with a square piece of corrugated plastic attached to the sides and curved over the bowl to a height of 15 cm above the bowl. Lures were attached to the cover and hung on a wire 3 cm above the surface of the water level. The trial was conducted from 16 November to 6 December 2002.

The wing trap caught significantly more male moths (652 moths per night) than all other designs. The daily trap counts of bottle trap (236), delta trap (194) and water bowl trap (161) were statistically similar. All traps were significantly superior to the tube trap (97).

Although the wing trap was most effective, it was costly since it could not withstand the effects of rain and its sticky surface required replacement at least every three days due to dusty conditions. More trap designs will be tested in the future, looking for sturdy traps that do not rely on sticky materials.

Flight activity of male H. undalis

Male *H. undalis* are most active during the night. Nevertheless, there is not much known about the flight activity of males when searching for a female partner. Traps with virgin females and synthetic pheromones were checked for five nights. Results showed that the main activity starts at 2:00 AM and generally reaches a peak between 4:00 AM and 6:00 AM (Table 143). After 8:00 AM it was rare to catch a male moth.

Training and outreach

Training of trainers

Twenty-six participants (25 local government officials with the Department of Agriculture and 1 farm leader) were trained to serve as FFS facilitators and to provide technical information to farmers.

Farmer field schools

Fifty-two local government officials and 323 farmers from the provinces of Bulacan, Batangas, Laguna, and Tarlac were trained to use the grafted tomato technology package of rain shelters, raised beds, plastic mulch, and trellising.

Fourteen Farmer field schools on grafted tomato were begun in 2002 and 13 were completed. Local

Table 143. *Flight activity of male* H. undalis *observed in San Leonardo, Philippines during February 2003*

Date	Minimum temp. (°C)	Time of night: 8:00 PM	10:00 PM	12:00 AM	2:00 AM	4:00 AM	6:00 AM	8:00 AM
9–10 Feb.	23.0	0	0	1	1	5	29	6
10–11 Feb	23.8	0	0	1	1	6	8	0
11–12 Feb.	24.2	0	1	0	–[1]	2	0	14
16–17 Feb.	–	0	0	1	0	52	204	68
27–28 Feb.	21.8	0	0	0	2	9	11	0

[1]No data

governments constructed the rain shelters and conducted training with the assistance of CLSU faculty.

Unfortunately, there was considerable variation in shelter design among municipalities. Most used bamboo rather than materials recommended by AVRDC/CLSU. Bamboo was chosen to reduce cost, but by cutting cost the durability and effectiveness of the shelters at most locations was compromised and yields from the technology package were low. By allowing municipalities to select participants with limited experience in growing tomatoes and to choose flimsy materials for shelter construction, performance of grafted tomato was generally mediocre.

Eleven local government officials and 101 farm leaders were trained to use the technology package developed for pak-choi.

Hanoi-CLV peri-urban agriculture project

The overall objective of the Sustainable Development of Peri-urban Agriculture in Southeast Asia (Cambodia, Lao, Vietnam) project is to increase the contribution of peri-urban agriculture to food security in Hanoi, Ho Chi Minh City, Phnom Penh, and Vientiane. The project focuses on strengthening the capacities of public institutions and private stakeholders to analyze and intervene on technical and institutional matters related to peri-urban agriculture, and increase regional cooperation for this purpose.

This project is a collaborative effort of several agencies with the major source of funds coming from the French Ministry of Foreign Affairs. Representing the overall region are the AVRDC and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD). Representing Cambodia are the Departments of 'Agronomy and Agricultural Land Improvement' and 'Planning, Statistics and International Relations' in the Ministry of Agriculture, Forestry and Fisheries and the Phnom Penh municipality. Representing Laos is the Department of Agriculture of the Ministry of Agriculture and Forestry. Representing Vietnam are Research Institute of Fruit and Vegetable (RIFAV) and Vietnam Agricultural Sciences Institute in Hanoi, and the University of Agriculture and Forestry in Ho Chi Minh City.

AVRDC assists the national collaborators in: 1) analyzing peri-urban production systems in Hanoi, Vientiane and Phnom Penh; 2) analyzing the seasonality of the vegetable consumption in Hanoi; and 3) assisting in the development and transfer of technologies for the production of vegetables in the off-season and for the production of safe vegetables overall.

Objectives in 2002 were to assess peri-urban production in the three capital cities and begin transferring vegetable production technologies. Activities included an initial regional workshop, training at AVRDC for six project collaborators, a study tour in Taiwan for three senior staff, and technical assistance missions.

Project Coordinator: H de Bon

Off-season production

Rain shelters, simple grafting chambers, and grafting nurseries were constructed in Hanoi, Phnom Penh and Vientiane. In Hanoi, during the hot-wet season, three scions (local cultivars VL2000 and HS902, and AVRDC line CHT501) were grafted onto two AVRDC-recommended rootstocks (eggplant EG 203 and tomato Hawaii 7996). The scion/rootstock combinations were cultivated under rain shelter and in open field using a split plot experimental design. Data were collected on plant survival as well as total and marketable yields. Statistical analysis showed interactions between scions and rootstocks, shelters and scions, and shelters and rootstocks for the total and marketable yields (Table 144). However, plant survival did not differ significantly between shelter and open field treatments among the grafting combinations. Scion CHT501 was the most productive scion for all rootstock combinations and shelter treatments. There was no significant advantage to grafting. The protocol doesn't allow statistical comparison of yields obtained under shelter and in the open field, but there was a trend for higher yields under the rain shelter protection.

In Vientiane, an observational trial was conducted with four scions (SR 382 and Sida as local cultivars, CHT501 and CLN2026D as AVRDC lines) grafted

Table 144. *Total yields for different scion/rootstock combinations during hot-wet season grown under shelter and in open field in Hanoi*

Scions / rootstocks	Total yield (t/ha)	
	Shelter	Open field
VL2000 / EG203	17.2 bc[1]	11.9 c
VL2000 / Hawaii 7996	17.7 bc	11.9 c
VL2000 nongrafted	15.6 c	11.5 c
HS902 / EG203	18.5 b	15.7 b
HS902 / Hawaii 7996	19.8 b	15.1 b
HS902 nongrafted	17.2 bc	13.5 bc
CHT501 / EG 203	19.8 b	23.1 a
CHT501 / Hawaii 7996	28.9 a	25.8 a
CHT501 nongrafted	25.6 a	24.9 a
Average	19.8	17.4
CV (%)	11.0	

Transplanted 11 July 2002
[1]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$

onto rootstocks (EG203 and Hawaii 7996). Grafting tomato onto EG203 increased plant survival and yield irrespective of the scions, both under shelter and open field conditions. SR382 and Sida were found suitable for the hot-wet season and outperformed other cultivars. Data for SR382 are shown in Table 145. Nongrafted plants struggled and many failed to survive. The use of rain shelters led to higher yields for nongrafted plants and scions grafted onto EG203. Plants grafted onto EG203 and grown under rain shelters produced the highest yields.

Table 145. *Plant survival and marketable yields for grafted and nongrafted SR382 grown under shelter and in open field in Vientiane.*

Scion / rootstock	Plant survival (%)		Marketable yield (t/ha)	
	Shelter	Open field	Shelter	Open field
SR382 / EG203	100	75	17.8	11.9
SR382 / Hawaii 7996	63	63	11.5	11.7
SR382 nongrafted	13	13	4.3	0.5

Transplanted 7 July 2002

Comparison of data from Hanoi and Vientiane shows that benefits from grafting and rain shelters are not systematic during the hot-wet season. In the subtropical climate of Hanoi, no bacterial wilt was observed during the trial and flooding did not occur. Potential benefits to grafting were not revealed due to lack of environmental stress. In the tropical climate of Vientiane, where the pH soil is around 5, bacterial wilt (BW) was very aggressive both in open field and under shelter, and the benefits of the technologies were evident. A cost/benefit analysis in relation to heavy rainfall is needed to assist farmers. Nevertheless, the dissemination of technologies for the grafting of tomato scions onto EG203 rootstock is underway in BW-infested soils in Hanoi and Vientiane.

Safe vegetable production

Three research assistants, one each from Vientiane, Hanoi and Phnom Penh were trained at AVRDC on the production of safe leafy vegetables. Two research assistants from Hanoi were trained on rapid biological assay techniques in order to disseminate the use of this quick test of pesticide residues in Hanoi.

Evaluation of net tunnels for reduction of pesticide usage was conducted. Various leafy vegetables were grown during the hot-wet season with and without nets, and with and without pesticides. In Hanoi, a replicated split plot experimental design was used for evaluation of treatments while in Phnom Penh an observational trial was planted. In Hanoi, pesticide residues on the harvested vegetables were analyzed by a quick bioassay test done at RIFAV and a chromatographic test done at the Plant Protection Department of the Ministry of Agriculture and Rural Development.

In Hanoi, marketable yields of leafy vegetables tested (amaranth and choysum) increased significantly through the use of the 32-mesh net tunnels. The use of pesticides led to higher yields in the open field but not under the net tunnels (Table 146). Insecticide residues for pesticide-treated vegetables were detected using both methods five to seven days after harvest. Pesticides used in Hanoi included dimehypo, dimethoate, and cartap.

In Phnom Penh, kangkong yields were fairly consistent throughout all treatments. So was the case for the other vegetable tested, Chinese kale, with the exception of the open field/no pesticide treatment that produced no marketable yield. Pesticides were required for protecting Chinese kale in the open field but were less useful for plants grown under the net tunnels.

Table 146. *Marketable yields of leafy vegetables grown in net tunnels (NT) and open field (OF) with and without use of pesticides; evaluated in a split plot experiment at Hanoi and an observational trial in Phnom Penh*

Treatment	Hanoi		Phnom Penh	
	Amaranth (kg/m^2)	Choysum (kg/m^2)	Kangkong (kg/m^2)	C. kale (kg/m^2)
NT w/ pesticides	1.13 a[1]	2.12 a	1.36	2.08
NT w/o pesticides	1.11 a	2.00 a	1.47	2.21
OF w/ pesticides	0.62 b	0.97 b	1.22	1.88
OF w/o pesticides	0.36 c	0.47 c	1.14	0
F-test	**	**	–[2]	–

Trials grown in Summer 2002
**Nonsignificant or significant at $P \leq 0.01$
[1]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$
[2]No analysis of variance was conducted

AVRDC-Asian Regional Center

The AVRDC-Asian Regional Center (AVRDC-ARC) is the link of AVRDC to national partners in Asia. It was established in 1992 as an expansion of Thailand Outreach Program (TOP) to determine the needs and capabilities of the region in terms of research and development in vegetables.

AVRDC-ARC conducts applied research on AVRDC priority vegetable crops as well as other vegetables important in the region, conducts regional and short training courses and information dissemination, and coordinates sub-regional networks and collaborative research and development programs. In 2002 the Collaborative Vegetable Research Network for Cambodia, Laos, and Vietnam, Phase II (CLVNET-II) was funded by Asian Development Bank for a 3-year term.

Studies on other vegetables with economic importance in the region are handled in the regional training course aside from focusing on AVRDC's major crops and important regional crops. In selected countries, in-country training and on-farm trials of promising AVRDC lines, together with those from private seed companies, are being conducted.

Research

Cultural practices to suppress anthracnose of pepper

The experiment aims to evaluate mulching and shelter practices for their effects on suppressing anthracnose disease in the hot-wet season. Pepper variety CA365 was used to evaluate different shelter conditions as follows: covered by rain shelter using plastic film at 2.5-m-height, covered by 16-mesh net at 2.5-m-height, and open field. In each shelter treatment, four different mulching treatments were used: rice straw alone, silver plastic film alone, rice straw on silver plastic film, and no mulching as control. The experiment started on 24 June 2002 and terminated on 20 December 2002.

There were no differences in total (marketable and non-marketable) production of pepper per plant among three shelter treatments, but there were signficant differences among mulching treatments ($P \leq 0.01$), as plots with silver mulching (with or without straw) outyielded those plots without. The average number of marketable anthracnose-free fruits was significantly higher under plastic film shelter than the other two shelter treatments (Fig. 30). The average number of infected fruits under the plastic film shelter was lower than the other two field treatments ($P \leq 0.05$).

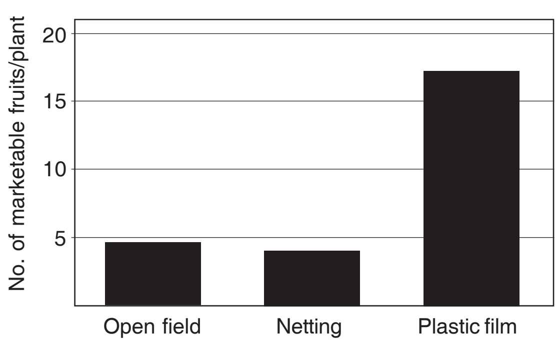


Fig. 30. *Effect of rain shelter treatments on production of marketable fruits of pepper with no anthracnose disease*

There were interactions between shelter treatment and mulching method ($P \leq 0.01$), i.e. silver film mulching and silver film plus rice-straw mulching in open field particularly suffered from increased incidence of disease (Fig. 31). In general, although plots with silver mulching produced more total fruit, they produced less marketable fruit. It is well known that raindrops hitting the ground or plant create splashes which can transmit the pathogen. The negative effect of plastic film mulching is probably due to enhancement of rain splash which may disperse more pathogens to the infection sites. In conclusion, mulches in this experiment cannot protect plants from anthracnose disease, but the plastic film shelters can; however, plastic film shelters are expensive and more affordable methods are still needed.

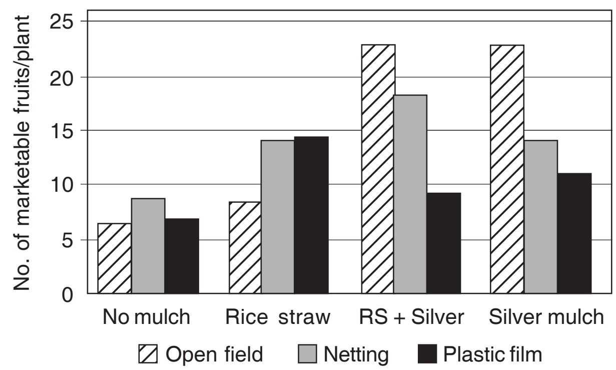


Fig. 31. *Interactive effects of mulching method and field condition on incidence of anthracnose disease of pepper*

Variation of Southern blight on pepper

Southern blight caused by *Sclerotium rolfsii* Sacc. is a common pathogen of vegetables in the tropics, creating a lesion at the base of the stem that leads to wilting. The fungus survives within the top 8 cm of the soil surface. Previous studies showed that this fungus easily survives in the field, either over winter or summer. However, those experiments have been conducted in temperate zones, not in tropics, where soil temperatures are much higher and often coupled with high moisture. It may be assumed that survival of fungus in tropical soil would be much more difficult. This experiment aims to avail survival period of *S. rolfsii* at different depths of soil, serving as a basis in the the development of cultural practices to control the disease.

Inoculum of *S. rolfsii* was prepared by culturing on sorghum seeds dipped in distilled water and autoclaved in 1,000-ml flasks. After mycelia fully grew in the flask, the inoculum was removed and used for the experiment. Samples of 5 g of inoculum were bagged with rough mesh-cloth and buried on raised beds in 0, 10, 20 and 30 cm depths in the open field at AVRDC-ARC. Every two weeks the inoculum bags were removed and rinsed to collect the sclerotia. Sclerotia were surface-sterilized by dipping in 0.5% sodium hypochlorite solution for 5 min and then rinsed in sterile distilled water. Then, the sclerotia were placed on potato dextrose agar medium in a petri dish and incubated at 25–30ºC for one week. The percentage of germinated sclerotia to grow characteristic mycelia was recorded. The experiments were conducted three times under different conditions, i.e. cool-dry, hot-dry, and hot-wet seasons.

Germination ability of sclerotia showed 100% for two weeks after being buried in soil and then gradually decreased in all cases of three experiments. In the cool-dry season, germination percentage decreased to 40–60% in the 6^{th} and 10^{th} weeks after treatment. There was no significant difference related to soil depth. In the hot-dry season, the germination percentage fluctuated between 100% and 40% for 12 weeks after mixing in soil, especially in 30-cm depth in soil; however, they recovered 100% after the occurrence of heavy rain. In the three experiments, most sclerotia in the cloth bag, which were left on soil surface or buried in soil at 10–30 cm depth, survived for 10–18 weeks and showed a 40–100% germination rate. The results indicates that deep plowing is not effective to control southern blight pathogen under tropical conditions.

Simple methods for storing soybean seeds in the tropics

Soybean (*Glycine max*) is one of the most important legumes in the world. AVRDC has promoted soybean and vegetable soybean production in the tropics through the introduction of improved varieties. A major constraint to soybean production is the rapid loss of its seed viability and vigor under ambient storage conditions. Germination rates drop precipitously after only two months of storage.

It is well known that mungbean and black gram store much better than soybean. These legumes' seeds are much smaller than those of soybean, particularly of vegetable soybean. It is assumed that bigger seeds of legumes are more difficult to dry during ordinary dehydration processing, especially during the hot-wet season. In turn, differences in the dehydration of seeds may alter seed viability and vigor after storage. The following experiment aimed to study this assumption, leading to the development of improved methods of soybean seed storage for poor farmers in the tropics.

Eight soybean varieties having different sizes of seeds were used. AGS-328, AGS-373, and AGS-292 have relatively large-sized seeds that weigh 34, 31, and 30 g/100 seeds, respectively. AGS-375, AGS-370, and TN3 have medium-sized seeds that weigh 21, 17, and 13 g/100 seeds, respectively. AGS-372 and AGS-190 have relatively small seeds that weigh only 11 and 9 g/100 seeds, respectively.

All varieties were sown on 26 November 2001 and harvested on 20 February 2002. The harvested pods were classified into two groups, yellow and brown pod color, for the purpose of separating maturity of seeds. Samples were collected immediately after solar drying and tested for moisture content and germination ability. The remaining seeds, approximately 200–300 g of each maturity and variety, were kept in a 1-liter capacity plastic box, which contained different desiccants at the bottom. Previous experiments showed no difference in seed moisture and germination among three different ratios of desiccants to seed in weight so this experiment used the same weight of desiccant to seeds for each container. The containers were sealed with plastic film to prevent entry of external moisture and kept in room temperature, 25–35ºC. Seed moisture was checked by weighing 3–5 g seeds for each sample before and after baking at 103ºC for 16 hours. Germination was tested by placing 25 seeds per sample onto autoclaved and water-saturated sand in small plastic boxes and kept at room temperatures for 5–8 days.

Seed moisture contents after solar drying were higher among seeds in brown pods (10.99% as average of 8 varieties) compared to yellow pods (9.89%) and also among varieties. Average germination percentage of brown-podded seeds was much higher (91.3%) than those of yellow-podded ones (82.2%). In some varieties, seeds from yellow pods were 20–30% lower in germination than those from brown pods. The results indicate that only seeds in brown pods should be used for seed storage.

Seed moisture after storage in baked limestone was much lower compared to the other five seed drying treatments (ash, rice husk charcoal, baked salt, $MgSo_4$, control). Moisture was at 2% after one month of storage in baked limestone and gradually increased to 8% after 5 months. The values among the other five treatments ranged from 7.2 to 9.2%, however, plant ash and baked salt treatments showed lower moisture contents than the remaining three treatments.

Seeds stored with limestone consistently showed near 100% germination after six months irrespective of seed size. In other treatments, there were differences in germination ability related to seed size. Small-seeded varieties showed high percentages of germination even without desiccant for six months. In contrast, large- and medium-sized seeds showed lower germination percentage, varying between 60–80%. There was no clear relation between germination ability and seed moisture among the other five treatments.

These results suggest that quick seed drying is important to maintain seed viability for long period. The assumption that smaller seeds dry more easily and maintain their viability longer than larger seeds, was verified. This project will continue to check seed viability after long-term storage conditions and develop practical, large-scale methods through the use of baked limestone.

Incidence of powdery mildew disease on mungbean at different growth stages

Twelve AVRDC mungbean lines were evaluated for resistance to powdery mildew on mungbean caused by *Erypsiphe polygoni*. The experiment was conducted from January to March 2002 at AVRDC-ARC, Nakhon Pathom, Thailand. Entries consisted of two susceptible lines: VC1778A (CN60) and VC2778 (KPS2); three moderately resistant lines: VC1793A (KPS1), VC1628 (CN36), and VC2768A (PSU1); and seven resistant lines: VC6173-14, VC1560C, V1104, V1132, V1445, V1844, and V4785. Spreader rows were planted ahead to serve as source of inoculum.

The disease occurred starting at 19 days after sowing (DAS). For susceptible lines, the disease incidence developed quickly from 24 to 34 DAS and peaked from 39 to 54 DAS. For resistant lines, the disease incidence often increased from 29 to 39 DAS and then gradually decreased from full pod stage to the end of growth stage. VC1560C and V4785 were most resistant to powdery mildew; they had the lowest percentages of infected plants, infected leaves, and the smallest area of leaf infection (Figs. 32–34).

Fig. 32

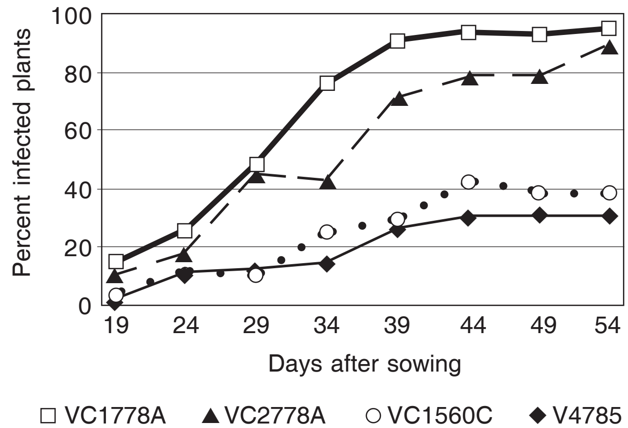


Fig. 33

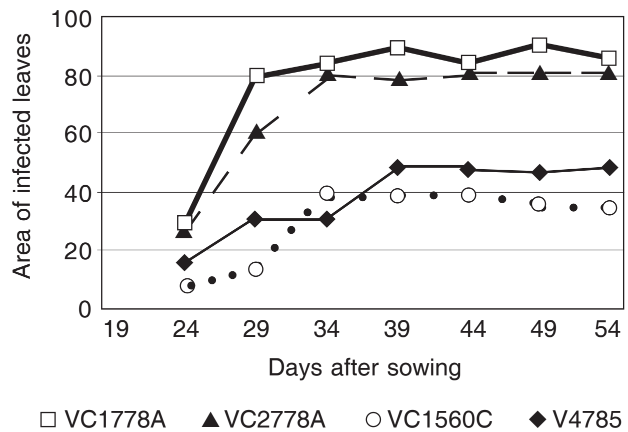
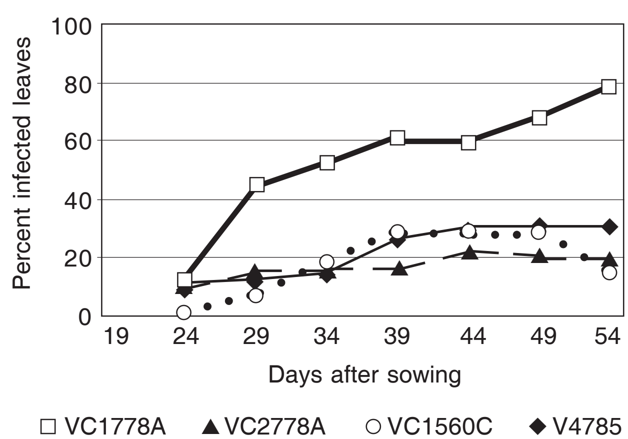


Fig. 34



Figs. 32–34. *Percent infected plants, percent infected leaves, and area of infected leaves for selected resistant and susceptible mungbean lines at different growth stages*

Training

Regional training course

Research and extension staff from six countries were included in the 20th Regional Training Course on Vegetable Production, Research and Extension held from 24 October 2001 to 23 March 2002. Seventeen of the participants were supported by the Swiss Agency for Development and Cooperation (SDC): four from Cambodia, three from China, four from Laos, three from Myanmar, and three from Vietnam, while the four participants from Bhutan were supported by their own government.

Three training scholars were awarded certificates of recognition for exemplary academic performance during the course: Ms. Nguyen Thi Thanh Xuan from Dalat Research Center for Food Crops in Vietnam, Mr. Hoang Xuan Quang from the Institute of Agricultural Sciences of South Vietnam, and Ms. Daw Nang Hmwe Hmwe from Myanma Agriculture Service, Myanmar. Two scholars were awarded certificates for Best Research Paper Award: Mr. Quang for his paper entitled "Incidence of Powdery Mildew Disease on Mungbean at Different Growth Stages," and Mr. Sangthong Silaphone of Agriculture and Forestry Office, Department of Agriculture in Vientiane, Laos, for his paper entitled "Potential of Eggplant and Soybean as Trap Crops for Management of Whitefly on Tomato."

The 21th Regional Training Course opened on 4 November 2002 with 15 participants from Cambodia, China, Laos, and Vietnam. All trainees are supported by SDC. Myanmar failed to send participants this year because of a new regulation not allowing trainees to leave Myanmar for more than one month.

Short-term training courses

Three short-term training courses were offered by AVRDC-ARC in 2001. Two of the courses were offered as per request of Pakistan and Sri Lanka to update their research, extension, and seed production personnel on modern technologies and techniques in vegetable and vegetable seed production.

- "Advanced Technologies for Vegetable Production" from 14 to 25 October 2002 for seven participants from Sri Lanka. The course consisted mainly of visits to vegetable production sites and seed companies in Thailand.
- "Seed Quality Assessment Training Course" from 2 to 27 September 2002 for ten key personnel from collaborating agencies working in Cambodia, Laos, and Vietnam, and four staff from private seed companies from Thailand and Indonesia. The four-week training course was held under the close supervision of Dr. Sutevee Sukprakarn, Director of Tropical Vegetable Research Center. Participants from Cambodia, Laos and Vietnam were supported by ADB through the CLVNET-II Project.
- "Seed Production Training Course" from 15 to 21 December 2002 for seven seed production personnel from Pakistan supported by the Aga Khan Foundation.

In-country training courses

Twelve in-country training courses were conducted in 2002 under collaboration with national partners. Among the courses, one entitled "Off-season vegetable production" was organized at Siem Reap in Cambodia under CLVNET-II project and another entitled "Hot-wet season vegetable production, emphasizing disease and pest control" was organized at Vientiane under SDC-Human Resource Development Project (HRDP-III). Eight courses were held in Vietnam, i.e. two in training for extension skills and six for off-season vegetable production and safe vegetable production technologies, supported by HRDP-III. A total of 392 participants including local extension staff and lead farmers were trained. The details of these training courses are shown in Table 147.

Information and scientific exchange

The AVRDC Technical Bulletin No. 27 entitled "The Vegetable Sector in Indochina Countries: Farm and household perspectives on poverty alleviation," edited by Dr. Mubarik Ali, was published in 2002. This survey and the subsequent publication was funded by the Asian Development Bank through the CLVNET project.

Three publications were made under collaboration between AVRDC-ARC and national partners supported by HRDP-III. AVRDC-Vegetable Production Training Manual was translated into Vietnamese language and published by Research Institute of Fruits and Vegetables (RIFAV). A technical guide book entitled "Off-season vegetable production —techniques and experience" was written in

Table 147. *List and description of in-country training courses in the CLV countries conducted in 2002*

1. Training on survey of natural enemies and their parasitism of DBM in major vegetable growing areas of CLVNET countries; Vietnam; 23–24 May; 6 participants
2. Training skills of trainers in transferring technologies to farmers and communities; Vietnam; 18–21 June; 24 participants
3. Training and transferring technique on growing vegetables in nethouse; Vietnam; 11 July (13 participants), 29 October (60 participants)
4. Off-season vegetable production (CLVNET-II); Siem Reap, Cambodia; 14–16 August; 34 participants
5. Training and exchanging experiences on off-season vegetable production due to hot and dry in the Central Vietnam; 19–21 August; 30 participants
6. Off-season vegetable production; Nghean Province, Vietnam; 19–21 August; 37 participants
7. Hot-wet season vegetable production; Vientiane, Laos; 21–23 August; 25 participants
8. Off-season vegetable production; Quangbinh Province, Vietnam; 23–25 August; 35 participants
9. Off-season vegetable production; Quangbinh Province, Vietnam; 4–6 October; 35 participants
10. Off-season vegetable production in Nghean Province, Vietnam; 7–9 October; 35 participants
11. Training on nethouse construction and vegetable production; Quang Binh Province, Vietnam; 20–21 December; 33 participants
12. Approaches to agricultural extension in RIFAV; Hanoi, Vietnam; 3–6 December; 25 participants

Total: 392 participants

Vietnamese language and published by Institute of Agricultural Sciences of South Vietnam (IAS). Chinese partners also published technical reports entitled "Industrial Development and Technology Utilization of Mungbean in China", written in Chinese with English summary.

AVRDC-ARC website made its debut in 2002, providing information on the Center's activities in research, networks, and training. A total of 7000 users accessed the website from September to December 2002.

Germplasm collection, multiplication and exchange

Table 148 lists the vegetable seed distribution through AVRDC-ARC based on the records of AVRDC Genetic Resources and Seed Unit and AVRDC-ARC/ Thailand Vegetable Research Center Germplasm Unit.

Table 148. *Distribution of vegetable seed germplasm packets sent to Asian countries in 2002*

Crop	Cambodia	China	Laos	Myanmar	Thailand	Vietnam	Total
Alliums		4					4
Brassicas						7	7
Eggplant		10				5	15
Mungbean		8			4	35	47
Pepper	51	227	40		119	83	520
Soybean		45			10	84	139
Tomato	68	120		13	45	82	328
Other		9			14	69	92
Total	119	423	40	13	192	365	1152

AVRDC-Regional Center for Africa

The AVRDC-Regional Center for Africa (AVRDC-RCA), located in Arusha Tanzania, works in close collaboration with national agricultural research and extension systems (NARES) in Africa to:

- conserve and enhance the genetic resources of selected vegetables;
- develop improved vegetable varieties, their seed production systems, and sustainable production technologies;
- train promising African vegetable researchers and extensionists;
- strengthen national research institutions; and
- disseminate relevant vegetable research information and technologies.

During a strategic planning workshop in February 2002, AVRDC-RCA invited stakeholders to chart the future scope of work of AVRDC in Africa. Three priorities were selected:

- germplasm management and promotion of African indigenous vegetables (AIV) and priority exotic vegetables for food security, national health and enhanced income;
- sustainable seed supply systems for AIV and priority exotic vegetables; and
- strengthening the capacity of researchers and extensionists of national systems through training, participatory technology development and transfer.

The training component of the Collaborative Network for Vegetable Research and Development in Southern Africa (CONVERDS) receives support from the United States Agency for International Development (USAID). Since its inception, 306 NARES personnel have been trained. Studies were initiated in January 2002 on improving AIV seed production systems; this project is funded by (BMZ/GTZ). Additional studies are ongoing in the second year of a project on promoting multidisciplinary approaches to prevent micronutrient malnutrition in Southern Africa. The study is being implemented with the Commonwealth Regional Health Community Secretariat for East, Central and Southern Africa. Two other studies initiated in 2002 focused on the collection, evaluation, and management of African indigenous vegetable (AIV) germplasm; these studies are in collaboration with the International Plant Genetics Research Institute and The Institute for Applied Research, Ben Gurion University of the Negev, Israel. Further research and promotional programs are in progress with African indigenous vegetables, tomato, and vegetable legumes; this work is supported by United Nations Children's Fund and USAID.

Director: ML Chadha

Research

Seed production practices for tomato cultivar Tanya

Tomato seed yield is often low in Sub-Saharan Africa due to poor management practices and lack of knowledge on seed production practices. A trial was conducted at AVRDC-RCA in Arusha, Tanzania from July to November 2001 to evaluate spacing and nitrogen effects on the seed yield of Tanya. Seeds were sown on 14 May and transplanted on 28 June 2001. The experiment was laid out in a 3 × 5 factorial randomized complete block design (RCBD) design with three replications. The seedlings were transplanted in double rows in an experimental plot measuring 6 m long and 60 cm between rows. Spacing between plants was 50, 60, and 75 cm while five levels of urea fertilizer (0, 27.6, 41.4, 55.2 and 82.8 kg N/ha) were tested in a factorial combinations. Fertilizer was applied in split application with the first application carried out two weeks after transplanting and the second application two weeks later.

Standard cultural practices including staking, furrow irrigation, weeding, and disease/pest management were done regularly. Data were collected and analysis of variance (ANOVA) determined using Cohort software.

Results showed an increase in fruit and seed yields with an increase in N fertilizer rates; however, these differences were not significant probably as a result of residual fertilizer effect. A decrease in spacing from 75 to 50 cm gave significant increases in fruit and seed yields per ha (Table 149). A decrease in spacing also gave the same upward trend with other parameters measured although the differences were not significant. For all parameters measured, there were no significant interaction effects between N rates and spacing treatments. Tanya has a relatively short vine and we conclude that tight spacings, in this case 50 cm between plants in the row, is best for its seed production.

Productive tomato lines for Sub-Saharan Africa

Tomato is one of the most important vegetable crops in Sub-Saharan Africa. Besides generating income and employment opportunities for farmers, the vegetable is an essential source of vitamins and minerals for the population in the region. Tomato yields are low in Sub-Saharan Africa; one of the reasons is that the cultivars grown in the region are not suited to the environment. An experiment was conducted to evaluate advanced AVRDC-RCA tomato lines for yield characteristics. The experiment was laid out in RCBD with three replications. Twelve AVRDC tomato lines were evaluated with cultivars Tanya and Tengeru 97 serving as checks. Seeds were sown in the nursery on 15 May 2001 and transplanted on 20 June in double rows in plots measuring 1.2 × 6 m with a spacing of 50 cm between plants and 60 cm between rows. Basal application of 20N–4.3P–8.3K kg/ha commercial fertilizer was applied and plants were sidedressed with 73.6N–0P–0K kg/ha in split application. Weeding, irrigation, and chemical spray for control of pests and diseases was done whenever required. All data were subjected to ANOVA analysis using Cohort software.

Lines ARP 366-4-23, ARP 365-3-25, ARP 365-3 and ARP 366-2 produced the highest yields in the trial although differences among lines were not significant (Table 150). Tanya matured earlier than other lines,

Table 149. *Effect of spacing on seed and fruit yield characteristics of tomato cultivar Tanya*

Spacing	Seed yield (kg/ha)	Seed yield/plant (g)	Seed yield/fruit (g)	No. seeds/ plant	No. fruits/ plant	Fruit yield (kg/ha)	Fruit yield/plant (g)
50 x 60	163.2 a[1]	4.93	0.24	1731	21	1364.5	44.84 a
60 x 60	132.3 b	4.75	0.24	1617	20	1174.1	34.67 b
75 x 60	95.5 c	4.28	0.24	1497	18	1183.5	28.02 b
LSD (0.05)	28.0	0.94	6.5	316	4.8	298.8	9.12
F-test	***	NS	NS	NS	NS	NS	**
CV (%)	29	27	0.36	26	26	32	33.98

Transplanted 28 June 2001 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Table 150. *Advanced evaluation of 12 AVRDC-RCA tomato lines for yield characteristics*

Entry	Days to maturity	Total yield (t/ha)	Marketable yield (t/ha)	Total yield/ plant (g)	Total fruit/ plant	Plant height (cm)	No. flowers/ 10 clusters	No. flower clusters
ARP 365-1	82.3 c	76.0	51.6	2158	30.4 ab[1]	84.4 a	59.9 a	16.2 bcd
ARP 365-2	83.0 bc	74.9	52.5	2246	24.2 ab	83.2 a	62.0 a	16.0 b-e
ARP 365-2-5	82.3 c	72.5	56.9	2175	29.6 ab	84.3 a	64.1 a	16.2 bcd
ARP 365-3	82.0 c	80.5	57.5	2414	28.4 ab	87.1 a	62.5 a	15.6 cde
ARP 365-3-25	82.7 bc	81.8	61.2	2453	34.4 ab	87.2 a	62.5 a	18.4 ab
ARP 366-1	82.3 c	61.1	44.8	1833	23.1 b	80.0 a	61.5 a	14.8 de
ARP 366-2	84.3 b	79.3	58.8	2379	29.9 ab	85.4 a	65.1 a	18.2 abc
ARP 366-3	83.3 bc	76.0	54.8	2250	31.8 ab	85.7 a	60.5 a	17.3 a-d
ARP 366-4-23	83.3 bc	84.2	63.1	2526	32.1 ab	87.5 a	59.9 a	17.4 a-d
ARP 367-1	83.0 bc	74.9	54.6	2213	37.8 a	77.3 a	61.7 a	15.2 de
Tanya (ck)	79.7 d	57.3	43.2	1719	27.0 ab	47.6 b	50.2 b	13.3 e
Tengeru 97 (ck)	89.0 a	70.0	53.3	2100	30.1 ab	85.7 a	65.9 a	19.6 a
F-test	***	NS	NS	NS	*	**	**	
LSD (5%)	1.58	28.8	22.7	863	12.4	6.1	2.4	
CV (%)	1.12	23.0	24.7	23	24.5	5.8	8.7	

Transplanted 20 June 2001 at AVRDC-RCA
NS,*,**, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

but produced the shortest vine, fewest flower clusters, and smallest fruits. Line ARP 365-3-25 produced the largest fruits (Table 151). Overall, ARP 366-4-23 was rated as the superior line in the trial. It will be promoted for further evaluation at different locations to determine its yield potential in wider environments.

Table 151. *Advanced evaluation of AVRDC-RCA tomato lines for fruit characteristics*

Entry	Fruit diameter (cm)	Fruit weight (g)	Fruit firmness[1]	Fruit shape[2]
ARP 365-1	3.24 a[3]	67.9 b	F	R
ARP 365-2	3.38 a	83.7 ab	F	R
ARP 365-2-5	3.38 a	73.3 b	F	R
ARP 365-3	3.18 a	80.5 ab	MF	R
ARP 365-3-25	3.32 a	93.9 a	F	SF
ARP 366-1	3.28 a	77.9 ab	MF	R
ARP 366-2	3.09 a	74.1 b	F	R
ARP 366-3	3.30 a	77.2 ab	MF	R
ARP 366-4-23	3.28 a	66.7 b	F	SF
ARP 367-1	3.22 a	70.2 b	MF	SF
Tanya (ck)	2.74 b	68.0 b	F	P
Tengeru 97 (ck)	3.14 a	71.5 b	F	SF
F-test	**	**		
LSD (5%)	0.28	17.1		
CV(%)	5.22	13.4		

Grown from July to November 2001 at AVRDC-RCA
**Significant at $P \leq 0.01$
[1]F = Firmness, MF = Moderate firmness
[2]P = Plum, R = Round, SF = Slightly flattened
[3]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Late blight-resistant tomato for Africa

Foliage and fruit infections by late blight *(Phytophthora infestans)* contribute to significant yield losses during the rainy season. There are no resistant cultivars available to farmers at this time. This trial compared the performance of ten F_{10} late blight-resistant lines to determine the level of resistance, yield potential, and other horticultural traits during the rainy season. Tengeru 97 and Marglobe were included as checks. The experiment was conducted at AVRDC-RCA from April to September 2002. The experiment was laid out in a RCBD with three replications. Seedlings were transplanted in double-row plots. Rows were 6 m long and plants were spaced 50 cm apart in rows spaced 75 cm apart. Fertilization included a basal application of 20N–4.3P–8.3K kg/ha, followed by sidedressings of 23N–0P–K kg/ha three, five and seven weeks after transplanting. All F_{10} lines are indeterminate and were staked and trellised accordingly.

Table 152. *Yield and other characteristics of late blight-resistant, F_{10} tomato lines*

Entry	Fruit yield (t/ha)	Fruit yield (kg/plant)	No. fruits/ plant	Fruit size (g)	Days to flowering	Incidence of late blight (%)
19-2	107.2 ab[1]	4.09 ab	29.6 abc	139.7 ab	27.0 f	0.0 b
19-3	101.3 bc	3.80 bc	29.3 abc	130.8 ab	26.6 f	0.0 b
44-1	71.9 de	2.76 bc	20.6 de	140.7 ab	31.7 cde	0.0 b
44-2	120.5 a	4.52 a	35.4 a	127.9 abc	30.3 e	0.0 b
44-3	61.3 cd	2.31 e	16.4 e	149.3 a	30.7 de	0.0 b
44-4	66.7 de	2.54 de	20.7 de	124.5 abc	31.0 cde	0.0 b
44-5	79.9 de	3.00 de	24.3 cd	123.1 abc	32.0 c	0.0 b
50-2	96.8 bc	3.68 bc	26.6 bcd	138.5 ab	30.0 e	0.0 b
80-5	85.3 cd	3.24 cd	32.5 ab	102.0 c	30.0 e	0.0 b
81-3	77.3 de	2.95 de	24.9 cd	118.4 bc	35.3 b	0.0 b
Tengeru 97 (ck)	0.0 f	0.0 f	0.0 f	0.0 d	33.3 b	4.96 a
Marglobe (ck)	0.0 f	0.0 f	0.0 f	0.0 d	26.3 f	4.93 a
F-test	***	***	***	***	***	***
LSD (5%)	0.63	0.63	6.7	25.5	1.14	0.08
CV (%)	13.7	13.7	18.1	13.9	2.2	5.6

Transplanted 10 April 2002 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

All F_{10} lines showed complete resistance to late blight (Table 152). Lines 44-2, 19-2, and 19-3 gave significantly higher fruit yields of 120.5, 107, and 101 t/ha, respectively, when compared to other lines (Table 152). Marglobe and Tengeru 97 were seriously affected by late blight and all fruits were lost.

Bulked seed and seeds from single plant selections of the best lines were collected, sown, and seedlings were transplanted for further evaluation. The F_{10} lines were tested during the wet season and have shown better yields than F_8 and F_9 lines tested during the dry season in 2001 as previously reported in *AVRDC Report 2001.* The high yields of late blight-resistant lines show potential for adaptability and production in the African highlands.

Sweet pepper lines with multiple disease resistance

Farmers in Africa face serious production constraints due to the susceptibility of sweet pepper to many diseases and pests. The development of multi-disease-resistant lines to stabilize yields has been a long-term priority of AVRDC. Since 1997, a collaborative project between AVRDC-RCA and Institut National de la Recherche Agronomique (INRA) in France has screened numerous pepper lines for resistance to fungal (phytophthora blight) and viral (cucumber mosaic virus, potato virus Y, and tobacco etch virus) diseases. Seeds of 40 progenies were selected based on their disease resistance, and harvested from intercrosses of the best sub-populations evaluated in 1998 and 2000.

These progenies were transplanted in February 2001 to evaluate for yield and disease resistance characteristics under field conditions at AVRDC-RCA in Arusha, Tanzania. The experiment was laid out in a RCBD with three replications in plot sizes measuring 0.75 × 6 m with 50 cm between plants. An application of 60N–12.9P–24.9K kg/ha inorganic fertilizer was applied at transplanting followed by a sidedressing of 23N–0P–0K kg/ha four weeks later. Actellic 50EC and Bayleton were sprayed whenever necessary to control thrips and powdery mildew, respectively.

Lines Tz 35, Tz 19, Tz 40, Tz 16, Tz 6, and Tz 18 showed good yield characteristics compared to the other lines and check variety (Table 153). Lines Tz 24, Tz 13, Tz 6, Tz 5, and Tz 19 showed the heaviest fruit weights while lines Tz 38, Tz 20, Tz 4, and Tz 5 gave the longest fruit lengths. Lines Tz18, Tz 19, Tz 15, and Tz 7 showed significantly larger fruit diameters (Table 153). Seeds of the best plants in each sub-population were harvested for further testing for disease resistance and horticultural characteristics.

Table 153. *Yield and horticultural traits of sweet pepper lines*

Entry	Yield (t/ha)	Yield (kg/ plant)	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Plant mortality[1] (%)
Tz 1	19.6	0.74	121 b-k[2]	8.17	6.53 b-f	49.2 a-f
Tz 2	21.6	0.81	132 b-i	9.77	6.67 a-e	26.1 fg
Tz 3	22.6	0.85	98 h-k	8.63	5.73 d-h	30.0 fg
Tz 4	16.7	0.62	136 b-h	10.67	6.93 a-d	43.1 a-g
Tz 5	24.4	0.92	152 abc	10.66	5.80 c-h	33.0 c-g
Tz 6	37.5	1.41	156 ab	9.83	6.77 a-e	40.8 a-g
Tz 7	24.0	0.90	148 a-e	9.73	7.10 ab	46.9 a-g
Tz 8	22.9	0.86	114 d-k	10.30	6.80 a-e	48.9 a-g
Tz 9	22.2	0.83	123 c-k	9.77	6.23 b-h	34.9 b-g
Tz 10	22.5	0.84	131 b-k	9.27	5.66 e-h	53.9 a-d
Tz 12	33.8	1.27	137 b-h	10.20	5.96 b-h	35.2 b-g
Tz 13	23.1	0.87	158 ab	9.83	6.80 a-e	51.1 a-f
Tz 14	33.3	1.25	128 b-j	10.13	5.20 gh	31.9 c-g
Tz 15	21.4	0.80	134 b-i	8.37	7.00 abc	56.1 a-c
Tz 16	37.2	1.40	111 e-k	11.37	6.06 b-h	27.3 fg
Tz 17	24.9	0.93	138 a-h	10.17	6.53 b-f	47.2 a-g
Tz 18	35.2	1.33	134 b-i	10.03	7.87 a	48.8 a-g
Tz 19	40.6	1.52	150 a-d	9.60	7.10 ab	53.9 a-d
Tz 20	27.1	1.02	132 b-i	10.83	6.57 b-f	48.8 a-g
Tz 21	20.9	0.78	106 h-k	9.67	5.47 f-h	44.9 a-g
Tz 22	24.4	0.92	144 a-f	8.66	6.43 b-g	45.0 a-g
Tz 23	29.5	1.11	142 a-h	9.60	6.77 a-e	26.1 fg
Tz 24	28.1	1.05	173 a	10.60	6.93 a-d	53.2 a-e
Tz 25	29.2	1.09	114 d-k	10.20	6.03 b-h	43.1 a-g
Tz 26	30.5	1.14	108 f-k	7.43	5.66 c-h	42.8 a-g
Tz 27	32.3	1.21	124 b-k	9.27	6.50 b-f	28.3 efg
Tz 28	26.0	0.98	108 f-k	8.13	6.06 b-h	48.8 a-g
Tz 29	31.8	1.19	133 b-i	9.60	5.90 b-h	45.0 a-g
Tz 30	24.3	0.91	106 g-k	10.60	5.63 e-h	41.1 a-g
Tz 31	28.6	1.07	135 b-i	9.93	6.83 a-e	54.8 a-d
Tz 32	30.8	1.15	106 h-k	8.33	6.26 b-h	44.2 a-g
Tz 33	32.9	1.23	143 a-g	8.77	6.50 b-f	23.4 g
Tz 34	22.7	0.85	115 c-k	8.93	6.33 b-g	53.4 a-e
Tz 35	43.8	1.64	131 b-i	10.23	6.47 b-f	31.9 c-g
Tz 36	17.4	0.65	126 b-k	8.67	5.86 b-h	59.2 ab
Tz 37	29.8	1.12	117 c-k	9.70	5.66 e-h	48.9 a-f
Tz 38	21.2	0.81	93 jk	11.40	5.03 h	46.9 a-g
Tz 39	27.2	1.02	91 k	10.37	5.50 f-h	61.9 a
Tz 40	39.2	1.47	106 g-k	10.30	5.93 b-h	48.8 a-g
Yolo Wonder (ck)	15.9	0.60	134 b-i	8.60	6.26 b-h	59.0 ab
F-test	NS	NS	**	NS	**	**
LSD (5%)	16.7	0.63	30	2.07	1.02	20.6
CV (%)	37.4	37.4	4.54	13.20	10.01	28.9

Transplanted February 2001 at AVRDC-RCA

NS,*,**Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively

[1]Taken at 50% fruit maturity

[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

High yielding hot peppers for Africa

Hot pepper is gaining importance in Africa as a source of income generation for small-scale farmers, both for local and export markets. The pungent vegetable is also used to diversify crops in home garden systems and to add spice to diets. Traditional varieties are low yielding and increasingly susceptible to diseases and pests. AVRDC is developing high yielding and stable chili inbred lines with multiple disease and insect pest resistances for the hot and humid tropics. As part of the AVRDC International Chili Pepper Nursery (ICPN) trials, ten AVRDC hot pepper lines were evaluated for yields and other horticulture characteristics at AVRDC-RCA, Arusha, Tanzania during the cool dry season.

Seedlings were transplanted on 11 July 2001 in plot sizes measuring 4.8 m^2 in two rows with a spacing of 40 cm between plants and 60 cm between rows. The trial was conducted in RCBD with three replications. An application of 46N–0P–0K fertilizer was applied as granular application in two splits with the first applied two weeks after transplanting and another application three weeks thereafter. An additional 20N–4.3P–8.3K was applied as a sidedress two weeks after transplanting. Furrow irrigation, weeding, and insecticide spraying was done as required.

Significant differences were observed in all the parameters measured. Line 97-7644 gave the highest fruit yields and number of fruits per plant while 97-7623 gave the highest fruit weight (Table 154). Line PBC-535 showed the highest mortality rate while 97-7127 had the longest fruit. PBC-7623 and 9852-170 showed the thickest fruit walls (Table 154). This trial indicates that 97-7644 has potential for adaptation under Arusha conditions.

Eggplant cultivars for Africa

Eggplant, *Solanum melongena*, is very popular in many regions of the world, but is relatively underutilized in Africa. This trial aimed to evaluate ten elite eggplant cultivars to determine their general adaptability under climatic conditions in Arusha, Tanzania.

Two separate trials were conducted at AVRDC-RCA during two seasons (October 2000 to April 2001 and from July 2001 to February 2002). The experiments

Table 154. *Evaluation of hot pepper lines for yield adaptation and horticultural characteristics*

Entry	Fruits/ plant	Yield (kg/plant)	Yield (t/ha)	Fruit weight (g/fruit)	Fruit length (cm)	Fruit width (cm)	Fruit wall thickness (cm)	Fruit shape	Transplant survival (%)	Days to 50% flowering
97-7126	184 b[1]	0.58 b	24.15 b	9.67 abc	7.62 e	0.75 d	0.13 abc	Elongate	94.4 ab	59 a
97-7127	244 ab	0.66 ab	27.42 ab	11.33 b	11.17 a	1.02 bc	0.12 c	Elongate	85.5 abc	52 c
97-7195	227 b	0.20 c	10.06 c	8.67 abc	8.67 de	0.92 cd	0.12 bc	Elongate	97.7	59 a
97-7623	204 b	0.53 b	22.19 bc	12.33 a	11.10 a	0.86 cd	0.14 abc	Elongate	81.1 bc	52 c
97-7644	396 a	0.92 a	38.46 a	5.67 cd	9.50 bcd	1.20 b	0.18 ab	Conical	92.1 ab	52 c
9852-170	238 ab	0.79 ab	33.27 ab	6.67 cd	10.50 ab	0.89 cd	0.19 a	Elongate	98.8 a	59 a
9852-173	146 b	0.81 ab	33.82 ab	9.40 abc	10.29 abc	0.90 cd	0.10 c	Elongate	93.3 ab	53 b
PBC-308	148 b	0.49 b	20.73 bc	7.40 bc	8.52 de	0.98 bcd	0.14 abc	Conical	82.2 bc	52 c
PBC-535	201 b	0.61 ab	25.35 ab	9.33 abc	8.97 cde	0.81 cd	0.10 c	Elongate	66.6 d	50 d
PBC-7623	289 ab	0.72 ab	29.72 ab	3.00 d	10.23 abc	1.42 a	0.19 a	Elongate	76.6 cd	52 c
F-test	*	***	**	**	***	***	*		***	***
LSD (5%)	151	0.29	12.01	3.9	1.25	0.22	0.06		12.8	0.5
CV (%)	28	30	29	27	7.6	13	23		8.6	0.5

Transplanted 11 July 2001 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

were laid out in a RCBD with three replications in plot sizes measuring 1.2 × 6.0 m. The seedlings were transplanted in double rows using a spacing of 0.40 m between plants and 0.60 m between rows. Fertilizer at the rate of 50N–10.8P–20.8K kg/ha was applied basally during transplanting followed by a total sidedressing of 46N–0P–0K in three split applications at an interval of three weeks, starting three weeks after transplanting. Ridomil, Actellic, Folimat, and Selecron were sprayed to control pests and diseases. Furrow irrigation was applied once a week from transplanting and whenever necessary until the end of harvest.

Results showed that EG195 took the shortest time to flower but produced the lowest yields (Table 155). S90 grew the fastest (5.70 mm/day) and produced the most fruit per plant (2.7 kg) and per ha (72 t/ha), during the first season. EG193 had the highest fruit set, 76.7%.

The best yielding cultivar in the second season was EG219, 139.7 t/ha, while cultivar EG048 produced the largest fruits, 355.4 t/ha (Table 155). In all parameters measured, the cultivars performed better during the second season, which was characterized by cooler temperatures. This preliminary evaluation trial will be evaluated further during a third season, but in general, EG219 appears very promising at this time.

Effects of spacing on promising African eggplant varieties

In recent years, consumption of African eggplant (*Solanum aethiopicum and S. anguivi*) has increased in Sub-Saharan Africa. Despite the rising demand, yields remain low due to the lack of production technologies and knowledge on managing the crop.

A study was carried out at AVRDC-RCA in Arusha, Tanzania from July 2001 to January 2002 to evaluate the response of four promising African eggplant lines to variation in row spacing. The experiment was laid out in a 4 × 4 factorial RCBD with three replications. Seedlings were transplanted in plots measuring 0.9 × 6.0 m in two rows spaced 60 cm apart. In-row spacings of 50, 60, 70 and 80 cm were evaluated. Fertilizer was basally applied at a rate of 24N–5.2P–10.0K kg/ha, followed by sidedressing with 46N–0P–0K kg N/ha three and six weeks after transplanting. Cultural practices such as weeding, furrow irrigation, and disease control were practiced as necessary.

The spacing of 80 cm significantly increased fruit yield and the number of fruits per plant when compared to other spacing treatments (Table 156). Among the lines tested, Manyire Green gave the highest fruit weight (94.7 g), fruit width (4.17 cm), and yields (55.6

Table 155. *Yield and fruit characteristics of elite eggplant lines*

	Days to 50% flowering		Growth rate (mm/day)	Fruit set (%)	Fruits/ plant	Yield (kg/plant)		Yield (t/ha)		Fruit length (cm^2)		Fruit weight (g)
Entry	Year 1[1]	Year 2[1]	Year 2	Year 2	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 2
EG048	-[2]	72 a[3]	4.79 abc	53.7 abc	-	-	2.4 bc	-	101 bc	-	481 a	355 a
EG192	48 a	60 e	5.17 ab	34.8 c	53 a	2.3 ab	2.7 ab	61 ab	114 ab	56 b	190 f	68 de
EG 193	48 a	62 d	4.72 bc	76.7 a	50 ab	2.1 abc	2.2 bc	56 abc	93 bc	55 b	310 d	79 d
EG195	27 b	47 g	4.05 cd	64.9 ab	40 c	1.0 d	1.7 c	27 d	70 c	37 c	239 e	78 d
EG 203	48 a	50 f	5.24 ab	64.4 ab	48 abc	1.9 bc	2.1 bc	52 bc	89 bc	33 cd	218 ef	105 c
EG219	48 a	63 cd	4.33 bcd	50.5 bc	48 abc	2.1 abc	3.4 a	56 abc	140 a	61 b	233 e	107 c
PAU-Feb	-	43 h	4.57 bcd	64.7 ab	-	-	0.6 d	-	26 d	-	134 g	44 ef
S3	41 ab	64 c	3.64 d	51.6 bc	48 abc	1.5 cd	2.5 abc	41 cd	103 abc	58 b	354 c	145 b
S47A	48 a	70 b	4.04 cd	55.7 abc	53 a	2.0 abc	2.8 ab	54 abc	115 ab	117 a	423 b	136 b
S56B	41 ab	50 f	4.33 bcd	54.7 abc	48 abc	1.2 d	1.7 c	32 d	72 c	18 e	117 g	46 ef
S69	41 ab	49 f	4.63 bc	48.6 bc	48 abc	1.2 d	1.6 c	32 d	65 c	17 e	106 g	39 f
S90	41 ab	50 f	5.70 a	54.8 abc	43 bc	2.7 a	2.2 bc	72 a	90 bc	25 de	128 g	58 def
F test	NS	***	**	**	NS	***	***	***	***	***	***	***
LSD (5%)	13.69	1.83	0.87	21.6	7.9	0.64	0.83	17	35	9	28	25
CV (%)	18.52	1.9	11.3	22.7	9.6	20.7	22.8	20.7	22.8	11.37	6.75	14.5

NS,*,**Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively

[1]Year 1 trial was grown from October 2000 to April 2001; Year 2 trial was grown from July 2001 to February 2002

[2]No data

[3]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

t/ha), although it had the lowest number of fruits per plant (Table 156). CN012 gave the highest number of fruits per plant although it had the lowest fruit yield per plant (Table 156). This line is characterized by very small fruits which are berry-shaped. There was no interaction effect between spacing and line. In general, line AB2 gave lower yields while DB3 gave higher yields than previously reported in the last season (*AVRDC Report 2001*). Overall, this preliminary study indicated that the optimum spacing for African eggplant is 80 cm.

Table 156. *Evaluation of plant population on yield adaptation and horticultural characteristics of promising African eggplant lines*

Trait	Fruits/ plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Yield/ plant (kg)	Yield (t/ha)
In-row spacings						
50	53.8	27.0	4.84	3.28	1.45 b[1]	32.2 b
60	59.5	32.1	4.77	3.30	1.91 b	35.4 ab
70	53.5	33.1	4.60	3.14	1.77 b	28.1 b
80	65.2	56.7	4.89	3.22	3.70 a	1.3 a
LSD (5%)	24.7	15	0.60	0.39	1.20	17.9
F-test	NS	NS	NS	NS	**	*
CV (%)	51.1	28.7	15	14.6	65	59
Lines						
M.Green[2]	36.3 b	94.7 a	4.64 c	4.17 a	3.46 a	55.6 a
CN012[3]	135.4 a	5.5 c	2.33 d	2.02 c	1.02 b	17.6 b
DB3[2]	46.7 b	64.2 ab	6.71 a	3.50 b	2.95 a	49.4 a
AB2[2]	28.1 b	57.9 b	5.43 b	3.25 b	1.43 b	24.3 b
LSD (5%)	24.7	14.5	0.60	0.39	1.90	17.9
F-test	**	**	**	**	**	**
CV (%)	32.0	28.7	15.2	14.6	65	59

Transplanted July 2001 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

[2,3]*Solanum aethiopicum* and *S. anguivi*, respectively

Effects of natural and synthetic pesticides in controlling diamondback moth in cabbage

Diamondback moth (DBM), *Plutella xylostella* is the dominant pest of crucifers in many parts of eastern and southern Africa. Complete yield loss is often associated with this pest if control actions are not undertaken.

Despite their negative effects on the environment and human health, synthetic pesticides such as deltamethrin, endosulfan, and lambda-cyalothrin were widely used by farmers in the sub-region until DBM became resistant to the chemicals. These pesticides are no longer efficient in protecting cabbage crops from DBM attacks and new chemicals or alternative control methods have to be identified. Seed extracts of the tropical neem tree, *Azadirachta indica*, have been reported to efficiently control DBM and their use to control the pest is increasing. Additionally, other botanicals have been reported to control DBM in crucifers.

This study aimed to evaluate the efficiency of neem seed extract and other natural extracts from tithonia, hot pepper, tephrosia, and cow urine in controlling DBM at AVRDC-RCA, Arusha, Tanzania. Five-week-old seedlings of cabbage (cultivar Glory of Enkhuizen) were transplanted in the field in September 2001. Plot sizes measured 0.5 × 6 m with a spacing of 50 cm between plants.

Two separate experiments were conducted. The first experiment compared two concentrations of neem (25 and 50 g/L) with profenofos (trade name Selecron) (1.5 ml/L) and water serving as control treatments. The second experiment compared extracts of neem seed (50g/l) with extracts of tithonia, tephrosia, hot pepper, and cow urine. Each experiment was laid out in RCBD with three replications. Neem seed extract and extracts of tithonia and tephrosia were used in aqueous solution. Spraying frequencies of once per week, once per two weeks, and once per three weeks were tested for efficacy, and solutions were sprayed on seedlings until run-off. Efficacies of the treatments were assessed by taking data on head yields, counting mean number of holes per leaf, and weekly counting of larvae and pupae up to two weeks before harvesting (15 to 16 week-old plants).

Results showed that plants treated with neem seed extract gave significantly lower larvae/pupae counts and leaf damage and recorded significantly larger head yields when compared to plants treated with Selecron and control plants (Table 157). There was no significant difference in results between the two neem seed extract concentrations (Table 157) and variation in the frequency of applications (data not shown).

In the second experiment, comparison of the efficacy of neem, tithonia, tephrosia, hot pepper, cow urine, selecron, and water showed cabbage head yields of 1.87, 1.46, 1.51, 1.27, 1.35, 1.65, and 1.26 kg, respectively. The results were significantly different from each other and confirm the effectiveness of neem in controlling DBM.

The data from the first experiment concurs with preliminary studies conducted in July 1999 (*AVRDC Report 1999*) and shows that the use of neem seed extract has potential for controlling DBM in sub-Saharan Africa. Neem seed extract is inexpensive throughout Africa and may therefore represent a cost-effective crop protection alternative as synthetic pesticides are very expensive and small-scale farmers cannot always afford them. However, these promising results need to be confirmed in future trials.

Table 157. *Efficacy of Selecron and neem seed extract in controlling diamondback moth in cabbage*

Treatment	Larvae or pupae counts/ leaf	Leaf damage (holes/leaf)	Head yield (kg)
Selecron (1.5ml/l)	1.88 b[1]	18.2 b	2.88 b
Neem (25g/l)	0.66 c	2.5 c	3.37 a
Neem (50g/l)	0.53 c	2.1 c	3.40 a
Water	2.90 a	29.2 a	2.06 c
LSD (5%)	0.62	1.8	0.23
F-test	**	**	**
CV (%)	42	14	8

Transplanted September 2001 at AVRDC-RCA
**Significant at $P \leq 0.01$
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Spacing and fertilizer requirements on leaf and seed yield of jute mallow

Jute mallow (*Corchorus olitorius)* is an important indigenous vegetable in many parts of Africa. The production of this crop is very low and is limited by low seed supply and lack of information on cultural practices. An experiment was conducted at AVRDC-RCA in Arusha, Tanzania from August to December 2001. The experiment was laid out in a 3 × 5 factorial RCBD with three replications. Treatments were urea fertilizer at rates of (0, 27.6, 41.4, 55.2, and 69.0 of N kg/ha) and spacing (20 × 60, 40 × 60 and 60 × 60 cm). Furrow irrigation and other cultural practices were carried out as necessary. Fertilizer was applied in two applications with half of the rate applied two weeks after sowing and another two weeks thereafter. Five harvests for leaf yield were carried out.

Spacing affected leaf and seed yields significantly, with the exception of seed yield per pod and percentage moisture content of leaves. Spacing of 60 × 60 cm gave higher yields in terms of total number of pods/plant, seed yield/plant, and leaf dry weight/plant (Table 158). The spacing of 20 × 60 cm performed well in all yield characteristics except in total number of pods/plant and seed yield/plant.

Fertilizer rates did not affect leaf yield significantly but showed significant increases in seed yields, leaf dry weight, and leaf moisture content. Fertilizer rate of 41.4 kg N/ha gave the highest seed yields and leaf yield per plant (Table 158).

The spacing of 20 x 60 cm is recommended for seed production and leaf yield of jute mallow. The crop responds to urea fertilizer application with the rate of 41.4 kg N/ha showing the best seed yields although the response can vary from location to location probably based on soil type. This preliminary study will be repeated next season for verification of results.

Production practices for spider flower plant

Spider flower plant (*Cleome gynandra*) is an important indigenous vegetable for many rural households in sub-Saharan Africa. In recent years, the production of this crop in Africa has decreased dramatically and soon the crop will be under threat of genetic erosion if conservation measures are not strengthened. An increase in the utilization of this vegetable could lead to the diversification of food crops in Africa and thus contribute to food security. However, the productivity of spider flower plant is still very low and information on agronomic and seed production requirements for the crop is scant. Since 1999, AVRDC-RCA has been involved in research aimed at conserving and increasing productivity of this vegetable.

An advanced evaluation trial was conducted at AVRDC-RCA in Arusha, Tanzania from July to December 2001 to assess the yield response and growth components of spider flower plant to nitrogen and

Table 158. *Determination of spacing effect and fertilizer requirements on leaf and seed yield of* Corchorus olitorius

Treatment	No. pods/ plant	Seed yield/pod (g)	Seed yield/plant (g)	Seed yield (kg/ha)	Leaf moisture content (%)	Leaf/ plant (g)	Leaf yield (t/ha)	Leaf dry weight/plant (g)	Leaf dry weight (t/ha)
Spacing (t/ha)									
20 × 60	73.1 b[1]	0.24	17.0 b	1419 a	68.7	39.5 a	2.9 a	10.3 a	0.87 a
40 × 60	92.1 a	0.26	25.2 ab	1051 b	74.3	39.3 a	1.9 b	11.8 b	0.49 b
60 × 60	96.7 a	0.33	31.3 a	869 b	70.7	30.5 b	1.4 c	16.3 a	0.46 b
F-test	**	NS	*	**	NS	*	***	**	***
LSD (5%)	12.4	0.09	9.3	345.6	6.2	7.5	0.47	4	0.16
CV (%)	19	22	31	32	12	28	30	28	25
Urea (kg N/ha)									
0	75.2 b	0.21 b	6.6 b	805 b	68.9 abc	32.9	1.8	11.4 bc	0.56 ab
27.6	94.9 a	0.23 ab	22.9 ab	1038 ab	77.5 a	33.4	2.1	9.4 c	0.47 b
41.4	90.5 ab	0.34 a	32.0 a	1455 a	70.6 abc	41.3	1.5	14.7 ab	0.65 ab
55.2	81.2 ab	0.34 a	27.4 ab	1198 ab	65.1 b	34.1	2.0	16.7 a	0.76 a
69.0	94.9 a	0.25 ab	23.6 ab	1068 ab	74.3 ab	40.4	2.3	11.9 bc	0.57 ab
F-test	*	*	*	*	*	NS	NS	*	*
LSD (5%)	15.9	0.11	12	446.1	6.2	9.7	0.6	4.6	0.2
CV (%)	19	22	31	32	12	28	30	28	25

Planted August 2001 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

spacing. The experiment was laid out in a 3 × 5 factorial RCBD with three replications. There were three in-row spacing treatments (25, 50 and 75 cm) with rows spaced 75 cm apart. Five nitrogen levels (0, 27.6, 41.4, 55.2 and 69.0 kg/ha) were evaluated with urea used as the nitrogen source. Seeds were sown in double rows in plot sizes measuring 6 × 0.9 m. The field was irrigated using furrow irrigation and weeded as necessary. Aphids were controlled with Selecron.

Reducing spacing from 75 to 25 cm significantly increased leaf yield, dry matter yield per ha, and seed yield per ha, but significantly reduced the dry matter yield and number of seeds per plant (Table 159). In general, a spacing of 25 cm gave the highest seed and leaf yields; this finding concurs with our previous studies in 1999 and 2000. The different rates of N did not affect yield responses, with the exception of higher N rates led to increases in the number of pods per plant. From this study and previous studies, we recommend that spider flower plant be grown at a spacing of 25 × 70 cm in double rows on raised beds.

Table 159. *Yield response of spider flower plant to spacing treatments*

Spacing (cm)	Leaf yield/plant (g)	Leaf yield (t/ha)	Dry matter yield/plant (g)	Dry matter yield (t/ha)	Pods/ plant	Seed weight/ plant (g)	Seed weight (kg/ha)	500-seed weight (g)	Seeds/ plant	Seeds/ pod
25 × 75	41	2.16 a[1]	5.55 b	0.29 a	189 ab	14.5 ab	774 a	0.69	10501 b	64.0
50 × 75	49	1.32 b	6.69 a	0.18 b	159 b	12.5 b	334 b	0.70	8995 b	84.6
75 × 75	44	0.78 b	6.25 ab	0.11 b	221 a	18.2 a	324 b	0.67	13649 a	61.7
F-test	NS	*	*	*	*	*	*	NS	**	NS
LSD (5%)	13	0.82	1.27	0.09	41.9	3.78	211	0.06	2059	47.8
CV (%)	12	26	9	19	10	11	19	4	8	30

Sown in in July 2001 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Seed production of vegetable soybean lines

Vegetable soybean (*Glycine max*) has potential in developing countries, especially in Africa, where it remains relatively unknown. It is currently being introduced in some countries in Eastern and Southern Africa. Vegetable soybean is a legume which can help diversify the cropping system, enhance soil productivity, improve farmer's income, and provide additional protein, vitamins and minerals to the diet, especially in home garden systems. However, different accessions are adapted to different seasons and localities, which necessitates the cultivation of an appropriate line at a specific location. Since 1997, AVRDC-RCA has been conducting evaluation trials to identify superior lines. Results from these previous performance tests identified lines AGS 339, AGS 329, AGS 338, and AGS 292 for good taste and high fresh pod yields ranging from 8.0 to 9.8 t/ha. These lines were selected for further evaluation, utilization and promotion.

A trial was conducted at AVRDC-RCA, Arusha, Tanzania from July to November 2001 to further evaluate these four promising lines for seed yield characteristics and fertilizer requirement. The experiments were laid out in a 4 × 5 factorial RCBD with three replications in beds measuring 6 × 1 m. The seeds were sown in six rows at a spacing of 15 cm between rows and 10 cm between plants. Inorganic fertilizer was applied at five levels: 0N–0P–0K, 20N–4.3–8.3K, 50N–10.8P–20.8K, 100N–21.5P–41.5K, and 150N–32.3P–62.3K kg/ha.

Among the four promising lines tested, AGS 338 gave the highest seed yield and number of pods per plant while AGS 339 showed the highest percentage of 2 and 3-seeded pods. AGS 229 had the lowest number of pods per plant, seed yields and percentage of 3-seeded pods (Table 160).

Fertilizer application did not influence seed yield but significantly increased the number of pods per plant, the percentage 1-seeded pods, and reduced the percentage of 3-seeded pods (Table 160).

The data shows that it may not be necessary to apply fertilizer to vegetable soybean for seed production. Line AGS 338 adapts well under Arusha conditions, reinforcing its positive performance of last year (AV*RDC Report 2001*).

Table 160. *Evaluation of promising vegetable soybean lines for fertilizer requirement and seed yield characteristics*

Entry	Pods/ plant	Seed yield (g/plant)	Seed yield (kg/ha)	1-seeded pod (%)	2-seeded pod (%)	3-seeded pod (%)
Lines						
AGS 229	10.5 c[1]	3.7 c	2507	39.9 a	43.7	17.8 c
AGS 329	12.3 bc	4.6 bc	2831	35.5 ab	43.1	25.2 ab
AGS 338	16.3 a	7.0 a	4179	36.1 ab	42.7	23.0 bc
AGS 339	13.0 b	5.3 b	3503	30.9 b	44.1	29.3 a
F-test	***	***	NS	*	NS	**
LSD (5%)	2.2	1.44	1135	6.0	3.7	5.4
CV (%)	23	28	27	23	12	31
Fertilizer (kg/ha)						
0N–0P–0K	11.0 b	5.8	3827	32.1 b	43.8	28.5 a
20N–4.3–8.3K	11.7 b	4.7	3140	34.4 ab	42.7	25.6 ab
50N–10.8P–20.8K	14.3 a	4.3	2604	32.4 b	46.7	23.9 ab
100N–21.5P–41.5K	13.2 ab	4.8	2905	40.4 a	41.7	20.4 b
150N–32.3P–62.3K	14.9 a	6.1	3798	38.9 ab	42.0	20.7 b
F-test	**	NS	NS	*	NS	*
LSD (5%)	2.4	1.7	1265	6.8	4.2	6.0
CV (%)	23	28	27	23	12	31

Sown in July 2001 at AVRDC-RCA

NS,*,**, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Onion performance trials for yield characteristics

Onion is a popular vegetable in the diets of rural and urban households in sub-Saharan Africa. There is a need to introduce improved cultivars that are adapted to different agro-ecological zones, especially in the African highlands.

Trials in 2000

A series of evaluations were conducted at AVRDC-RCA in Arusha, Tanzania to determine the yield characteristics and adaptation potential of commercial and AVRDC onion cultivars/lines, with commercial cultivars serving as checks. Fifty-four entries were sown on 18 May and transplanted on 22 August 2000. Since the number of treatments was large, the experiment was split in three trials for timely management to increase precision of data collection. All management operations and data collection were undertaken at the same time for the three trials. Each trial was laid out in a RCBD with three replications in plot sizes measuring 4 × 0.9 m; plants were spaced 15 × 10 cm apart. Fertilizer applications consisted of a sidedressing of 111.5N–4.3P–8.3K kg/ha two weeks after transplanting followed by a second sidedressing of 11.5N–0P–0K kg/ha two weeks later. Furrow irrigation was carried out twice a week and harvesting was done when 50% of the necks had fallen.

In Trial 1, harvesting was done on average 130 days after transplanting. Entries AC745, Granex 429 and AC571 gave the highest bulb yields, exceeding 187 t/ha (Table 161). Biological yield (bulbs and tops) varied between the entries but was highest in lines AC581, AC726-1, and AC745. Plant height at maturity varied from 49 to 71cm between lines; line AC47-1 recorded the least incidence of thrips damage. Line AC319ST-C showed a high bolting percentage of 64%, which indicates it has potential for seed production under Arusha conditions.

In Trial 2, cultivars matured earlier than AC lines. Cultivars Regia, Texas Grano 438, and Texas Grano 502-PRR exhibited the highest bulb yields, each exceeding 167 t/ha (Table 162). Regia, Ringer Grano (Improved), TA-377-VST-N, Serrana PVP, and Early

Table 161. *Characteristics of onion lines grown in Trial 1 at AVRDC-RCA in 2000*

Entry	Days to maturity	Bulb yield (t/ha)	Bulb weight (g)	Bulb shape	Bulb color	Neck thickness (mm)	Plant height (cm)	Bolting (%)	Thrips incidence (%)
AC47-1	134	102 ef[1]	150 ef	Deep flat	Red	5.7 ab	61.1 bc	44 b	25.6 e
AC119-C	134	93 f	140 f	Deep flat	Red	4.8 ab	59.4 c	1 f	52.4 a-d
AC199-C	134	107 ef	160 def	Deep flat	Red	5.3 ab	62.4 bc	0 f	41.6 b-e
AC319ST-C	–[2]	107 ef	160 def	–	–	5.7 ab	51.6 d	64 a	57.1 abc
AC461	140	100 ef	150 f	Deep flat	Red	5.5 ab	60.7 bc	0 f	50.0 a-e
AC566	140	137 cde	210 cde	Deep flat	Red	5.2 ab	49.7 d	26 cde	46.6 b-e
AC 566-1	134	160 bcd	240 bc	Deep flat	Red	5.8 ab	72.7 a	17 de	23.3 de
AC569	134	122 def	180 def	Deep flat	Red	6.5 a	55.3 cd	38 bc	32.6 cde
OC11HT-13R-A-C	134	100 f	150 f	Deep flat	Red	5.2 ab	48.8 d	30 cd	53.7 a-d
OC47-EHT-A-A-C	134	140 cde	210 cd	Oval	Red	5.9 ab	70.4 a	29 cd	48.6 a-e
006-10-C-C	134	160 bcd	240 bc	Globe	Yellow	6.3 ab	61.5 bc	8 b	52.2 a-d
AC571	116	187 ab	280 ab	Oval	Yellow	4.6 b	67.4 ab	0 f	60.5 ab
AC581	121	167 abc	240 abc	Oval	Yellow	4.9 ab	67.0 ab	0 f	49.3 a-e
AC 726-1	134	167 abc	250 abc	Oval	Yellow	5.8 ab	71.3 a	13 ef	41.7 b-e
AC745		200 a	300 a	Oval	Yellow	4.6 b	70.9 a	0 f	47.0 b-e
Granex 429	127	193 ab	290 ab	Globe	Yellow	4.0 b	69.7 a	0 f	72.1 a
Mean		140	200			5.4	62.5	19.3	47.7
F test		**	**			*	**	*	*
CV (%)		14.3	14.0			16.9	6.3	41.2	26.0

Transplanted 22 August 2000 at AVRDC-RCA
NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$
[2]– = no data.

Table 162. *Characteristics of onion cultivars grown in Trial 2 at AVRDC-RCA in 2000*

Entry	Days to maturity	Bulb yield (t/ha)	Bulb weight (g/bulb)	Bulb shape	Bulb color	Neck thickness (mm)	Plant height (cm)	Bolting (%)	Thrips incidence (%)
Agri Found Rose	60	44.4 f[1]	66 g	Flat	Red	9.0 a	57.6 a	0	4.6
Early Red/Moulin Rouge	57	68.9 ef	145 b-g	Flat/globe	Red	5.7 b-f	45.5 b	66	5.8
Red Bone	87	127.8 a-e	191 a-f	Rounded top	Red	5.0 c-f	62.7 a	0	5.8
Red Comet	88	103.8 b-f	155 a-g	Globe	Red	4.7 def	60.9 a	0	4.9
Red Kano	89	91.1 c-f	136 c-g	Globe	Red	5.4 b-f	61.6 a	0	6.3
Roxa-IPA-11	60	128.0 a-e	191 a-f	Globe	Red	7.9 ab	60.9 a	0	5.1
Composto-IPA-6	68	115.5 a-e	173 a-g	Globe	White	5.0 c-f	62.7 a	0	5.0
Primero	90	74.4 ef	111 e-g	Oval	White	5.7 b-f	57.6 a	0	5.2
Colossal	52	127.8 a-e	191 a-f	Oval	Yellow	4.3 ef	56.0 a	0	5.6
Contessa	90	130.0 a-e	193 a-f	–	Yellow	4.3 ef	59.5 a	0	5.6
Gladaun Brown	91	155.5 abc	171 a-g	Deep flat	Yellow	5.4 b-f	60.2 a	0	4.6
Houston PVP	89	155.5 abc	216 a-e	Flat/globe	Yellow	6.0 b-e	63.6 a	0	6.7
Mercedes	89	128.9 a-e	191 a-f	Deep flat	Yellow	4.6 def	63.7 a	0	6.0
Ori	89	61.1 ef	91 fg	Globe	Yellow	3.1 f	60.4 a	0	5.3
Pera IPA-4	70	103.8 b-f	156 a-g	Globe	Yellow	7.7 abc	59.5 a	0	6.0
Pyramid	89	113.3 a-e	170 a-g	Flat/globe	Yellow	4.2 ef	57.6 a	0	5.9
Regia	68	180.0 a	270 a	Flat/globe	Yellow	5.5 b-f	60.6 a	57	6.0
Ringer Grano (Improved)	88	144.4 a-d	195 a-f	–	Yellow	5.9 b-e	60.2 a	67	5.1
Serrana PVP	69	104.4 b-f	156 a-g	Flat/globe	Yellow	4.3 ef	58.1 a	67	7.0
TA-377-VST-N	102	106.7 b-f	160 a-g	Oval	Yellow	6.2 b-e	44.8 b	55	6.0
Texas Grano 438	87	178.9 a	280 ab	Flat/globe	Yellow	7.4 a-d	62.2 a	0	5.3
Texas Grano 502	68	167.8 ab	251 a-c	Flat	Yellow	5.9 b-e	61.2 a	0	5.2
Valeouro IPA-3	90	86.2 def	130 d-g	Rounded top	Yellow	6.8 a-e	64.3 a	0	5.2
LSD (5%)	-	57.4	9.8	-	-	2.3	9.2	40	1.4
F test	-	***	*	-	-	**	**	NS	NS
CV (%)	-	29.8	34.1	-	-	24.8	9.4	18	15.3

Transplanted 22 August 2000 at AVRDC-RCA
NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$
[2]– = no data.

Red/Moulin Rouge showed high bolting percentages of 55% or higher. Texas Grano 438, Valeouro-IPA-3 and Houston PVP registered good bulb uniformity while Agri-Found Rose, Roxa-IPA-11, Pera IPA-4 and Texas Grano-438 had the thickest bulb necks.

In Trial 3, cultivars matured on average 102 days after transplanting. The bulb yields were markedly lower compared to other cultivars in other trials except for cultivars XP6700 (H) and XP6712 which gave bulb yields of 127 and 157 t/ha, respectively (Table 163). Rox had the best bulb uniformity but had thin necks (Table 163).

In conclusion, these trials showed that entries AC745, Granex 429, AC571, Regia, and Texas Grano 438 show good promise for adaptation in tropical African highlands.

Trials in 2001

Twelve yellow and red onion lines were evaluated for yield and horticultural characteristics at AVRDC-RCA in Arusha, Tanzania from July to November 2001. The experiment was conducted in clay loam soil with a pH ranging from 6.0 to 6.5. Seeds were sown on raised beds on 12 June and seedlings transplanted on 25 July 2001. The experiment was laid out in a RCBD with three replications; in plot sizes measuring 1 × 4 m. Seedlings were planted at a spacing of 0.10 m × 0.15 m apart. Fertilizer was applied at the rate of 70.7N–10.8P–20.8K kg/ha two weeks after transplanting, followed by an application of 20.7N–0P–0K three weeks later. Water was applied twice weekly by furrow irrigation. Data were recorded and statistically analyzed using ANOVA.

Table 163. *Characteristics of onion cultivars grown in Trial 3 at AVRDC-RCA in 2000*

Entry	Days to maturity	Bulb yield (t/ha)	Bulb weight (g/bulb)	Bulb shape	Bulb color	Neck thickness (mm)	Plant height (cm)
Flare	106 b	55.2 bc	83 bc	Flat	Red	13.5 abc	58.1 b-e
Lucifer	100 bc	57.2 bc	85 bc	Flat	Red	13.4 abc	53.8 de
Orient	107 b	70.6 bc	106 bc	Flat	Red	15.9 a	60.6 bc
Red Bombay	102 bc	71.2 bc	106 bc	Flat	Red	14.0 ab	54.4 de
Red Creole	115 a	69.2 bc	103 bc	Flat	Red	14.0 abc	53.5 de
Rox	120 a	34.6 c	51 c	Globe	Red	9.0 d	53.1 e
Tropix	120 a	55.2 bc	48 c	Globe	Red	8.1 d	45.6 f
White Hawk	90 de	82.0 b	121 b	Globe	White	12.0 a-d	53.9 de
2512	92 de[1]	86.7 b	130 b	Globe	Yellow	13.1 abc	62.3 a
2516	97 cd	72.0 bc	108 bc	Globe	Yellow	8.5 d	53.6 de
Domingo	100 bc	75.2 bc	113 bc	Globe	Yellow	11.0 bcd	55.1 cde
E515	88e	130.0 a	195 a	Globe	Yellow	11.0 bcd	55.06 cde
XP6700	91 de	126.7 a	190 a	Globe	Yellow	11.4 bcd	59.5 bcd
XP6712	90 de	157.2 a	220 a	Globe	Yellow	10.4 cd	66.4 a
Mean	102	39.8	123			11.3	56.2
F test	***	***	***			**	***
LSD(5%)	6.51	38.2	56.0			3.5	5.34
CV (%)	3.8	28.7	29.0			17.4	5.69

Transplanted 22 August 2000 at AVRDC-RCA
NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Highly significant differences were observed in all the characters measured for all genotypes (Table 164). Granex 429 gave the highest bulb yield (116 t/ha) and bulb weight followed by Texas Grano 502 (98 t/ha) and AC 853 (D)-N (78 t/ha). Line OAA 089 (N18) showed more tolerance to thrips damage than the other varieties while Granex 429 had the largest equatorial bulb diameter (6.8 cm). Line AC 731(A)-N matured earliest at 84.7 days from transplanting (Table 164). Results from this data show that Granex 429 and Texas Grano are superior yellow varieties for Sub-Saharan Africa and local check variety Red Bombay performs very well among red types.

Productivity of garlic lines grown and propagated in open field conditions

Garlic crops face several constraints in Africa, including low yields, lack of resistance to pests and diseases, inadequate markets, and low consumption. The vegetable is propagated vegetatively and yield-reducing viruses are easily transmitted from generation to generation. AVRDC routinely eliminates viruses through meristem-tip culture and three years ago provided ten virus-free lines to AVRDC-RCA. These lines have been grown and propagated in the open field for three years. This year's trial evaluated the productivity of these lines along with check entry (Kenya 2) in the open field from June to November 2002. The experiment was laid out in RCBD with three replications. Cloves were planted on plot sizes 75 cm wide and 4 m long with a spacing of 10 × 15 cm. Furrow irrigation was applied weekly, and 101.4N–12.9P–24.9K kg/ha was applied six weeks after planting.

Results showed that line VFTA 325 produced bulb yields greater than 20 t/ha while VFG 180 gave the largest bulb weight, the thickest neck, and the tallest plant height at maturity (Table 165). VFG 173 gave the highest number of cloves/bulb while Kenya 2 gave the longest bulb length. VFG 176 showed the highest top setting percentage (24%). The yield results are within conformity of results previously reported (*AVRDC Report 2000 and 2001*) although variations in yield responses have been noted in all the lines tested.

Table 164. *Yield and horticultural characteristics of onion lines grown in 2001 at AVRDC-RCA*

Entry	Days to maturity	Bulb weight (g)	Bulb yield (t/ha)	Harvest index (%)	Equatorial bulb diam (cm)	Bulb uniformity[1] (± se)	Thrips severity score[2]	Bulb doubling (%)	Bulb color
AC 319-C	96.0 a[4]	91.0 cd	60.7 cd	67.0 cd	5.1 cd	0.08 bc	2.76 cd	11.1 b	Red
OAA 089 (N18)	96.0 a	68.7 d	45.8 d	65.0 d	4.8 d	0.09 abc	1.48 f	4.4 c	Red
TA 364-CST-C-N	96.0 a	94.0 cd	62.7 cd	68.2 cd	4.8 d	0.08 c	2.62 cd	15.6 a	Red
Red Bombay (ck)	96.0 a	99.0 cd	66.0 cd	72.7 bc	5.8 bc	0.10 ab	2.76 cd	11.1 b	Red
AC 450-U-A-N	90.0 b	94.2 cd	62.8 cd	71.3 b-d	4.9 cd	0.08 abc	3.24 ab	0.0 d	Yellow
AC 731(A)-C	84.7 g	112.8 bc	75.2 bc	80.9 a	5.5 bcd	0.09 abc	2.57 cd	0.0 d	Yellow
AC 853(D)-N	86.3 de	117.5 bc	78.3 bc	75.8 ab	5.1 cd	0.09 abc	3.38 ab	0.0 d	Yellow
AC 854(B)-C	85.7 ef	102.8 cd	68.6 cd	72.9 bc	5.2 cd	0.09 abc	3.29 ab	0.0 d	Yellow
TA 6 P-K-C	88.7 c	102.2 cd	68.1 cd	73.0 bc	5.1 cd	0.09 abc	3.67 a	0.0 d	Yellow
TA 377-C	85.0 fg	100.2 cd	66.8 cd	81.4 a	5.1 cd	0.10 a	2.43 de	0.0 d	Yellow
Granex 429 (ck)	88.7 c	173.5 a	115.7 a	81.5 a	6.8 a	0.09 abc	3.05 bc	0.0 d	Yellow
Texas Grano 502 (ck)	86.7 d	147.5 ab	98.3 ab	81.1 a	6.2 ab	0.09 a-c	2.10 e	0.0 d	Yellow
F-test	***	***	***	***	***	**	***	***	
LSD (5%)	0.86	36.2	24.1	–[4]	–	0.02	0.44	3.8	
CV (%)	0.56	19.7	19.7	4.7	8.5	10.49	9.32	63.2	

Transplanted 25 July 2001 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively

[1]Determined from the diameter of 10 randomly selected bulbs per replicate

[2]Measured as percent of leaf area damaged by thrips with 1 = 0%; 2 = 1–25%; 3 = 26–50%; 4 = 51–75%; 5 = 76–100%. Evaluation was done 98 days after transplanting

[3]DAT = Days after transplanting

[4]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Table 165. *Yield and horticultural characteristics of garlic accessions grown in open field*

Entry	Bulb yield (t/ha)	Bulb weight (g)	Neck thickness (mm)	Cloves/ bulb	Bulb length (mm)	Bulb diameter (mm)	Plant height (cm)	Top-setting (%)
G 50-1-1-2	14.0 b[1]	31.3 bc	9.28 a	10.5 de	39.9 abc	43.1	39.0 cd	6.4 b
G 98-6-1-1	8.0 de	14.7 e	6.84 bc	20.1 abc	26.9 e	37.4	39.1 cd	2.2 b
G 98-9	10.7 bcd	32.0 bc	9.40 a	7.3 e	40.5 abc	40.9	38.7 cd	2.2 b
VFG 34	5.1 e	22.7 cde	6.32 c	22.1 a	34.3 d	35.6	38.7 cd	1.1 b
VFG 173	9.3 cde	25.3 cde	8.74 ab	13.4 cde	35.9 cd	43.2	38.4 cd	0.0 b
VFG 176	7.6 de	15.3 de	6.40 c	21.0 ab	28.8 e	36.3	36.3 d	24.3 a
VFG 180	14.4 b	47.3 a	10.45 a	11.7 de	39.8 abc	38.7	56.7 a	18.9 a
VFTA 158	13.3 bc	27.3 bcd	8.64 ab	13.2 cde	38.3 bcd	42.1	41.9 c	0.3 b
VFTA 275	12.7 bc	27.3 bcd	9.38 a	8.3 de	38.2 bcd	40.4	35.8 d	0.3 b
VFTA 325	21.3 a	38.7 ab	9.17 a	15.1 bcd	41.6 ab	40.3	49.1 b	2.7 b
Kenya 2 (ck)	11.8 bcd	29.3 bc	8.53 ab	9.4 de	44.4 a	39.0	41.0 c	0.0 b
F-test	***	***	**	***	***	NS	***	***
CV (%)	20.5	23.3	8.48	27.3	7.1	12.5	5.4	75.6

Transplanted June 2002 at AVRDC-RCA

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001 respectively

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$

Training

Training courses

Vegetable production courses in Sudan

Three intensive in-country vegetable production courses were held in Shilluk Kingdom (Western Upper Nile), Yambio (Western Equitoria Province) and Nyal (Western Upper Nile) in southern Sudan on 19–26 April, 30 June to 6 July, and 18–25 September 2002, respectively. A total of 96 participants from self-help groups and NGOs attended the training courses. The courses were organized by AVRDC-RCA in collaboration with United Nations Children's Fund - Operation Lifeline Sudan (UNICEF-OLS). Following these training courses, publications and 850 kg of vegetable seeds were distributed to participants, local authority representatives and farmers. Seventy-five percent of the training participants rated the course as excellent and very useful.

Ninth Regional Vegetable Crops Production Training Course

The Ninth Regional Vegetable Production Training Course for sub-Saharan African countries was held from 7 July to 7 November 2002. Twenty participants (10 female, 10 male) from NARES in 12 countries, namely Angola (1), Botswana (1), Kenya (1), Lesotho (1), Malawi (1), Mauritius (1), Mozambique (1), South Africa (2), Swaziland (1), Tanzania (6), Zambia (2), and Zimbabwe (2), attended the course. An evaluation of the course by the participants showed they found the course useful and helpful for them to improve the quality of their duties upon returning to work.

Course on production, processing and utilization of vegetable crops

In collaboration with Commonwealth Regional Health Community Secretariat for East, Central and Southern Africa (CRHCS-ECSA), AVRDC-RCA organized a training course in production, processing and utilization of vegetable crops to prevent micronutrient malnutrition. The course was conducted from 1–17 May 2002. Twenty-three participants (17 from Tanzania and 6 from Mozambique) attended the course, which the participants rated useful for their work.

Courses for local farmers and rural women

Numerous regional training courses were conducted for farmers and rural women of Arusha, Tanzania. Four training courses on nursery management, four courses on IPM techniques, two courses on tomato processing, and two courses on indigenous vegetable utilization and preservation were conducted. Each course was held for two days and spaced out through the year. A total of 148 persons developed new skills on processing tomato, preserving indigenous vegetables for long term utilization, establishing seedling nurseries, and using IPM in vegetable production.

Vegetable production training in Zambia

An in-country training course, with emphasis on home gardening, was conducted in Monze, Zambia at the Zambian College of Agriculture from 18–23 November 2002. The course was organized in collaboration with UNICEF-Zambia. A total of 30 personnel from the Ministry of Agriculture and local NGOs attended the course. The participants learned how to combat malnutrition through the implementation of vegetable home garden programs in marginal areas of Zambia. The course was officially opened by the Minister of Agriculture of Zambia, the Honorable Mr. Mundia Sikatana, and the Deputy Country Representative of UNICEF-Zambia, Ms. Tomoko Nishimoto.

Farmers' field day at AVRDC-RCA

A Farmers' Field Day was conducted at AVRDC-RCA on 25 October 2002. The event featured technology demonstrations for applied vegetable production. One hundred and twenty farmers, scientists, and personnel from NARES and the private sector attended the field day. Demonstrations were followed by a question-and-answer session that addressed farmers' problems.

Workshops

Strategic planning workshop

A strategic planning workshop was held at AVRDC-RCA from 28 January to 2 February 2002 to define the future focus of AVRDC's work in Africa. A total of 29 stakeholders attended the workshop. The participants came from NARES in Tanzania, Kenya, Uganda, Ethiopia, Malawi, Swaziland, Senegal, Benin, and Niger, as well as from the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, German Development Service (Tanzania), Association for Strengthening Agricultural Research in Eastern and Central Africa (Uganda), International Plant Genetic Resource Center (Kenya), ICIPE (Kenya), Helen Keller International (USA), and AVRDC. The workshop identified priorities, outlined a logical framework for AVRDC's future strategy and program in Africa, and familiarized participants with the principles of logical framework planning.

Consumption of micronutrient-rich foods in eastern and southern Africa

In collaboration with United Nations Food and Agriculture Organization (FAO), AVRDC-RCA organized a workshop on "Increasing Consumption of Micronutrient-rich Foods Through Production and Promotion of Indigenous Foods" at AVRDC- RCA in Arusha, Tanzania on 5–8 March 2002. The objectives of the workshop were to discuss the effectiveness of indigenous vegetable crops in reducing micronutrient deficiencies and to develop a work plan for improving the nutritional status of vulnerable communities in Tanzania, Uganda, Swaziland, and South Africa through food-based approaches. Twenty-five participants attended the workshop, including representatives from NARES in South Africa, Swaziland, Tanzania and Uganda, and other representatives from CRHCS-ECSA and AVRDC. The Director General of AVRDC, Dr. Samson Tsou, opened the workshop.

Production, Processing and Utilization of Vegetable Crops

A participatory planning workshop on "Production, Processing and Utilization of Vegetable Crops" was held at AVRDC-RCA from 28–30 April 2002. The aim of the workshop was to promote the utilization of nutritive vegetables to arrest the deleterious impact of micronutrient malnutrition in Tanzania and Mozambique. The specific objective was to prioritize activities and collate views on the nutrition status of the target countries. Seven participants from Mozambique and 14 participants from Tanzania attended the workshop. The participants came from NARES, NGOs, and international development organizations. The workshop participants jointly developed a work plan for three years.

Organizational Statement

Our Mission

Reduce malnutrition and poverty among the poor through vegetable research and development

Our Strategy

Build partnerships and mobilize resources from private and public sectors to effectively tackle problems of vegetable production and consumption in the tropics. This strategy will contribute to:

- Increased productivity of the tropical vegetable sector
- Equity in economic development in favor of rural and urban poor
- Healthy and more diversified diets for low-income families
- Environmentally-friendly and safe production of vegetables
- Improved sustainability of cropping systems

Our Core Expertise

- Management of diverse vegetable germplasm
- Innovations in crop improvement, including the use of molecular tools
- Sustainable production of safe and nutritious vegetables in the tropics
- Networks of strategic alliances for generating and sharing knowledge
- Analysis of direct and indirect impacts of vegetables

Our Unique Role

AVRDC functions as a catalyst to:

- Build international and interdisciplinary coalitions that engage in timely issues
- Generate and disseminate international public goods that address economic and nutritional needs of the poor
- Collect, characterize, and safeguard genetic resources for worldwide use
- Provide globally accessible, user-friendly, science-based information

Board members

Mr. Declan J. Walton, Chairman
United Kingdom

Dr. Paul M.H. Sun, Vice-Chairman
Republic of China

Dr. Anna Ferro-Luzzi
Italy

Dr. Shan-Ney Huang[2]
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Mr. Ming-Lai Wang
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Dr. Samson C.S. Tsou (ex-officio)[1]
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[1] Left during 2002
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[1] Left during 2002
[2] Arrived during 2002
[3] Promoted in 2002

Trainees at Headquarters

All programs

Thi K. Tran, Visiting Scientist, Vietnam (02 October 2002–17 October 2002)
Kham Sanatem, Visiting Scientist, Lao PDR (02 October 2002–17 October 2002)
Leng Phat, Visiting Scientist, Cambodia (02 October 2002–17 October 2002)

Bulb Alliums Unit

Li-hang Lin, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)

Crop and Soil Management

Boumchamh Komboungnasith, Research Intern, Lao PDR (04 March 2002–27 February 2003)

Communication and Training Office

James J.S. Tsay, Special Purpose Trainee, Belize (19 July 2002–24 July 2002)
Chun-I Chen, Special Purpose Trainee, St. Christopher (05 August 2002–09 August 2002)
Octavio A. Menocal, Visitor, Nicaragua (08 November 2002–13 November 2002)
Syriphonh Phithaksoun, Research Intern, Lao PDR (10 November 2002–17 November 2002)
Yin Yin Mar, Research Intern, Myanmar (10 November 2002–17 November 2002)
Jean-Joshph Cadilhon, Graduate Student, France (17 November 2002–24 November 2002)
Thin B. Nguyen, Visitor, Vietnam (17 November 2002–26 November 2002)
Hoan T. Nguyen, Visitor, Vietnam (17 November 2002–26 November 2002)
Nguyen V. Le, Visitor, Vietnam (17 November 2002–26 November 2002)
Hoa G. Ton, Visitor, Vietnam (17 November 2002–26 November 2002)
Thuy X. Vu, Visitor, Vietnam (17 November 2002–26 November 2002)
Con V. Nguyen, Visitor, Vietnam (17 November 2002–26 November 2002)
Duong V. Nguyen, Visitor, Vietnam (17 November 2002–26 November 2002)
Khang V. Nguyen, Visitor, Vietnam (17 November 2002–26 November 2002)
Trung T. Diep, Visitor, Vietnam (17 November 2002–26 November 2002)
Thanh H. Huynh, Visitor, Vietnam (17 November 2002–26 November 2002)
Cui Q. Tran, Visitor, Vietnam (17 November 2002–26 November 2002)
Von La, Visitor, Vietnam (17 November 2002–26 November 2002)
Hoan T. Tran, Visitor, Vietnam (17 November 2002–26 November 2002)
Thien V. Chu, Visitor, Vietnam (17 November 2002–26 November 2002)
Thanh V. Luong, Visitor, Vietnam (17 November 2002–26 November 2002)

Entomology Unit

Huy Chung Nguyen, Research Intern, Vietnam (20 November 2001–19 November 2002)
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Wan-chun Liu, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Yu-po Chen, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
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Katherine R. Ramirez, Undergraduate Student Trainee, Philippines (04 April 2002–30 May 2002)

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Edward Ryan A. Collantes, Undergraduate Student Trainee, Philippines (04 April 2002–30 May 2002)
Jason Alessandro C. Manilay, Undergraduate Student Trainee, Philippines (04 April 2002–30 May 2002)
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Mary Chang, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
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Hsing-jen Sung, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Po-win Chen, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Chin-wei Lin, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Lavernee S. Gueco, Research Fellow, Philippines (01 September 2002–31 December 2002)
Yenni Kusandriani, Research Intern, Indonesia (01 September 2002–30 September 2002)
Surayadi, Research Intern, Indonesia (01 September 2002–30 September 2002)
Dedi Arif, Research Intern, Indonesia (01 September 2002–30 November 2002)
Tawatchai Charoenchaipaiboon, Research Intern, Thailand (06 October 2002–31 December 2002)
Rozina Afroz Chhanda, Research Fellow, Bangladesh (15 October 2002–31 December 2002)
Toan D. Vu, Research Intern, Vietnam (01 November 2002–31 December 2002)
Young Chae, Research Fellow, Korea (01 December 2002–31 March 2003)

Legume Unit

Chung-Kuen Lee, Research Intern, Korea (18 February 2002–18 July 2002)
Pauline Joy A. Pastor, Undergraduate Student Trainee, Philippines (14 April 2002–30 May 2002)
Zhi-hao Chiang, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Chuen-jiun Yang, Undergraduate Student Trainee, Taiwan (10 July 2002–30 August 2002)
Haque Moynul, Research Fellow, Bangladesh (02 August 2002–31 October 2002)
Joginder S. Brar, Research Fellow, India (02 August 2002–31 October 2002)
Gurdip Singh, Research Fellow, India (02 August 2002–31 October 2002)
Md. Ali Afzal, Research Fellow, Bangladesh (09 August 2002–07 October 2002)
Davinder K. Grover, Research Fellow, India (01 December 2002–28 February 2003)

Nutrition and Analytical Laboratory

Wen-shan Chang, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Hsiao-ting Huang, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Fen-yi Chen, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Ruey-long Chiou, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Kuan-ling Chen, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)

Pathology, Entomology, Crop and Soil Management, Tomato Breeding, Physiology

Thi Thuy Le, Research Intern, Vietnam (17 April 2002–30 May 2002)
Duy Hung Nguyen, Research Intern, Vietnam (17 April 2002–30 May 2002)
Sarith Mao, Research Intern, Cambodia (17 April 2002–30 May 2002)
Samnang Ngi, Research Intern, Cambodia (17 April 2002–30 May 2002)
Phanpradith Phandara, Research Intern, Lao PDR (17 April 2002–30 May 2002)
Keo Oudone Philangam, Research Intern, Lao PDR (17 April 2002–30 May 2002)

Pepper Breeding

Damtew Mamo Dubale, Research Intern, Ethiopia (01 October 2001–29 March 2002)

Plant Pathology: Bacteriology Unit

Katharine M. Inis, Undergraduate Student Trainee, Philippines (04 April 2002–30 May 2002)
Young-Kee Lee, Research Fellow, Korea (01 May 2002–31 July 2002)
Plant Pathology: Bacteriology Unit and Mycology Unit
Manolito A. Bayugan, Research Intern, Philippines (07 January 2002–16 February 2002)
Plant Breeding, Physiology, Mycology, Bacteriology & GRSU
Praveen Noojibail, Visitor, India (06 June 2002–07 June 2002)

Plant Pathology: Mycology Unit

Thi Thu Huong Le, Graduate Student, Germany (01 May 2001–15 November 2002)
Plant Mycology & Molecular Biology
Kamonsiri Petchaboon, Graduate Student, Thailand (01 October 2002–31 October 2002)

Plant Pathology

Leake Mesfin Kidane, Research Intern, Ethiopia (01 November 2001–30 April 2002)
Dagne Belay Anteneh, Research Intern, Ethiopia (01 November 2001–30 April 2002)
Nattaya Srisawad, Graduate Student, Thailand (01 October 2002–31 October 2002)

Plant Physiology

Ngoc Bao Chau Nguyen, Research Intern, Vietnam (14 January 2002–13 January 2003)
Julius Cesar G. Laban, Undergraduate Student Trainee, Philippines (04 April 2002–30 May 2002)
Noel T. Declines, Undergraduate Student Trainee, Philippines (04 April 2002–30 May 2002)
Po-lin Huang, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Yi-shan Wu, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Shang-zhi Chen, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Ming-hsun Lin, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Hsiao-ni Huang, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)

Socio-economics

Andrea Ilsabe Kuehn, Graduate Student, Germany (11 September 2002–20 February 2003)
Phuong Anh T. Mai, Research Intern, Vietnam (12 November 2002–21 December 2002)
Anh L. Hoang, Research Intern, Vietnam (12 November 2002–21 December 2002)

Technology and Promotion Services

Maria Leah D. Balba, Undergraduate Student Trainee, Philippines (14 April 2002–30 May 2002)
Salve Kristina T. Mogul, Undergraduate Student Trainee, Philippines (14 April 2002–30 May 2002)
Chun-liang Lai, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Tse-wui Lim, Undergraduate Student Trainee, Malaysia (01 July 2002–30 August 2002)
Hui-wen Chen, Undergraduate Student Trainee, Taiwan (06 July 2002–30 August 2002)
Chia-lien Wang, Undergraduate Student Trainee, Taiwan (06 July 2002–30 August 2002)

Tomato Breeding

Abera Tesfaye Yesuf, Research Intern, Ethiopia (01 October 2001–29 March 2002)
Dany Heang, Research Intern, Cambodia (03 January 2002–30 December 2002)
Chuan-chun Lin, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Hsin-I Lee, Undergraduate Student Trainee, Taiwan (01 July 2002–30 August 2002)
Chao-jung Kuan, Undergraduate Student Trainee, Taiwan (06 July 2002–30 August 2002)

Tomato and Pepper Breeding

Wing Yee Liu, Research Intern, HongKong (01 October 2002–30 January 2003)
Sonam, Research Intern, Bhutan (03 October 2002–29 January 2003)
Rinchen Sonam, Research Intern, Bhutan (03 October 2002–29 January 2003)

Staff publications

Abedullah and **M. Ali**. 2001. Wheat self-sufficiency in different policy scenarios and their likely impact on producers, consumers, and public exchequer. Pakistan Development Review 40(3):203–224.

Alam, S.N., F.M.A. Rouff, M.A. Rashid, A. Cork, and **N.S. Talekar**. 2002. Brinjal shoot and fruit borer control: easy, safe, economical and reliable method. Joydebpur, Gazipur, Bangladesh: Bangladesh Agricultural Research Institute. 16 pp. (in Bengali)

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Black, L.L. 2002. Fusarium wilt. In: Compendium of pepper diseases. K. Pernezny, P. Roberts, J. Murphy, and N. Goldberg (eds.). St. Paul, MN: APS Press. (accepted)

Black, L.L. 2002. Gray leaf spot. In: Compendium of pepper diseases. K. Pernezny, P. Roberts, J. Murphy, and N. Goldberg (eds.). St. Paul, MN: APS Press. (accepted)

Black, L.L. 2002. Gray mold. In: Compendium of pepper diseases. K. Pernezny, P. Roberts, J. Murphy, and N. Goldberg (eds.). St. Paul, MN: APS Press. (accepted)

Chunwongse, J., C. Chunwongse, **L.L. Black**, and **P. Hanson**. 2002. Molecular mapping of the ph-3 gene for late blight resistance in tomato. Journal of Horticulture Science & Biotechnology 77:281–286.

Chadha M.L. 2001. Mungbean (*Vigna radiata* L.), a choice crop for improvement of human and soil health in Southern Africa. Pp. 263-271. In: Pasternak, D. and A. Schlissel (eds). Combating desertification with plants. New York: Kluwer Academic/Plenum Publishers.

Chadha, M.L. 2002. Promoting *Moringa*—a multipurpose plant for household food security. Paper presented at the First Prota International Workshop on *Moringa*, 23–25 September 2002. Nairobi, Kenya.

Chadha, M.L., D. Dumar, S.N. Naidu, and **M.O. Oluoch**. 2001. National planning and priority setting workshop on vegetable research and development in Mauritius. Pp. 1–109 In: Proceedings of a workshop held at St-Pierre, Mauritius, 12–13 September 2001.

Chadha, M.L., **L.M. Engle**, and **M.O. Oluoch**. 2001. Vegetable germplasm conservation and management. Pp. 1–207. In: Proceedings of a training course held at AVRDC- Africa Regional Program, Arusha, Tanzania, 26 March to 1 April 2000.

Chadha, M.L., **R. Nono-Womdim**, and **M.O. Oluoch**. 2001. Vegetable research and development in West Africa. Pp 1–137. In: Proceedings of the workshop held at AVRDC-Africa Regional Program, Arusha, Tanzania, 5–6 February 2001.

Chadha M.L. and **M.O. Oluoch**. 2001. Adaptation and utilization of AVRDC vegetable soybean lines in Eastern and Southern Africa. Pp. 29–33. In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

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Chen, K.C., C.Y. Lin, M.C. Chung, C.C. Kuan, H.Y. Sung, **S.C.S. Tsou**, **C.G. Kuo**, and C.S. Chen. 2002. Cloning and characterization of a cDNA encoding an antimicrobial protein from mung bean seeds. Bot. Bull. Aced. Sin. 43:251–259.

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Cottorone, C., and **T. Kalb**. 2002. Vegetables are vital: Healthy diets, productive lives, strong economies. Shanhua: Asian Vegetable Research and Development Center.

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Deahl, K.L., L.R. Cooke, **L.L. Black**, **T.C. Wang**, F.M. Perez, B.C. Moravec, M. Quinn, and R.W. Jones. 2002. Population changes in *Phytophthora infestans* in Taiwan associated with the appearance of metalaxyl resistance. Pest Management Science 58: 951–958.

Deahl, K.L., L.R. Cooke, **L.L. Black**, **T.C. Wang**, and R. Jones. 2002. Displacement of the *Phytophthora infestans* population in Taiwan. Phytopathology 92(6S): 143.

Green, S.K., **W.S. Tsai**, **S.L. Shih**, and A. Rezaian. 2001. Molecular characterisation and phylogenetic relationships of tomato geminiviruses in Australasia. P. 37. In: Programme and Abstracts 3rd International Geminivirus Symposium, 24–28 July, John Innes Centre, Norwich, UK.

Green, S.K., **W.S. Tsai**, **S.L. Shih**, M.A. Rezaian, and U. Duangsong. 2002. Molecular characterization of a new Begomovirus associated with tomato yellow leaf curl and eggplant yellow mosaic diseases in Thailand. J. Plant Disease (accepted for publication).

Hamid, A., M. Moynul Haque, M.A. Afzal, and **S. Shanmugasundaram**. 2002. Registration of BU-Mug 1 mungbean. (submitted to Journal of Crop Science for publication).

Hanson, P., **J.T. Chen**, and **C.G. Kuo**. 2002. Gene action and heritability of high temperature fruit set in tomato line CL5915. HortScience 37:172–175.

Hamid, A., M. Moynul Haque, M.A. Afzal and **S. Shanmugasundaram**. 2002. Registration of BU-Mug 2 mungbean. (submitted to Journal of Crop Science)

Huang, C.C., W.K. Peng, and **N.S. Talekar**. 2002. Larval population changes in the bean pod borer, *Maruca vitrata* (Lepidoptera: Pyralidae) on *Sesbania cannabina* on AVRDC farm, Tainan, Taiwan. Formosan Entomologist 22:271–278. (in Chinese with summary in English)

Khalid, S., I. Ahmad, **S.L. Shih**, **W.S. Tsai**, J. Smith, and **S.K. Green**. 2001. Molecular characterization of tomato- and chili leaf curl begomoviruses from Pakistan. Plant Protection Bulletin, R.O.C. 43(4):247–248.

Ko, S.S., **W.N. Chang**, **J.F. Wang**, **S.J. Cherng**, and **S. Shanmugasundaram**. 2002. Storage variability among short-day onion cultivars under high temperature and high relative humidity, and its relationship with disease incidence and bulb characteristics. J. Amer. Soc. Hort. Sci. 127(5):848–854.

Ko, S.S, J.W. Huang, **J.F Wang**, **S. Shanmugasundaram**, and W.N. Chang. 2002. Evaluation of onion cultivars for resistance to *Aspergillus niger*, the causal agent of black mold. J. Amer. Soc. Hort. Sci. 127(4):697–702.

Kondo, K., M. Yamamoto, D.P. Matton, **T. Sato**, M. Hirai, S. Norioka, T. Hattori, and Y. Kowyama. 2002. Cultivated tomato has defects in both S-Rnase and HT genes required for stylar function of self-incompatibility. The Plant Journal 29(5): 627-636.

Kondo, K., M. Yamamoto, R. Itahashi, **T. Sato**, H. Egashira, T. Hattori, and Y. Kowyama. 2002. Insights into the evolution of self-compatibility in *Lycopersicon* from a study of stylar factors. The Plant Journal 30(2):143-153.

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Muniyappa, V., A.S. Padmaja, H.M. Venkatesh, A. Sharma, S. Chandrashekar, R.S. Kulkarni, **P. Hanson**, **J.T. Chen**, **S.K. Green**, and J. Colvin. 2002. Tomato leaf curl virus resistant tomato lines TLB111, TLB130, TLB182. HortScience 37:603-606.

Nono-Womdim, R., I.S. Swai, L.K. Mrosso, **M.L. Chadha**, and **R.T. Opeña**. 2002. Identification of root-knot nematode species occurring on tomatoes in Tanzania and resistant lines for their control. Plant Disease 86:127–130.

Opeña, R.T., **J.T. Chen**, **T. Kalb**, and **P. Hanson**. 2001. Hybrid seed production in tomato. International Cooperator's Guide. Shanhua: Asian Vegetable Research and Development Center.

Opeña, R.T., **J.T. Chen**, **T. Kalb**, and **P.M. Hanson**. 2001. Seed production of open-pollinated tomato lines. International Cooperators' Guide. Shanhua: Asian Vegetable Research and Development Center.

Palada, M., and **L.C. Chang**. 2002. Suggested cultural practices for *Basella*. International Cooperators' Guide. Shanhua, Taiwan: Asian Vegetable Research and Development Center.

Palada, M., and **L.C. Chang**. 2002. Suggested cultural practices for kangkong. International Cooperators' Guide. Shanhua, Taiwan: Asian Vegetable Research and Development Center.

Shanmugasundaram, S. 2002. Induced systemic resistance and systemic acquired resistance in vegetable crops. Paper presented in the Vegetable for Sustainable Food and Nutritional Security in the New Millennium 2002. International Conference on Vegetables, 11–14 November 2002. Bangalore, India.

Shanmugasundaram, S. 2002. Potential of vegetable soybean in rice-fallows in South Asia. Paper presented in the Vegetable for Sustainable Food and Nutritional Security in the New Millennium 2002. International Conference on Vegetables, 11–14 November 2002. Bangalore, India.

Shih, S. L., G. Singh, **W.S. Tsai**, **S.K. Green**, and **S. Shanmugasundaram**, 2002. Mungbean Yellow Mosaic Geminivirus detection on mungbean seeds. Plant Protection Bulletin, R.O.C. 44(4):361–362.

Shih, S.L., **W.S. Tsai**, **S.K. Green**, **P. Hanson**, G.B. Valand, and G. Kalloo. 2002. Molecular characterization of a new resistance-breaking tomato begomovirus from India. Plant Disease (accepted).

Shih, S.L., **W.S. Tsai**, **S.K. Green**, S. Khalid, I. Ahmad, A. Rezaian, and J. Smith. 2002. Molecular characterization of tomato and chili leaf curl begomoviruses from Pakistan. Plant Disease (accepted).

Talekar, N.S. 2002. Controlling eggplant fruit and shoot borer. Brochure. Shanhua, Taiwan: Asian Vegetable Research and Development Center.

Talekar, N.S. 2002. Controlling eggplant fruit and shoot borer: A simple, safe, cheap and reliable approach. International Cooperators' Guide. Shanhua, Taiwan: Asian Vegetable Research and Development Center.

Talekar, N.S. and **M.Y. Lin.** 2002. Training manual on survey of natural enemies and evaluation of parasitism of diamondback moth. Shanhua, Taiwan: Asian Vegetable Research and Development Center. 48 pp.

Tsai, W.S., **S.L. Shih**, and **S.K. Green**. 2001. Molecular characterization of a second distinct tomato leaf curl begomovirus in Taiwan. Plant Protection Bulletin, R.O.C. 43(4):247.

Tsai, W.S., **S.L. Shih**, and **S.K. Green**. 2002. Genetic Diversity of Ageratum yellow vein Taiwan virus and Infectivity on Tomato. Plant Protection Bulletin, R.O.C. 44(4):361.

Tsai, W.S., **S.L. Shih**, and **S.K. Green**. 2002. Genetic Diversity of Ageratum yellow vein Taiwan virus and Infectivity on tomato. Plant Protection Bulletin, R.O.C. Accepted for publication.

Walsh, J.A., R.L. Rusholme, S.L. Hughes, C.E. Jenner, J.M. Bambridge, D.J. Lydiate, and **S.K. Green**. 2002. Different classes of resistance to turnip mosaic virus in *Brassica rapa*. European Journal of Plant Pathology 108:15–20.

Wang, T.C., **L.L. Black**, S.W. Lin, **S.C. Shieh**, **P. Gniffke**, and **C.A. Liu**. 2002. Identification of anthracnose resistance and introgression of resistance into pepper (*Capsicum annuum*). Plant Pathol. Bull. 11:233–234 (Abstr.).

Wang, J.F. and **C.H. Lin**. 2002. Colonization capacity of *Ralstonia solanacearum* tomato strains different in aggressiveness on tomatoes and weeds. Proceeding of the 3rd International Bacterial Wilt Symposium (in press).

Weinberger, K. 2002. The impact of iron bioavailability-enhanced diets on health and nutrition of school children: Evidence from a mungbean feeding trial in Tamil Nadu, Contributed paper during the CIMMYT IMPACT Conference, 4–8 February 2002, San Jose, Costa Rica.

Weinberger, K. 2002. Women's participation: Is it the same thing under a different setting? Pp. 43–63. In: Leonhäuser, I.-U. (ed.). Women in context of international development and cooperation, Schriften zur internationalen Entwicklungs-und Umweltforschung, Vol. 3. Frankfurt: Peter Lang.

Weinberger, K., J. Khan, and B. Mazhar-ul-Haq. 2002. Consumption of iron-rich foods and productivity: On the indirect impact of pulses and vegetable research. Shanhua, Taiwan: Asian Vegetable Research and Development Center.

Yang, R.Y., **S.C.S. Tsou**, and T.C. Lee. 2002. Effect of cooking on in vitro iron bioavailability of various vegetables. Pp. 130–142. In: Lee, T.C. and C.T. Ho (eds.). Bioactive compounds in foods: effect of processing and storage. Washington D.C.: American Chemical Society.

Financial statements

AVRDC—THE WORLD VEGETABLE CENTER
STATEMENTS OF ASSETS, LIABILITIES AND NET ASSETS
(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	31 December	
	2002	2001
ASSETS		
CURRENT ASSETS		
Cash	$4,323,524	$2,480,549
Advances and other receivables	737,906	503,072
Prepaid expenses	358,935	312,297
Inventories	12,450	-
Total Current Assets	5,432,815	3,295,918
LONG-TERM INVESTMENT	534,099	1,721,566
PROPERTIES - NET	29,598	-
TOTAL ASSETS	$5,996,512	$5,017,484
LIABILITIES AND NET ASSETS		
CURRENT LIABILITIES		
Accrual expenses	$371, 118	$7,268
Receipts for custody	54,778	58,100
Total Current Liabilities	425,896	65,368
Reserves for employee benefits	1,031,345	1,028,181
Total Liabilities	1,457,241	1,093,549
NET ASSETS		
Unrestricted		
Core fund	385,828	412,169
Working capital fund	900,000	900,000
	1,285,828	1,312,169
Restricted		
Special projects fund	1,892,210	1,890,644
Appropriated fund	1,042,385	297,568
Self-sustaining operation fund	318,848	271,818
Restricted core fund	-	151,736
	3,253,443	2,611,766
Total Net Assets	4,539,271	3,923,935
TOTAL LIABILITIES AND NET ASSETS	**$5,996,512**	**$5,017,484**

Additonal notes are an integral part of the financial statements and available upon request
(T N Soong & Co report dated 17 March 2003)

AVRDC—THE WORLD VEGETABLE CENTER
CONTRIBUTIONS TO CORE FUND AND ADDITIONS TO SPECIAL PROJECTS FUND

(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	2002	2001
CORE COUNTRIBUTIONS, BY COUNTRY		
Republic of China	$3,746,089	$3,390,437
Japan	191,000	382,000
Federal Republic of Germany	179,995	336,406
Australia	105,300	98,495
Thailand	101,300	101,932
Republic of Korea	75,000	75,000
France	-	108,000
Philippines	-	34,686
Total contributions	4,398,684	4,526,956
SPECIAL PROJECTS FUND ADDITIONS, BY SPONSOR		
BMZ/GTZ/Germany	1,421,405	1,191,762
COA & NSC/ROC	1,277,877	1,186,031
Asian Development Bank	502,000	188,947
SDC/Swiss	460,000	67,105
DFID/UK	374,483	139,713
USAID	225,000	324,427
Japan	184,000	368,000
France	174,368	-
RDA/Korea	70,000	40,000
Australia	67,125	21,810
Japan-ASEAN	-	18,788
UNICEF	-	132,271
Others	88,539	705,730
Total additions	4,845,157	4,384,584

Additonal notes are an integral part of the financial statements and available upon request
(T N Soong & Co report dated 17 March 2003)

AVRDC—THE WORLD VEGETABLE CENTER
STATEMENTS OF CHANGES IN CORE FUND AND SPECIAL PROJECTS FUND
(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	Year Ended December 31			
	Core Fund		Special Projects Fund	
	2002	2001	2002	2001
REVENUES				
Contributions	$4,398,684	$4,526,956	$4,845,157	$4,384,584
Other revenues and support	1,224,183	1,474,396	-	-
Translation adjustment	-	(166,068)	-	-
Total Revenues	5,622,867	5,835,284	4,845,157	4,384,584
EXPENDITURES				
Operating expenses				
Personnel	4,885,047	5,014,932	1,817,304	1,746,970
Operating costs	563,292	564,646	2,978,741	1,734,764
Travel	32,012	62,711	170,842	177,267
Total operating expenses	5,480,351	5,642,289	4,966,887	3,659,001
Loss on disposal of investment	163,913	-	-	-
Loss for decline value on long-term investments	4,944	328,825	-	-
Capital expenditures	-	62,435	-	-
Total Expenditures	5,649,208	6,033,549	4,966,887	3,659,001
NET INCREASE (DECREASE) IN FUND	(26,341)	(198,265)	(121,730)	725,583
FUND BALANCE BEGINNING OF YEAR				
As previously reported	412,169	666,711	1,890,644	1,166,507
Translation adjustment	-	(56,277)	123,296	(1,446)
As restated	412,169	610,434	2,013,940	1,165,061
FUND BALANCE, END OF YEAR	$385,828	412,169	$1,892,210	$1,890,644

Additonal notes are an integral part of the financial statements and available upon request.
(T N Soong & Co report dated 17 March 2003)

Meteorological information

Meteorological data (monthly mean) collected at the AVRDC weather station, 2002.

	Daily avg humidity (%)	Daily air temp. max (ºC)	Daily air temp. min (ºC)	Daily soil temperature 10 cm max (ºC)	Daily soil temperature 10 cm min (ºC)	Daily soil temperature 30 cm max (ºC)	Daily soil temperature 30 cm min (ºC)	Daily avg wind velocity (m/s)	Daily avg solar radiation (W-hour/m^2)	Monthly precipitation (mm)	Daily avg evaporation (mm)
January	74	24.2	12.8	23.6	17.7	21.6	20.0	2.08	3482	22	3.3
February	77	25.0	14.5	25.6	19.8	22.9	21.2	1.33	4348	0	3.6
March	79	28.0	18.7	29.2	23.5	26.2	24.6	1.54	4231	2	4.4
April	79	30.8	21.5	33.5	27.0	29.8	28.0	2.28	4977	0	5.7
May	81	31.8	23.7	33.8	28.3	31.1	29.5	2.06	4718	194	6.1
June	80	33.3	25.6	33.2	28.9	31.2	29.6	2.01	5432	65	6.5
July	83	33.0	25.9	31.6	28.3	30.9	29.3	2.78	4668	579	6.1
August	79	34.1	26.0	32.3	28.9	30.3	29.4	1.91	5448	171	5.5
September	79	33.2	24.9	31.6	27.6	29.9	28.7	2.20	4518	84	4.9
October	78	32.2	22.9	31.1	27.0	29.1	28.0	1.85	4236	0	4.7
November	75	29.0	19.0	28.4	23.9	26.7	25.5	2.30	3662	0	4.1
December	82	26.0	16.4	25.3	21.3	24.3	22.9	2.20	2999	75	3.1