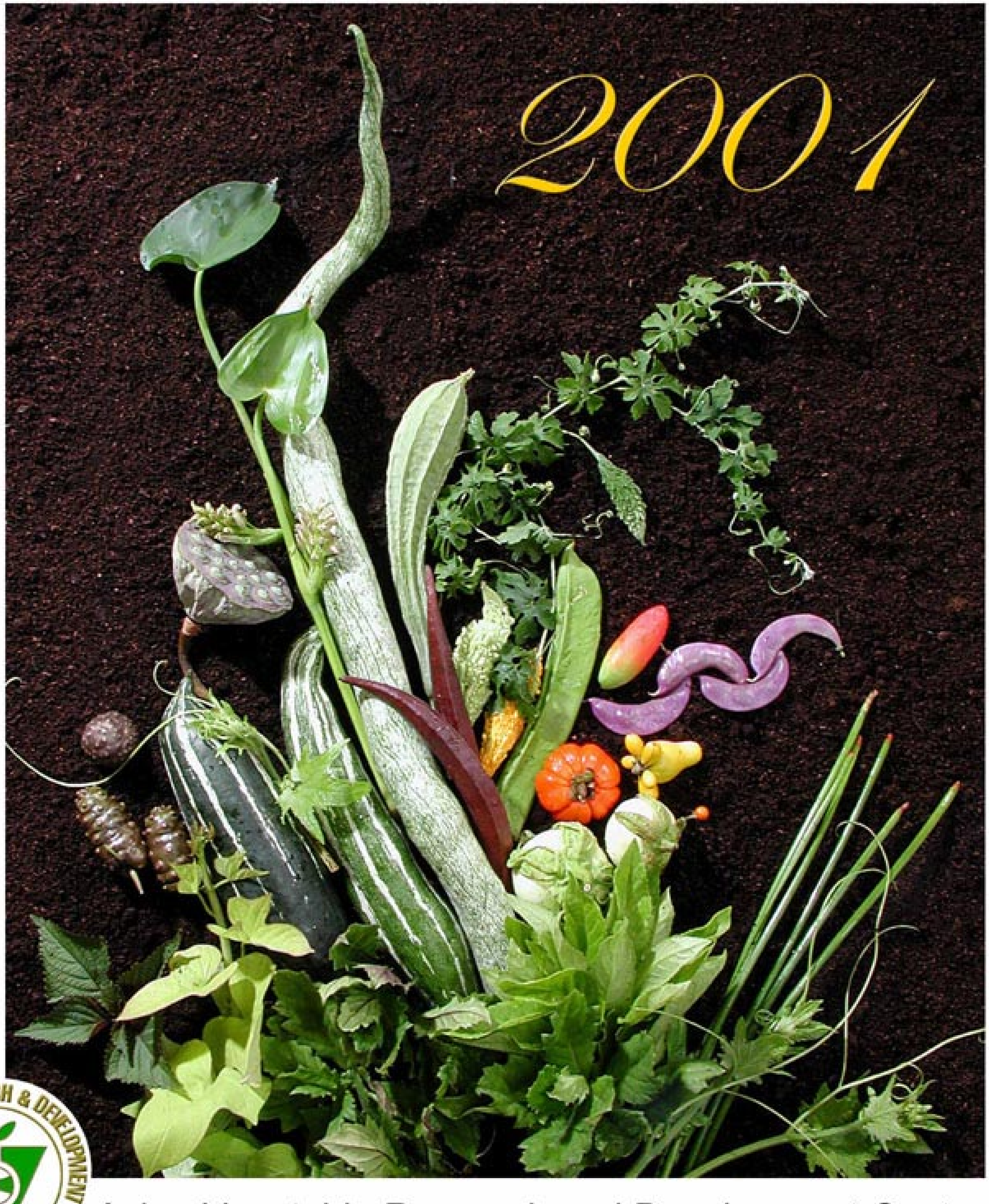
AVRDC Report



Asian Vegetable Research and Development Center

AVRDC Report 2001

Asian Vegetable Research and Development Center

Asian Vegetable Research and Development Center (AVRDC)
PO Box 42, Shanhua, Tainan, Taiwan 741, ROC
Tel: +886 6 583 7801
Fax: +886 6 5830009
Email:avrdcbox@netra.avrdc.org.tw
www.avrdc.org.tw

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Editors: Thomas Kalb and George Kuo
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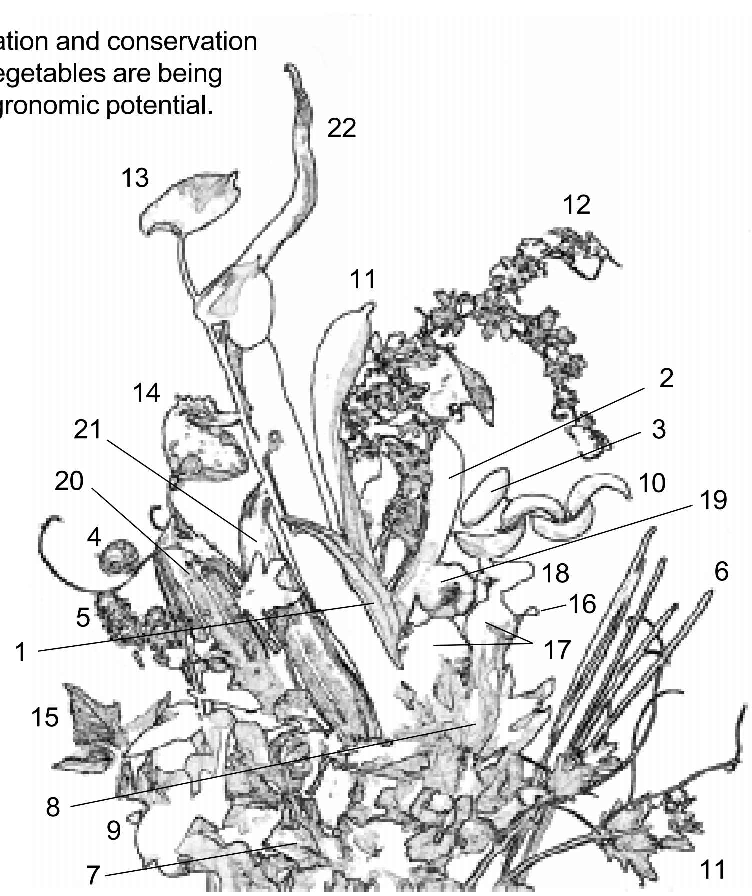
About the cover:
AVRDC is a world leader in the collection, evaluation and conservation of indigenous vegetables. These underutilized vegetables are being investigated for their nutritional properties and agronomic potential. Shown in this photo are:

1. *Abelmoschus esculentus* (okra)
2. *Canavalia gladiata* (sword bean)
3. *Coccinia grandis* (ivy gourd)
4. *Dioscorea bulbifera* (air potato)
5. *Dioscorea* sp. (yam species)
6. *Eleocharis dulcis* (Chinese water chestnut)
7. *Gynura bicolor* (purple gynura)
8. *Gynura oralis* (white gynura)
9. *Ipomoea batatas* (sweet potato leaf)
10. *Lablab purpureus* (lablab bean)
11. *Luffa acutangula* (angled luffa)
12. *Momordica charantia* (bitter gourd)
13. *Monochoria vaginalis* (duck's tongue grass)
14. *Nelumbo nucifera* (lotus)
15. *Perilla frutescens* (perilla)
16. *Solanum indicum* (Indian nightshade)
17. *Solanum macrocarpon* (African eggplant)
18. *Solanum mammosum* (five-finger eggplant)
19. *Solanum* sp. (eggplant species)
20. *Trichosanthes anguina* (snake gourd)
21. *Trichosanthes cucumerina* (snake gourd)
22. *Trichosanthes* sp. (snake gourd)



Contents

Foreword

It was an exciting year in international vegetable research. Modern advances in life science and information technologies have demonstrated their potential in opening new vistas in science and development. As the leading international center for vegetable research in the world, AVRDC is pleased to be a part of it.

During the past year, our scientists have made significant strides in many areas of scientific endeavor, including germplasm collection and utilization, crop improvement, sustainable production technologies, and human capacity building.

For example in tomato, AVRDC has developed lines resistant to leaf curl viruses, often cited as the #1 problem of tomato production in the tropics. AVRDC and its partners used a series of molecular-based tools to efficiently develop resistant varieties from wild tomato germplasm. Molecular tools also assist scientists to better understand the distribution of pathogens and identify genetic sources of resistance to these pathogens. The rewards of these efforts have been significant. After only a few years, new virus resistant lines are now being released in India. AVRDC and our partners will further employ marker-assisted vegetable breeding in the future.

In today's knowledge-based agriculture, access and utilization of quality, research-based information is vital for the empowerment of farmers. Revolutionary changes in information dissemination systems of vegetable production and marketing are underway in the developing world. AVRDC is responding to this challenge with dynamic innovations in its information technologies, in reorganizing its research findings to better serve agricultural communities, and in establishing an on-line learning school. Our partners are able to access quality information and utilize it through the use of modern technology. AVRDC is developing expert systems that help extension specialists, and ultimately farmers in developing countries, to manage diseases and pests, select improved plant materials, manufacture quality compost, and learn about indigenous vegetables.

Indigenous vegetables are, indeed, a new strategic program direction of AVRDC. The Center, in collaboration with partners, is actively collecting, evaluating, and conserving these treasures of nature. Several promising materials are now purified and seeds are becoming available for further testing. Our emphasis is on utilizing these materials for raising incomes and improving diets of families in the developing world.

Taking families as our focus, AVRDC is seeking to understand the impact of our technologies on rural and urban families. Socio-economic studies are now an integral part of all research programs. This increased understanding will lead to the development of technologies that will have the greatest impact in the future.

In 2001, we were excited to document that there were high annual growth rates of vegetable production and increased per capita availability of vegetables in Asia during the last 20 years. These data strongly indicate that the joint efforts of AVRDC and its partners are successfully progressing toward our goal—increased production and consumption of vegetables, thereby providing better health and more income for people in developing countries.

Research outputs included in this report are part of a team effort in the fullest sense, including AVRDC staff at regional programs in Africa and Asia, scientists outposted in partner countries, numerous collaborating agencies, and private companies worldwide. Information in this report will further enrich the knowledge base on vegetables in the tropics and make additional positive impact on the welfare of the poor in the developing world.

AVRDC's collaborators are countless, and we always believe partnership is the key to making impacts. AVRDC looks forward to working with its partners in improving the lives of families in the developing world.

Samson C.S. Tsou
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Director General, AVRDC

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[a] Left during 2001
[b] Assumed office during 2001

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. Off-season tomato, pepper, and eggplant

Project 1 encompasses 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 effective and economical management practices, must be developed to overcome these constraints and extend tomato production into the hot-wet season. Management of bacterial wilt (BW) of tomato has received considerable attention at AVRDC because of the importance of this disease in the hot-wet season. In hot-dry environments, production of tomato is limited by tomato leaf curl virus (ToLCV) and production of sweet pepper is constrained by high temperatures.

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

Project Coordinator: P Hanson

Fresh market tomato lines for the tropics

Fresh market tomato cultivars in the tropics must have the ability to set fruit under high temperatures, resist multiple diseases, and have good fruit quality. AVRDC conducted one advanced yield trial (AYT) and two preliminary yield trials (PYT) during 2001 to identify promising determinate and indeterminate lines. The AYT and PYT1 were sown 15 Feb., transplanted 15 Mar. and harvested from 30 May to 11 June 2001. PYT2 was sown 14 Sept., transplanted 16 Oct. 2001 and harvested 29 Jan. to 26 Feb. 2002. AYT plots were two 1.5-m-wide beds with two 4.8-m-long rows per bed; plants were staked and pruned. PYT1 plots included two 1.5-m-wide beds with two 4.8-m-long rows per bed; plants were staked and pruned. PYT2 plots were two 1.5-m-wide beds with one 4.8- m-long rows per bed; plants were not staked or pruned. A randomized complete block design was used in all trials; entries were replicated three times in the AYT and twice in PYT1 and PYT2.

PYT1 entries CLN2418A and CLN2418B produced yields statistically equivalent to the highest yielding hybrid check (Table 1). Fruit sizes of entries were above 80 g and most exceeded 100 g, an improvement over the normally small-fruited tropical tomato. Most entries showed excellent bacterial wilt resistance and were clearly superior in this respect to the hybrid checks. Of this group, CLN2418A and CLN2418B have been included in the set of determinate lines for international distribution and CLN2413D will be included in the indeterminate set.

The trial mean for yields of the AYT was slightly less than PYT1 but fruit size and bacterial wilt resistance of most entries were excellent (Table 2). From this trial, entry CLN2413L will be included in the determinate set for international distribution and CLN2413J will be included in the indeterminate set.

PYT2 entries were selected for resistance to both ToLCV and BW. Marketable yields (Table 3) were high because the trial was conducted in the cool-dry season. Entries CLN2443DC$_2$B-7-23-2-25-6-17 (re-coded CLN2443A), CLN2443DC$_2$B-7-23-2-7-5-16 (re-coded CLN2443B), and CLN2443DC$_2$B-7-23-2-18-1-19 (re-coded CLN24443C) will be re-tested in Spring 2002 under high ToLCV disease pressure. Limited seed quantities of the three lines are available for international distribution.

Table 1. *Yield and horticultural characteristics of fresh market tomato inbred lines in preliminary yield trial 1 at AVRDC, transplanted 15 Mar. 2001.*

Entry	Plant habit[1]	Marketable yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to maturity	Solids (°Brix)	Acid[2] (%)	Color[3] (a/b)	BW survival[4] (%)
CLN2413A	ID	32	35	133	77	4.60	0.30	1.78	73
CLN2413B	D	33	37	131	77	4.37	0.29	1.43	75
CLN2418A	D	49	33	95	77	4.07	0.29	1.46	81
CLN2418B	D	48	35	86	77	4.27	0.28	1.61	80
CLN2418C	D	39	27	125	79	3.77	0.22	1.01	92
CLN2418D	SD	41	30	127	78	4.03	0.25	1.49	67
CLN2413C	ID	45	23	125	78	4.27	0.20	1.22	97
CLN2413D	ID	39	21	148	80	4.53	0.34	1.34	96
CLN2418E	ID	36	25	138	80	4.70	0.33	1.44	90
Taichung ASVEG #4 (ck)	ID	55	22	168	78	4.80	0.35	1.54	29
Taichung ASVEG #10 (ck)	ID	46	24	166	78	4.83	0.36	1.25	33
Known-You 301 (ck)	ID	17	16	125	78	5.37	0.33	1.88	0
Mean		40	27	131	78	4.47	0.30	1.4	57
CV (%)		13.2	26.5	7.8	1.2	6.4	10.5	12.1	36
LSD (0.05)		9	12	17	2	0.49	0.05	0.29	4

[1]ID = indeterminate, D = determinate, SD = semideterminate.
[2]Equivalent of citric acid.
[3]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.
[4]Percentage of healthy plants after drench inoculation with the bacterial wilt (BW) pathogen in a separate greenhouse trial.

Table 2. *Yield and horticultural characteristics of fresh market tomato inbred lines and checks in an advanced yield trial at AVRDC, transplanted 15 Mar. 2001.*

Entry	Plant habit[1]	Marketable yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to maturity	Solids (°Brix)	Acid[2] (%)	Color[3] (a/b)	BW survival[4] (%)
CLN2413I	ID	20	17	113	79	4.95	0.33	1.59	100.0
CLN2418C	ID	30	22	112	78	3.60	0.22	1.12	92.2
CLN2424B	ID	44	29	98	77	4.70	0.34	1.80	75.8
CLN2413J	ID	40	24	142	79	4.40	0.28	1.04	97.5
CLN2413T	ID	34	26	147	80	4.70	0.37	1.09	90.0
CLN2413K	ID	34	33	115	79	4.90	0.30	1.00	96.2
CLN2413L	D	36	27	120	79	4.40	0.27	1.20	92.0
CLN2413M	ID	20	22	124	79	5.15	0.36	1.66	91.3
Taichung ASVEG #4 (ck)	ID	42	22	145	77	4.75	0.34	1.42	29.0
Taoyuan ASVEG #9 (ck)	ID	45	21	152	77	4.85	0.35	1.25	38.0
Taichung ASVEG #10 (ck)	ID	52	74	152	79	4.85	0.34	1.36	33.0
Known-You 301 (ck)	ID	13	7	129	80	5.20	0.34	1.36	0.0
Mean		34	22	129	79	4.70	0.32	1.32	43.0
CV (%)		17	25	12.2	1.5	8.7	12.1	18.9	36.0
LSD (0.05)		12	12	35	3	0.9	0.08	0.55	4.0

[1]ID = indeterminate, D = determinate, SD = semideterminate.
[2]Equivalent of citric acid.
[3]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.
[4]Percentage of healthy plants after drench inoculation with the bacterial wilt (BW) pathogen in a separate greenhouse trial.

Table 3. *Yield and horticultural characteristics of determinate tomato leaf curl virus and bacterial wilt resistant F_8 lines in preliminary yield trial 2 at AVRDC, transplanted 16 Oct. 2001.*

Entry	Marketable yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to maturity	pH	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	BW survival[3] (%)	Disease resistance[4]
CLN2443DC$_2$B-7-23-2-7-3-14	74	53	75	73	4.36	3.60	0.34	1.89	67	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-25-6-17	98	55	80	74	4.32	4.00	0.31	1.75	84	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-7-5-1	107	53	77	74	4.36	3.95	0.29	1.94	72	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-7-5-10	101	56	72	74	4.35	3.85	0.31	1.97	72	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-7-5-16	100	58	75	74	4.46	3.65	0.29	1.94	85	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-7-5-23	116	56	75	75	4.36	3.95	0.32	1.99	74	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-18-1-13	118	56	75	73	4.37	3.65	0.30	1.87	74	ToMV, F-1, GLS
CLN2443DC$_2$B-7-23-2-18-1-19	103	53	76	73	4.41	3.80	0.34	1.99	75	ToMV, F-1, GLS
CLN2123F (ck)	90	53	60	76	4.29	3.55	0.29	1.92	–[5]	
PT4723 (ck)	76	51	77	77	4.25	4.25	0.34	2.01	–	
CLN2026D (ck)	79	40	80	75	4.43	3.70	0.31	1.98	–	
Mean of all entries	96	53	75	74	4.36	3.80	0.31	1.93		
CV (%)	8.5	12.3	6.8	2.1	1.39	4.99	5.19	4.47		
LSD (0.05)	18.2	14.5	11	3	0.13	0.42	0.03	0.19		

[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 0. 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 (BW) pathogen in a separate greenhouse trial.
[4]ToMV = tomato mosaic virus; F-1 = resistance to fusarium wilt race 1; GLS = gray leaf spot.
[5]Not tested.

Processing tomato lines and hybrids for the tropics

Processing tomato cultivars are suitable for use in making processed tomato products such as paste or ketchup, or for sale in the fresh market. However, BW is a major tomato problem in the tropics and few processing cultivars are tolerant to the disease. Two preliminary yield trials (PYT) were conducted at AVRDC during the cool-dry season to identify superior entries for international distribution. The PYT1 included BW-resistant inbred lines and PYT2 included hybrids designed for resistance to ToLCV and BW. Both PYTs were sown 14 Sept. 2001 and transplanted on 16 Oct. 2001. Trial plots were two 1.5-m-wide beds with one 4.8-m-long row per bed. Plants were not staked or pruned. Entries were replicated twice and plots were arranged in a randomized complete block design. Harvest took place between 29 Jan. and 26 Feb. 2002.

Favorable growing conditions led to very high marketable yields in PYT1, ranging from 70–131 t/ha, but low solids content (Table 4). This is not surprising because yield and soluble solids are negatively correlated. Color values were generally mediocre in PYT1. Based on yield, internal color, absence of cracking, firmness, and disease resistance, entries CLN2396-94-16-11-23-1-4 (CLN2396B), CLN2396-94-16-11-23-1-21 (CLN2396C), CLN2396-94-16-11-23-24-13 (CLN2396D), CLN2400-24-21-9-10-14-20 (CLN2400A), and CLN2400-24-21-9-10-14-23 (CLN2400B) will be made available for international distribution.

Hybrids producing high marketable yields were found in PYT2, notably PT4755, but also PT4767 and PT4733 (Table 5). Most entries produced excellent internal color and low solids contents. All hybrids in PYT2 were crosses between a ToLCV-resistant processing parent and a susceptible parent with good processing fruit characteristics. All hybrids demonstrated complete resistance to ToLCV, indicating dominant gene action. From this group, the best five hybrids will be further evaluated in the May–July season under higher ToLCV pressure and temperatures.

Table 4. *Yield and horticultural characteristics of bacterial wilt-resistant processing lines in preliminary yield trial 1 at AVRDC, transplanted 16 Oct. 2001.*

Entry	Marketable yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to maturity	pH	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	BW survival[3] (%)	Disease resistance[4]
CLN2396-94-16-11-1-6-1	101	45	70.7	78	4.32	3.75	0.31	1.82	84	ToMV, F-1, F-2
CLN2396-94-16-11-1-8-8	78	45	80.8	79	4.34	3.80	0.32	1.82	79	ToMV, F-1, F-2
CLN2396-94-16-11-23-1-4	106	48	75.4	77	4.41	3.90	0.29	1.68	79	ToMV, F-1, F-2
CLN2396-94-16-11-23-1-11	94	41	77.7	76	4.39	4.05	0.31	1.90	79	ToMV, F-1, F-2
CLN2396-94-16-11-23-1-21	106	49	76.3	78	4.47	3.80	0.32	1.72	79	ToMV, F-1, F-2
CLN2396-94-16-11-23-8-9	99	45	79.9	78	4.33	3.95	0.31	2.01	75	ToMV, F-1, F-2
CLN2396-94-16-11-23-24-13	88	51	75.8	77	4.75	4.00	0.31	1.84	100	ToMV, F-1, F-2
CLN2399-14-16-8-10-1-4	79	58	87.3	84	4.37	3.75	0.32	1.83	70	ToMV, F-1
CLN2399-14-16-8-10-7-4	93	63	70.8	85	4.34	3.80	0.30	1.87	63	ToMV, F-1
CLN2400-24-21-9-10-14-1	115	45	80.4	79	4.28	3.75	0.34	1.94	70	ToMV, F-1, F-2, GLS
CLN2400-24-21-9-10-14-20	110	58	70.8	79	4.41	3.90	0.34	1.74	70	ToMV, F-1, F-2, GLS
CLN2400-24-21-9-10-14-23	110	51	67.7	78	4.41	3.70	0.34	1.89	70	ToMV, F-1, F-2, GLS
CLN2400-24-21-9-10-23-15	118	51	72.3	79	4.32	3.70	0.34	1.83	66	ToMV, F-1, F-2
CLN2400-45-18-12-24-1-13	131	33	75.8	78	4.49	3.80	0.26	1.92	75	ToMV, F-1, F-2, GLS
CLN2400-45-18-12-24-23-11	119	39	66.8	77	4.45	3.80	0.28	1.94	50	ToMV, F-1, F-2, GLS
H9497 (ck)	74	47	65.7	81	4.37	4.75	0.42	1.72	–[5]	
UC204A (ck)	70	44	76.9	82	4.38	3.55	0.31	1.98	–	
CLN2123A (ck)	105	53	59.5	75	4.52	3.55	0.27	1.99	–	
Mean of all entries	100	48	73.9	79	4.39	3.85	0.32	1.86		
CV (%)	12.7	14.8	8.4	1.8	1.12	6.9	7.9	3.4		
LSD (0.05)	26.6	15.0	13.1	3	0.10	0.56	0.05	0.13		

[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.
[4]ToMV = tomato mosaic virus; F-1 and F-2 = fusarium wilt races 1 and 2, respectively; GLS = gray leaf spot.
[5]NT = not tested.

Tomato leaf curl virus-resistant tomato lines TLB111, TLB130, and TLB182

Tomato leaf curl viruses (ToLCV) are caused by a number of different geminiviruses vectored by the whitefly, *Bemisia tabaci*. These viruses are spreading worldwide and constitute a major constraint to tomato production. In a recent survey of 174 tomato farmers in Karnataka State of India, 89% stated that the disease was a serious problem, particularly in the hot season. Infection in early stages of crop growth results in the highest yield losses. Infection of a susceptible variety with the virus two weeks after transplanting can result in a 95% yield loss. Tomato plants infected with the south Indian strains of ToLCV exhibit a range of symptoms including leaf curling, vein clearing, stunting of vines, and partial or complete sterility.

Three lines of fresh market tomatoes resistant to south Indian and Taiwan geminiviruses and tolerant to bacterial wilt were developed for tropical and subtropical farmers. This was achieved through a cooperative project between the University of Agricultural Sciences at Bangalore (UASB), India; the Asian Vegetable Research and Development Center (AVRDC), Taiwan; and the Natural Resources Institute (NRI) in the United Kingdom.

The AVRDC Tomato Unit initiated crosses in 1995 to develop tropically adapted inbred lines resistant to geminiviruses, bacterial wilt (caused by *Ralstonia solanacearum*), tomato mosaic virus (ToMV), and which possessed a high yield potential and good fruit quality. Two double crosses were among a set of crosses designed to achieve these objectives (Figure 1). CLN is the prefix for AVRDC tomato crosses

Table 5. *Yield and horticultural characteristics of tomato leaf curl virus resistant, processing tomato hybrids in preliminary yield trial 2, AVRDC, transplanted 16 Oct. 2001.*

Entry	Marketable yield (t/ha)	Fruit set (%)	Fruit size (g)	Days to maturity	pH	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)
PT4729	118.9	45.2	81	78	4.34	3.80	0.38	1.95
PT4730	123.7	44.7	58	75	4.40	3.80	0.32	1.89
PT4731	125.4	53.1	76	78	4.51	4.40	0.33	2.02
PT4732	116.3	51.1	75	76	4.46	3.90	0.35	1.95
PT4733	129.0	41.4	76	77	4.33	3.95	0.38	1.98
PT4734	121.8	46.7	99	75	4.35	4.25	0.35	1.87
PT4753	100.0	63.8	73	75	4.29	3.70	0.32	1.97
PT4754	120.1	62.3	67	77	4.39	3.95	0.33	1.95
PT4755	147.6	56.8	62	75	4.43	3.60	0.33	2.02
PT4756	119.3	55.5	66	75	4.43	3.80	0.30	2.03
PT4757	108.6	51.1	77	74	4.32	3.45	0.32	2.06
PT4758	110.7	48.5	81	72	4.39	3.85	0.30	2.06
PT4759	84.9	53.1	76	74	4.41	3.85	4.32	2.10
PT4760	99.5	41.5	80	73	4.38	4.10	0.32	2.19
PT4761	89.9	37.1	80	73	4.39	4.45	0.30	1.99
PT4762	110.4	50.1	79	75	4.43	3.60	0.31	1.94
PT4763	104.6	57.7	63	77	4.40	3.30	0.28	1.89
PT4764	113.3	56.3	59	77	4.55	3.40	0.30	2.02
PT4765	102.3	55.5	79	78	4.46	3.00	0.28	1.77
PT4766	116.0	53.1	75	76	4.47	3.50	0.29	1.86
PT4767	134.7	54.9	88	77	4.49	3.40	0.27	1.95
PT4768	101.2	47.0	92	78	4.56	3.85	0.31	1.94
PT4769	90.1	48.0	80	75	4.47	3.70	0.28	2.00
PT4770	110.9	48.3	78	78	4.54	3.60	0.29	1.94
PT4771	111.0	65.6	68	79	4.46	3.50	0.29	1.77
PT4772	120.8	57.5	79	78	4.54	3.55	0.34	2.09
PT4773	111.3	55.4	74	76	4.45	3.35	0.27	1.90
PT4774	116.2	59.3	94	76	4.52	3.45	0.30	2.01
UC204A (ck)	85.9	49.2	80	82	4.57	3.60	0.33	1.94
PT4727 (ck)	130.2	61.0	79	75	4.47	4.15	0.33	1.98
PT4723 (ck)	104.3	51.4	77	77	4.26	4.25	0.34	2.01
Mean of all entries	111.0	52.4	77	76	4.44	3.7	0.31	1.97
CV (%)	13.8	13.4	7.9	1.9	1.2	5.2	7.8	4.6
LSD (0.05)	31.4	14.4	12.4	3	0.11	0.41	0.05	0.19

[1]Equivalent of citric acid.

[2]Values for a and b were measured with a chronometer using a red standard surface. Immature green tomatoes have an a/b ratio less than 0. The a/b ratio increases to zero and above as the fruits ripen toward a dark red.

followed by a cross number. H24 is a ToLCV-resistant inbred line from India. Resistance in H24 was derived from an accession of *L. hirsutum* f. *glabratum* and mapped to an introgression located on the lower end of chromosome 11. CL5915-93D4-1-0-3 is a small fruited, heat-tolerant, ToMV-resistant AVRDC line. CRA84-58-1 is a selection from CRA84-58, a large fruited, BW-resistant line bred by the Institut National de la Recherche Agronomique in the Guadeloupe, French West Indies. PT4671A and PT4664A are firm-fruited, processing tomato lines developed by AVRDC.

In 1996, 300 F_1 seedlings per cross were mechanically inoculated with ToMV. Plants found to be resistant were evaluated in the field for high temperature fruit set and F_2 seed was harvested from

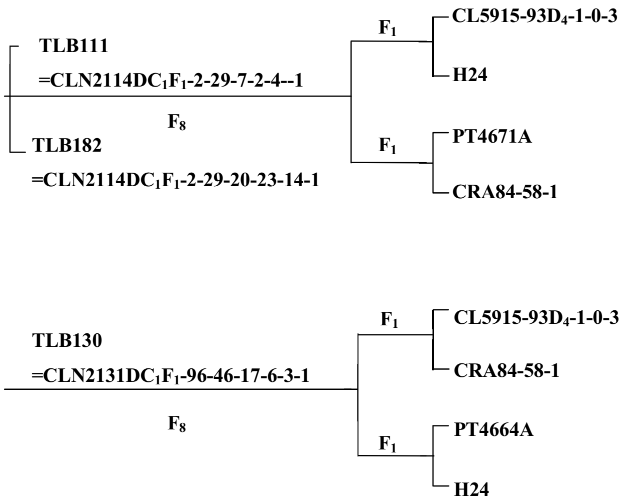

Figure 1. *Pedigree of TLB tomato lines.*

individual F_1 plants. From the F_2 through the F_4 generations, evaluation for resistance to the Taiwan strains of ToLCV was carried out by exposure to viruliferous whiteflies. In each generation, symptomless plants were transplanted to the field, evaluated for fruit set and fruit quality, and tested for virus infection by DNA hybridization. F_3 families were tested for bacterial wilt resistance by drench inoculation with *R. solanacearum* strain Pss4 from Taiwan. In a separate trial, F_3 families were evaluated for resistance to races 1 and 2 of *Fusarium oxysporum* f. sp. *lycopersici* by root-dip inoculation.

In June 1998, 21 F_5 lines from CLN2114 and CLN2131 were sent to the UASB for evaluation for resistance to south Indian strains of ToLCV, as well as yield potential and fruit quality. About 12 plants of each F_5 line plus ToLCV-resistant and susceptible checks were inoculated with viruliferous whiteflies and scored weekly for disease incidence and severity, up to 12 weeks after inoculation.

In a separate trial, about 30 plants per F_5 line and susceptible checks were grown at the UASB farm at Hebbal from Nov. 1998 to Mar. 1999 under natural ToLCV inoculum pressure. Seven F_5 lines were identified with both high resistance levels and good horticultural characteristics. UASB and NRI researchers as well as invited farmers selected individual plants within each of these lines to obtain F_6 lines.

From Apr. to Aug. 1999 under peak ToLCV inoculum pressure, the seven F_6 lines were entered in replicated trials at the UASB Hebbal farm and four other UAS field stations located over a range of agroecological zones in Karnataka. UASB researchers and invited farmers selected individual F_6 plants at the UASB Hebbal trial to obtain F_7 lines. In the F_7, five plants per line were selected and the seed bulked. In 2000, three lines were selected for on-farm trials in different parts of Karnataka and given simplified codes with the prefix TLB. The TLB codes and their equivalent AVRDC codes are given in Figure 1.

The 1999 on-station trials in Karnataka included TLB111 and TLB130 but not TLB182. The results indicated that in locations such as Bangalore or Arasikere where ToLCV incidence was high and occurred in early stages of crop growth, yields of TLB111 and TLB130 were twice those of susceptible cultivars Arka Vikas and Rashmi and comparable to ToLCV-tolerant hybrid Avinash-2 (Table 6). Yields of TLB111 and TLB 130 were similar to those of Arka

Table 6. *Incidence of tomato leaf curl virus and fruit yields of* TLB111, TLB130, *and checks evaluated at five research stations of the University of Agricultural Sciences, Karnataka, India, Summer 1999.*

	Shimoga		Mandya		Nagenahalli		Arasikere		Bangalore	
Entry	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)
TLB111	0.0	23.9	0.0	39.8	0.0	17.1	0.0	32.6	0.0	28.4
TLB130	0.0	24.7	0.0	29.1	0.0	21.4	0.0	41.1	0.0	28.8
Rashmi	57.3	18.8	12.5	22.5	100.0	12.8	100.0	10.0	100.0	9.7
Arka Vikas	36.8	14.0	7.5	20.9	23.1	13.4	38.1	19.4	100.0	13.4
Avinash-2	0.0	23.9	0.0	38.7	0.0	21.0	33.7	43.0	75.3	23.8
CV (%)	20.3	14.2	17.3	9.6	21.1	36.9	14.2	10.4	27.8	21.5
LSD (0.05)	13.4	7.2	9.4	6.2	8.5	10.1	6.6	7.2	26.1	10.5

Vikas and Rashmi at locations where ToLCV incidence was low or occurred later in the season.

On-farm trials conducted in 2000 over four agro-ecological zones in Karnataka showed that ToLCV incidences on TLB 111, TLB 130, and TLB 182 were low or zero (Table 7). Mild disease symptoms such as slight foliar yellowing or curling did appear on some TLB 111 and TLB 130 plants while susceptible Arka Vikas developed severe stunting and curling. Over locations, yields of the three TLB entries were almost twice those of Arka Vikas.

Plants of TLB111, TLB130, and TLB182 are of semideterminate growth habit and have demonstrated high levels of resistance to geminiviruses in southern India and Taiwan after seedling inoculation with ToLCV. Probing of the three TLB lines with restriction fragment-length polymorphism markers TG26, TG36, and TG393 mapped to the lower end of tomato chromosome 11 indicated that all three lines are homozygous for part of the wild tomato introgression associated with geminivirus resistance at TG26 and TG36, but they lack wild tomato alleles at TG393. Stems of these lines are green because of the presence in homozygous state of the allele anthocyaninless of Hoffman (*ah*); *ah* in these lines is linked to the tobacco mosaic virus resistance-2^2 allele (*Tm*-2^2), conferring resistance to multiple strains of the virus.

In a greenhouse trial, plants were screened for resistance to bacterial wilt pathogen (*R. solanacearum* strain Pss4), using three replications and 20 plants per replication. The average percentages of healthy plants four weeks after inoculation were 81, 77, and 59 for TLB111, TLB130, and TLB182, respectively; percentages of healthy plants for susceptible check L390 and resistant check H7996 were 5 and 90, respectively.

TLB 111 and TLB182 are resistant to race 1 of *Fusarium oxysporum* f. sp. *lycopersici* but susceptible to race 2; TLB130 is susceptible to both races of the fusarium wilt pathogen. TLB 111 and TLB182 are susceptible to gray leaf spot (caused by *Stemphylium solani*) and TLB130 segregates for gray leaf spot resistance. It is expected the three lines will be released by UASB in 2002 for production in Karnataka State.

Table 7. *Tomato leaf curl virus (ToLCV) reactions and fruit yields of TLB tomato lines tested at 36 on-farm trials in Karnataka, India, Summer 2000.*

Entry	ToLCV (%) Incidence	ToLCV (%) Range	Yield (t/ha)
TLB111	1.4	0-10	34.8
TLB130	1.3	0-15	34.8
TLB182	0.0	0	31.5
Arka Vikas (ck)	62.9	20-100	19.4
Waller-Duncan (*K* = 100)	9.5		3.6

Tomato late blight studies

Late blight caused by *Phytophthora infestans* is a major disease of tomato in cool and wet environments. Currently, there are no cultivated tomato varieties that have effective resistance against late blight in Taiwan and many other parts of the world. For these reasons, AVRDC initiated a program to: 1) characterize the isolates of *P. infestans* in Taiwan; 2) identify sources of resistance in wild tomato species; 3) study the inheritance of resistance; and 4) introgress resistance genes into cultivated tomato.

When AVRDC began characterizing tomato races among Taiwan isolates of *P. infestans* by differential hosts, i.e., TS19, TS33, W.Va.700, L3708 and LA1033 in 1994, the only tomato race identified was T1,2 which overcomes the *Ph-1* and *Ph-2* genes for resistance found in some commercial tomato varieties. Resistance to race T1,2 was identified in *L. pimpinellifolium* accessions (L3707, L3708, and others) and *L. hirsutum* accessions (L3683, L3684, LA1033, and others). Subsequently, two new races have been identified, one that overcomes L3708 but not LA1033 resistance, and another that overcomes LA1033 but not L3708 resistance. A total of 117 isolates were collected during the period 1998 to 2001 among which tomato races T1; T1,2; T1,2,3; T1,4; and T1,2,4 have been putatively identified.

Accessions L3707, L3708, L3683, and L3684 were first shown to be resistant to Taiwan populations of *P. infestans* by testing them in the field at different locations. Later they were also shown to be resistant under field conditions in the highlands of Indonesia, Nepal, Philippines, Tanzania, and Thailand where tomato entries that carry the *Ph*-1 and *Ph*-2 genes were susceptible. To study inheritance of late blight resistance in L3708, AVRDC's Tomato Unit made susceptible x resistant (L3708) crosses and generated F_1, F_2, and backcross populations. The responses of these populations in greenhouse inoculation tests showed that resistance is inherited as a monogenic dominant trait, but it is not fully expressed until plants reach five to six weeks of age.

L3708 was used as the donor parent and resistance was introgressed into tomato by backcrossing and selection with a tomato race T1,2 isolate. Money Maker was the parent for the cross and first backcross; the second and third backcrosses were carried out with AVRDC line CLN657-285-0-21-0. Nine BC_3F_6 lines designated CLN2037 (A-I) exhibited a high level of resistance and were made available for international distribution and testing (*AVRDC Report 2000*). Recently, AVRDC developed five experimental hybrids using CLN2037 lines as the resistant parent. These hybrids have been tested in a few locations in Taiwan under high levels of late blight pressure and have expressed good levels of resistance.

A total of 139 isolates of *P. infestans* dating back to 1991 have been collected in Taiwan, maintained by AVRDC, and characterized with the assistance of the United States Department of Agriculture Vegetable Laboratory in Beltsville, Maryland, USA and the Department of Agriculture and Rural Development in Belfast, Northern Ireland. These isolates were characterized according to their mating type, metalaxyl sensitivity, allozyme genotype, mitochondrial haplotype, and restriction fragment-length polymorphism (RFLP) fingerprint. Up to 1997, all isolates were found to belong to the old US-1 clonal lineage of *P. infestans*, but a new genotype that belongs to the US-11 clonal lineage appeared in the 1998 collection. By 2000, the US-11 genotype had completely displaced the old US-1 population throughout Taiwan. The US-11 genotype appears to be more aggressive plus it carries resistance to metalaxyl, a fungicide on which Taiwanese farmers had relied upon to manage late blight in tomato and potato. Fortunately, US-11 is of the A1 mating type as was the old US-1 genotype.

AVRDC's tomato late blight resistance breeding program is based on resistance sources selected against the old US-1 genotype. Thus far, these resistance sources also hold up against the new US-11 genotype of pathogen. It is important to constantly monitor *P. infestans* populations for possible emergence of new physiological races and for the introduction of additional genotypes, in particular those that may be of the A2 mating type. Should the A2 mating type be introduced, the *P. infestans* population in Taiwan could become much more complex through sexual recombination.

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

Geminiviruses have become increasingly serious over the past few years on solanaceous as well as other economically important food crops in tropical and subtropical Asia. Breeding for resistance is considered the most effective and environmentally friendly way to control these viruses. Knowledge of the genetic diversity and variability of these viruses is important to develop stable resistance. This report summarizes the routine characterization of geminiviruses infecting tomato, chili pepper, and weeds in selected countries in Asia. This work was funded by the Australian Centre for Agricultural Research. In addition, this report describes the diversity and characterization of tomato leaf curl virus (ToLCV) in Taiwan. This work was partially funded by the Council of Agriculture in Taiwan.

Fresh or dried leaf samples collected by collaborators were subjected to polymerase chain reaction using the general degenerate primer pair PAL1v1978/PAR1c715H which amplifies the top part (approx. 1.5 kb) of the DNA-A of whitefly-transmitted geminiviruses. This was followed by cloning and sequencing. Finally, a Basic Local Alignment Search Tool (BLAST) analysis was conducted with DNA-A sequences of all geminiviruses available in the GenBank database of the U.S. National Center for Biotechnology Information (NCBI). Two special primer pairs DNABLc1/DNABlv2, DNABLc2/DNABLv2 were developed for the detection of DNA-B based on three known DNA-B sequences, i.e., ToLCV-IN (X89653), ToLCV-IN New Delhi/Sev. (U15015), and TYLCV-TH (X63015).

Table 8 lists 14 geminiviruses cloned and sequenced in 2001 and the most closely related geminivirus, based on DNA BLAST analysis. Two distinct new tomato geminiviruses were identified from India, one from Anand (Gujarat State) and the other one from Varanasi (Uttar Pradesh State). The former one, AF 413671, has been isolated from a ToLCV-resistant breeding line that carries resistance derived from *Lycopersicon hirsutum* f. *glabratum* B 6013 ex. *L. esculentum* H-24. One new tomato geminivirus each was found in Indonesia (AF 189018) and in Thailand (TT05-A). Interestingly, the latter is not related to the tomato geminivirus reported previously from that country (X63015). Our newly designed DNA-B primer pairs allowed us to identify the new tomato virus from Thailand as a bipartite geminivirus. However its DNA-B sequence was found only remotely (77.6% sequence homology) related to the DNA-B of the other bipartite tomato geminivirus from Thailand (X63016). The tomato geminivirus from Pakistan was found to be closely related (96% sequence homology) to the ToLCV from New Delhi, India (U15015), and is considered a strain of the latter. The tomato geminivirus from Bangladesh (AVRDC clone BD-1) had 90% sequence homology with another tomato geminivirus from the same country (AF188481), indicating that these two viruses are strains of the same virus. From Malaysia, a chili pepper geminivirus was cloned whose sequence was found to have 96% homology with the pepper leaf curl virus from Thailand (AF134484) indicating that these are closely related strains of the same virus, if not the same virus. This is not surprising given the close proximity of these two countries.

Nucleotide sequence comparisons of eight ToLCV isolates collected from different areas in Taiwan indicated that with one exception (clone number N1 from Hsinchu) all isolates are the same virus or are very closely related strains of the same virus ToLCV-TW (U88692), based on their sequence homologies of 94% or higher (Table 9). Isolate N1 is a distinct new tomato geminivirus having closest sequence homology (79%) with ageratum yellow vein virus from Singapore (X74516). Specific primer pairs were designed for this new virus designated ToLCV-TW2 and for the ToLCV-TW which will be useful in conducting field surveys to determine the distribution and occurrence of this new virus in Taiwan.

Specific primers and probes of 238 to 265-bp length were also developed for four tomato geminiviruses from India, namely Ban 1 (L11746), Ban 2 (Z48182), Ban 3 (U38239) and New Delhi Sev. (U15015), as well as one from Sri Lanka (AF274349). The probes were tested by nucleic acid hybridization on leaf squashes of symptomatic tomato plants collected from various locations in the Kolar and Bangalore areas in Karnataka State and from selected locations in other states (Madhya Pradesh, Rajasthan, Maharastra and Gujarat). The results of this survey are shown in Table 10. This test revealed the presence of multiple geminiviruses at each location and even in individual

Table 8. *DNA sequence BLAST analyses of begomoviruses of crops and weeds cloned and sequenced in 2001.*

Country	Crop	Clone designation[1]	Sequence similarity (%)	Accession no.[2]	Virus with highest sequence similarity (GenBank accession)
Bangladesh	Tomato	BD1	90	-	Tomato leaf curl virus - Bangladesh (BD2) (AF188481)
Bangladesh	Ageratum	BD0020	92	-	Tobacco geminivirus – China (AF240675)
Bangladesh	Croton	BW2	95	-	Papaya leaf curl virus – India (Y15934)
India (Gujarat)	Tomato	IndG5[3]	87	AF413671	Tomato leaf curl virus - India (Ban 3) (U38239)
India (Varanasi)	Tomato	IndVar	87	AF449999	Tomato leaf curl virus – India (Ban 3) (U38239)
Indonesia	Tomato	I8341	65	AF189018	Squash leaf curl virus (M38183)
Malaysia	Pepper	MP6	96	AF414287	Pepper leaf curl virus – Thailand (AF134484)
Pakistan	Tomato	PaKT 5-6	96	AF448058	Tomato leaf curl virus – India (New Delhi/severe) (U15015)
Taiwan (Hsinchu)	Tomato	N1	79	-	Ageratum yellow vein virus – Singapore (X74516)
Taiwan (Hsinchu)	Tomato	N2	99	-	Tomato leaf curl virus – TW (Taoyuen)
Taiwan (Taoyuen)	Tomato	TT1	99	-	Tomato leaf curl virus – TW (Changhua)
Taiwan (Hualien)	Tomato	ET1	97	-	Tomato leaf curl virus – TW (Taitung)
Taiwan (Hualien)	Tomato	ET2	94	-	Tomato leaf curl virus – TW (Tainan) (U88692)
Thailand	Tomato	TT05-A	73	-	Ageratum yellow vein virus – Singapore (X74516)
Thailand	Tomato	TT05-B	77	-	Tomato yellow leaf curl virus (DNA-B) – Thailand (X63016)

[1]Full length DNA-A was used for comparisons, except TT05-B, for which full length DNA-B was used.
[2]Submitted to GenBank.
[3]Virus infects H24-derived AVRDC tomato breeding lines.

Table 9. *Complete DNA-A nucleotide sequence identities (%) of tomato leaf curl virus-Taiwan (ToLCV-TW) isolates and ageratum yellow vein virus (AYVV) from Singapore.*

Clone no.	Clone name	Hsinchu 1	Hsinchu 2	Taoyuan	Changhua	Tainan	Taitung	Hualien 1	Hualien 2	AYVV-Singapore
N1	Hsinchu 1	100	77	77	77	77	77	77	78	79
N2	Hsinchu 2		100	99	99	98	95	96	94	78
TT1	Taoyuan			100	99	98	95	96	94	78
CH1	Changhua				100	98	95	96	94	78
TW	Tainan					100	96	96	94	78
KD	Taitung						100	97	94	78
ET1	Hualien 1							100	94	78
ET2	Hualien 2								100	79
SA	AYVV-Singapore									100

plants. It is noteworthy that the Delhi geminivirus has already spread south to Karnataka.

Table 10. *Survey for geminiviruses of tomato in India, using specific probes.*

Collection site, state[1]	Samples with reaction pattern	Specific probe			
		Ban1-A	Ban2-A	Ban3-A	Delhi
Bangalore, Kar.	1	+		+	
Bangalore, Kar.	3	+		+	+
Bangalore, Kar.	1	+			+
Bangalore, Kar.	1			+	
Kolar, Kar.	1		+		+
Kolar, Kar.	3	+		+	+
Kolar, Kar.	3	+			+
Kolar, Kar.	2	+	+	+	+
Kolar, Kar.	3	+	+		+
Kolar, Kar.	1	+	+	+	
Kolar, Kar.	1	+			
Kolar, Kar.	1	+	+		
Kolar, Kar.	1		+	+	+
Badalkhaid, Ma. Prad.	1				+
Udaipur, Raj.	1				+
Kota, Raj.	2				-
Dhule, Mah.	1				-
Kolhar, Mah.	1				+
Nasik, Mah.	1				+
Anand, Guj.	1				+

[1]Kar = Karnataka; Raj = Rajasthan; Ma. Prad = Madhya Pradesh; Mah = Maharashtra; Guj = Gujarat.

Transformation of tomato with hypersensitive response-assisting gene and amphipathic gene

The hypersensitive response (HR) induced by pathogenic bacteria is characterized by a rapid localized cell death in resistant or non-host plants at the site of infection. The HR is an important defense response to prevent further multiplication and restrict the spread of the pathogen in plant tissue. Harpin_{pss} from the plant pathogen *Pseudomonas syringae* pv. *syringae* is a proteinaceous elicitor that induces HR in non-host plants. According to the elicitor-receptor model, an exogenous cell membrane receptor infiltrated into the intercellular space will interfere with the interaction between harpin_{pss} and the putative receptor. A plant amphipathic protein (hypersensitive response-assisting protein, HRAP) from sweet pepper interacting with harpin_{pss} was able to cause the dissociation of harpin_{pss} multimeric forms and resulted in inducing HR during the harpin_{pss}-insensitive stage of sweet pepper. The *hrap* gene was widely distributed throughout the plant world and its transcription level was correlated with plant sensitivity to harpin_{pss}. HRAP is a novel plant protein that intensifies the harpin_{pss}-mediated hypersensitive response in harpin_{pss}-insensitive plants, such as sweet pepper, tobacco, *Arabidopsis*, and rice. Another plant amphipathic protein (AP1) had been shown to delay the HR induced in non-host plant by *P. syringae* pv. *syringae* through the release of harpin_{pss}. Further analysis suggested that AP1 was competitively inhibiting the interaction between harpin_{pss} and its receptor on the plant cells, and consequently suppressed bacterial growth. The *ap1* gene from sweet pepper was transferred to rice. Rice plants carrying the *ap1* gene showed enhanced resistance to *Xanthomonas oryzae* pv. *oryzae* race. The objective of this study is to transform tomato with *ap*1 and *hrap* genes provided by Dr. Teng-Yung Feng of Institute of Botany, Academia Sinica, Taiwan and later to determine their respective resistance spectrum.

Agrobacterium-mediated transformation was employed to separately transfer *hrap* and *ap1* genes in sense orientation into tomato line CLN1558A. Cotyledons were infected by *Agrobacterium* strains LBA4404 that transformed with the plasmid carrying the *hrap* and *ap*1, respectively. Regeneration and selection procedures for transgenic tomatoes were as previously described. Polymerase chain reaction (PCR) and Southern blot analysis were used to confirm the transformation. Standard CTAB (hexadecyltrimethyl ammonium bromide) method was followed to isolate genomic DNA from young leaves of putative transgenic tomatoes. PCR with primers NOS (5'-TGATAATCATCGCAAGACCG GCAACAGGAT-3') and 35S (5'-AAGGGATGAC GCACAATCCC ACTATCCTTC-3') was carried out to detect the presence of transgene in transgenic plants. The reaction was performed under the following conditions: 40 cycles of 1 min at 94 °C, 1 min at 60 °C, 1 min at 72 °C. For Southern blot analysis, genomic DNA was digested with restriction enzyme *Bam*HI/*Eco*RI, and fractionated by 1% agarose gel electrophoresis. Probe was prepared by random labeling method with digoxigenin (DIG)-dUTP. Up until now, there have been 27 transgenic tomatoes transformed with *hrap* disease resistance gene and 28 *ap1* transgenic tomatoes. Southern blot analysis of tomatoes transformed with *ap*1 and *hrap* are shown in Figures 2 and 3. Most putative transgenic tomatoes, derived from in vitro kanamycin selection process, turned out to be transgenic ones with less than 5% of escape rate. *Ap*1- and *hrap*-transgenic tomatoes will be self-pollinated as well as cross-pollinated to generate R_1 transgenic plants with individual *ap*1 and *hrap*, and both transgenes will be analyzed to determine their respective and combined disease resistance spectrum and whether there are any synergetic effects.

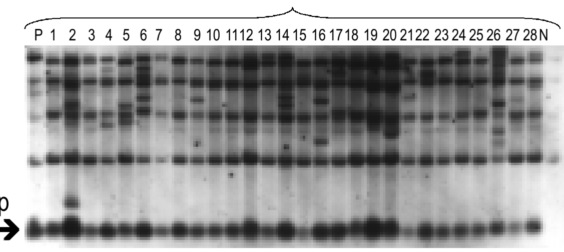

Figure 2. *Southern blot hybridization analysis of putative transgenic tomato plants with* ap*1 gene. P = positive control. N = negative control.*

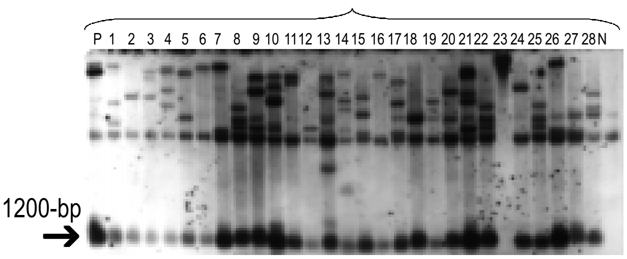

Figure 3. *Southern blot hybridization analysis of putative transgenic tomato plants with* hrap *gene. P = positive control. N = negative control.*

Pyramiding tomato leaf curl virus resistance genes by marker-assisted selection

Tomato leaf curl virus (ToLCV) is a serious worldwide production constraint of tomato, particularly in the hot-dry season. Incorporation of multiple ToLCV resistant resources to prolong the durability of host-plant resistance has been emphasized in various breeding programs. To achieve this goal, employment of molecular markers is indispensable. Selections based on markers are mostly environment-independent and marker-assisted selection can simultaneously pyramid multiple resistance genes, which are not accessible through traditional breeding processes.

Ty-1 and *Ty*-2 (originated from *Lycopersicon chilense* and *L. hirsutum*, respectively) are two ToLCV resistance genes identified so far. Restriction fragment-length polymorphism (RFLP) molecular markers are available for both genes. To incorporate these two genes, three tomato lines (CLN399, CH154 and CLN2026) were doublecrossed with BL982 (with *Ty*-1 gene) and CLN2116 (with *Ty*-2 gene). Double-cross populations CLN2513, CLN2514 and CLN2515 were generated. Selections with RFLP markers had previously been conducted in DC_1 and $DCBC_1$

generations to identify double heterozygous individuals. A total of five RFLP-selected plants (2 $DCBC_1$ plants from CLN2513 population, 2 $DCBC_1$ plants from CLN2514 and 1 $DCBC_1$ plant from CLN2515) were advanced to backcross two generation ($DCBC_2$). One hundred and thirty-two plants of each $DCBC_2$ line were subject to viruliferous whiteflies in a greenhouse on 14 Dec. 2000. For each $DCBC_2$ line, 35 to 63 plants without significant ToLCV symptoms were transplanted on 10 Jan. 2001. Symptomless plants with good fruit traits were tested with RFLP probes. Plant DNA was extracted, digested with proper restriction enzymes and probed with TG97, TG36, TG26 and TG393 for detection of *Ty*-1 and *Ty*-2 genes.

Ty-2 gene had been reported to be located on chromosome 11 and spanned RFLP markers TG36 to TG393. According to our previous data, TG36 is the closest available RFLP marker linked to *Ty*-2 gene. For marker analysis, all plants were first probed with TG97 and TG36 (major probes for *Ty*-1 and *Ty*-2 genes). Plants showing positive results for these two regions were further probed with TG26 and TG393 to assure full length *Ty*-2 gene is inherited.

Table 11 shows the results. Eighty-seven of the 140 analyzed symptomless plants carried the *Ty*-2 gene (as indicated by TG36 marker), while only 42 carried the *Ty*-1 gene. This is because protection from *Ty*-2 (a resistant gene) is stronger than *Ty*-1 (a tolerant gene). Among the 140 analyzed plants, 19 inherited both *Ty*-1 and full length *Ty*-2. These plants will be further advanced to $DCBC_2F_2$ generation for selection of homozygous individuals at both *Ty*-1 and *Ty*-2 alleles as well as for favorable horticultural traits.

Table 11. *Detection of* Ty-*1 and* Ty-*2 genes in* $DCBC_2$ *generation by restriction fragment-length polymorphism markers. All data are expressed as number of plants.*

Cross code[1]	Plants[2]	Analy. plants[3]	*Ty*-1 positive	*Ty*-2 positive	*Ty-1 & 2* positive
$CLN2513BC_2F_1$ (48)	64	38	9	12	7
$CLN2513BC_2F_1$(12)	54	27	7	23	7
$CLN2514BC_2F_1$ (2)	35	21	8	14	6
$CLN2514BC_2F_1$ (38)	37	28	10	19	6
$CLN2515BC_2F_1$ (12)	64	26	8	19	7

[1]For each cross, 132 plants were subjected to viruliferous whiteflies in a greenhouse.
[2]Transplants without significant tomato leaf curl virus symptoms.
[3]Symptomless plants with good fruit yields.

High yielding, disease-resistant chili pepper lines

Development of high yielding and stable chili inbred lines to be grown under hot-wet environments is the main objective of AVRDC chili breeding research. Incorporation of multiple disease resistance is critical for yield stability.

International Chili Pepper Nursery Trial

The 11^{th} AVRDC International Chili Pepper Nursery (ICPN11) consisted of 12 entries, including nine new AVRDC inbred lines, two hybrid checks, and long term check PBC142 (Table 12). The trial was sown at AVRDC on 3 Apr., transplanted 8 May, and harvested 10 times from 17 July to 17 Sept. 2001, spanning the months of greatest environmental stress in our location. The experimental design was randomized complete block design with four replications (10 plants per plot, 30,000 plants per hectare). AVRDC pathology units conducted disease evaluations on the entries in separate greenhouse trials, and the Center's analytical lab assayed fruit pungency via high pressure liquid chromatography (HPLC).

Large differences between trial entries were noted in fruit size, yield, and capsaicin content. Most entries were resistant to potato virus Y (PVY) and showed moderate tolerance to bacterial wilt; two entries were resistant to chili veinal mosaic virus (ChiVMV) and at least two were moderately resistant to cucumber mosaic virus (CMV). Genetic resistances to tomato mosaic virus (ToMV) and phytophthora blight (PB) race 3 were generally lacking. Much of the total fruit yield was rendered unmarketable due to anthracnose infection. Marketable and total yields of four entries were significantly greater than PBC142 and the two hybrid checks. Entry 9852-173 stood out in particular, yielding twice as much marketable fruit as the next best yielding line, combined with resistance to PVY and bacterial wilt, and a low but noticeable level of pungency. This line has proven itself a superior performer in at least four years of replicated trials.

Six international cooperators provided results from evaluations of the ICPN11 in their locations; average performances for average fruit weight and for total yield at these locations are presented in Table 13. Spearman Rank correlations show that in this set of entries, the relative ranking of the ten entries is very similar in all locations with regard to their average fruit weight; however, ranking for total yield showed

Table 12. *Yield, plant and fruit traits of 11th International Chili Pepper Nursery at AVRDC, transplanted 8 May 2001.*

Entry	Maturity (DAS)[1]	Market. yield (g/plant)	Total yield (g/plant)	Vegetative fresh wt. (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Capsaicin (SHU)[2]	Disease resistance (%)[3] PVY	ToMV	CMV	ChiVMV	BW	PB race3
9848-4773	102	291	928	718	9.3	1.5	6.2	40.5	0	0	0	100	79	0
9848-4996	105	103	343	1159	8.0	0.9	2.5	131.3	100	0	73	27	63	0
9852-173	105	776	1877	729	9.4	1.7	9.5	7.1	100	0	0	0	63	0
9848-5032	107	98	278	923	11.0	1.2	6.9	61.4	100	0	83	0	59	0
9946-2027	113	64	418	828	6.3	1.5	5.4	10.1	–[4]	0	0	0	0	0
9955-15	106	316	1088	868	14.0	1.8	16.6	52.7	92	0	8	0	5	0
9946-2049	103	332	946	868	11.2	1.0	4.5	12.9	100	0	0	0	17	8
9950-5141	107	102	347	430	8.7	1.4	7.1	47.7	100	0	25	8	42	0
9950-5633	112	52	293	805	10.0	1.5	9.1	18.6	100	0	92	8	50	0
PBC142 (ck)	110	100	434	879	7.1	1.0	2.8	86.0	0	0	0	100	0	0
F_1 Hy Hot (ck)	107	66	298	944	13.0	1.2	8.9	49.2	100	0	40	8	50	0
F_1 Super Flavor (ck)	107	59	274	751	12.4	1.2	9.0	51.6	100	0	40	0	42	4
Mean	107	197	627	825	10.0	1.3	7.4							
CV (%)	2	31	23	19	4.9	4.7	12.9							
LSD (0.05)	4	104	242	260	0.8	0.1	1.6							

[1]DAS = days after sowing.
[2]Scoville Heat Units (1000s).
[3]Disease screening was carried out in separate greenhouse trials using Taiwan pathogen strains. PYY = potato virus Y; ToMV = tomato mosaic virus; CMV = cucumber mosaic virus; BW = bacterial wilt; PB = phytophthora blight (tested on root tissue). Numbers are the percent resistant plants after inoculation.
[4]Not tested.

Table 13. *Average fruit weight and total yield of the 11th International Chili Pepper Nursery, evaluated by AVRDC and cooperators in six locations, 2001.*

Entry	Identification	AVRDC	Hong Kong	India	Netherlands	So. Korea	Vietnam (highld)	Vietnam (lowld)	Mean	AVRDC	Hong Kong	India	Netherlands	So. Korea	Vietnam (highld)	Vietnam (lowld)	Mean
#1	PBC142 (ck)	2.8	2.6	4.0	4.0	2.0	2.6	3.9	3.1	434	40	454	180	410	223	351	299
#2	9848-4773	6.2	16.0	12.5	9.2	5. 5	10.4	10.3	10.0	928	100	873	360	405	445	497	515
#3	9848-4996	2.5	3.4	4.9	4.2	1.8	4.5	3.7	3.6	343	72	331	–[1]	263	483	618	352
#4	9852-173	9.5	9.6	9.8	8.8	7.1	8.8	5.4	8.4	1877	120	551	320	818	443	549	668
#5	9848-5032	6.9	8.0	8.4	11.9	5.4	9.2	13.2	9.0	278	110	855	240	780	600	223	441
#6	9848-2027	5.4	10.0	9.6	10.3	4.4	6.8	6.2	7.5	418	172	516	220	403	295	432	351
#7	9955-15	16.6	28.0	15.2	29.3	10.4	9.2	28.9	19.7	1088	77	1032	550	283	413	690	590
#8	9946-2049	4.5	4.0	8.6	5.5	5.4	5.0	7.5	5.8	946	68	743	220	630	752	511	553
#9	9950-5141	7.1	9.0	10.9	11.9	7.2	8.4	18.9	10.5	347	107	828	360	773	649	600	523
#10	9950-5633	9.1	12.0	13.7	16.3	8.5	9.7	20.3	12.8	293	134	725	480	665	637	623	508
Mean		7.1	10.3	9.8	11.1	5.8	7.5	11.8	9.0	695	100	691	326	543	509	494	480

[1]Not determined.

no consistent pattern (Table 14). No location proved to be a useful indicator of relative yield performance for any of the other locations reporting, even comparing two locations in Vietnam (one trial conducted in the humid lowlands near Ho Chi Minh City, the other in the Central Highlands at about 800 m elevation). Little or no information was provided regarding the specific climatic or disease factors that may have impacted varietal performance at each location.

Table 14. *Spearman rank correlations among locations evaluating the 11th International Chili Pepper Nursery Trial entries, 2001.*

Country	AVRDC	Hong Kong	India	Nether-lands	South Korea	Viet. (highld)	Viet. (lowld)	AVRDC	Hong Kong	India	Nether-lands	South Korea	Viet. (highld)	Viet. (lowld)
AVRDC	1.00	0.73*	0.81**	0.79**	0.94**	0.73*	0.72	1.00	-0.26	0.18	-0.20	-0.07	-0.33	0.08
Hong Kong		1.00	0.93**	0.76*	0.76*	0.69*	0.86**		1.00	0.06	-0.03	0.36	0.01	0.08
India			1.00	0.81**	0.90**	0.79**	0.82**			1.00	0.16	0.15	0.26	0.07
Netherlands				1.00	0.84**	0.93**	0.72*				1.00	-0.35	0.24	0.77
South Korea					1.00	0.87**	0.77*					1.00	0.38	-0.20
Vietnam (highld)						1.00	0.73*						1.00	0.30
Vietnam (lowld)							1.00							1.00

*,** Significant at 5% and 1% levels, respectively.

Preliminary yield trials

To identify new lines for future ICPNs, advanced lines from ongoing AVRDC pepper breeding activities are evaluated in preliminary yield trials (PYT). Two such trials were conducted in 2001 to identify entries adapted to the hot-wet summer season and to compare yields of the hot-wet summer versus the cool-dry fall. The summer trial included 57 inbred lines and two hybrid checks. It was sown 3 Apr., transplanted 8 May, and harvested once on 18 July 2001. Experimental design was randomized complete block design with two replications, 10 plants per plot, planted at a density of 30,000 plants per hectare. The most promising 24 entries from the summer trial were evaluated in the fall trial which was sown 14 Aug., transplanted 24 Sept., and harvested beginning 17 Dec. 2001. Data from both trials on the 10 best performing inbreds and the two hybrid checks are given in Table 15.

Mean total yield of the fall trial was over three times greater than the summer trial, reflecting the more favorable conditions of the fall environment. The Spearman Rank correlation for total yield of these ten entries, along with two standard check varieties, was low and insignificant (r_s = -.479), indicating large rank differences between the two trials. Rank correlation for average fruit size was positive, but still not statistically significant (r_s = .612). Three lines performed relatively well in both environments and showed other special qualities: 0007-2247 (early maturity and high fruit yield), 0037-7568 (largest fruit weight), and 9950-5197 (resistance to ChiVMV). Altogether, four lines showed high levels of ChiVMV resistance but no entries were detected that showed resistance to phytophthora blight, race 3. Several of these lines will be included in future ICPN entry lists.

Heat-tolerant, disease-resistant sweet pepper lines

Sweet pepper production in the tropics and subtropics is limited primarily by the lack of heat-tolerant, disease-resistant varieties. Varieties adapted to both cool-dry and hot-wet environments are desirable.

International Sweet Pepper Nursery Trial

The 3rd International Sweet Pepper Nursery (ISPN) was evaluated at the AVRDC for yield and fruit quality. Plots were laid out in randomized complete block design, with four replications, 10 plants/plot, and 30,000 plants/ha. Entries for the ISPN were chosen because they displayed resistance to one or more important diseases, combined with potentially high yield and fruit quality. The trial was sown 3 Apr., transplanted 8 May and harvested six times beginning 20 July 2001. Twelve entries were selected for the trial, including nine new inbred lines, the long term inbred line check 9852-131, and two hybrid checks (Table 16). Disease reactions of entries were tested in separate greenhouse screening trials conducted by the plant pathology units.

None of the inbred line entries yielded significantly more than 9852-131 or hybrid checks. However, three entries, 9852-174, 9950-5662, and PBC271 produced relatively high yields and significantly heavier fruit than 9852-131. Entry 9950-5662 also demonstrated resistance to races 1-3 of bacterial spot. PBC271 was resistant to potato virus Y (PVY) and showed a relatively high level of resistance to race 1 of the phytophthora blight pathogen. PBC275 produced among the largest and best shaped fruit of the lines tested. However, its yields were quite poor and it was susceptible to most pathogens.

Table 15. *Yield, plant and fruit traits, and disease reactions of the top 10 chili pepper inbred lines in preliminary yield trials at AVRDC, transplanted 8 May (summer trial) and 24 Sept. (fall trial), 2001.*

	Summer					Fall						Resistance (%)[3]	
Entry	Total yield (g/plant)	Veget. biomass[1] (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Maturity (DAS)[2]	Total yield (g/plant)	Vegetative fresh wt. (g/plant)	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	ChiVMV	PB race 3
0007-2269	405	499	8.1	1.4	4.9	119	802	312	8.7	1.5	7.0	33	8.3
0007-2271	364	518	8.8	1.6	6.9	118	1080	355	10.2	2.1	12.5	100	0
0007-2259	255	623	5.9	1.4	4.6	123	909	517	8.1	1.4	6.8	90	0
0007-2263	221	341	6.9	1.8	7.4	124	985	308	8.9	1.6	9.3	92	0
0007-2231	281	356	8.1	1.5	6.1	128	864	237	12.9	1.8	14.3	0	0
0007-2247	541	547	11.3	1.3	7.5	111	1082	302	13.5	1.7	11.5	0	–[4]
0037-7568	454	613	14.5	1.9	18.3	122	1046	348	17.6	2.2	31.0	0	0
0037-7501	347	571	9.9	1.1	4.1	117	960	547	11.0	1.1	5.3	0	0
0037-7544	282	479	7.8	1.3	4.5	118	1026	351	10.3	1.4	8.3	25	0
9950-5197	371	803	8.5	1.5	6.3	118	1349	345	10.5	1.8	10.3	100	0
F_1 Hy Hot 3	230	691	12.8	1.2	8.6	126	1426	449	15.2	1.4	14.0	0	0
F_1 Good Choice	374	765	10.1	1.2	6.2	120	1016	280	12.1	1.4	10.0	0	8.3
Mean	277	519	8.8	1.4	6.6	118	938	303	11.5	1.6	12.0		
CV(%)	28	21	7.4	7.4	16.2	3.12	19	16	5.8	5.6	15.7		
LSD (0.05)	158	216	1.3	0.2	2.2	7.51	385	95	3.2	0.2	3.5		

[1]Fresh weight of aboveground tissue excluding fruit.
[2]DAS = days after sowing.
[3]Disease screening was carried out in separate greenhouse trials using Taiwan pathogen strains. Numbers are the percent resistant plants after inoculation. ChiVMV= chili veinal mottle virus; PB = phytophthora blight (tested on root tissue).
[4]Not tested.

Table 16. *Yield, plant, and fruit traits, and disease reactions of entries in the 3rd International Sweet Pepper Nursery, AVRDC, transplanted 8 May 2001.*

Entry	Maturity (DAS)[1]	Market. yield (g/plnt)	Total yield (g/plnt)	Vegetative fresh wt. (g/plnt)	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Fruit no./plnt	Disease resistance[2] PVY	CMV	ChiVMV	BW	Disease reactions[3] PB race 1	BS race 1	BS race 2	BS race 3
9852-174	115	341	513	402	7.9	5.9	66	15	0	0	0	13	0	3.8	7.8	5.3
9852-190	122	270	429	431	13.3	4.3	51	14	100	0	0	4	4	8.0	4.6	6.0
9950-5513	120	212	278	319	5.5	5.3	43	7	0	0	0	0	13	8.7	6.0	5.8
9950-5558	121	328	396	353	6.2	4.6	34	16	0	0	0	42	13	6.0	4.2	3.4
PBC271	113	284	371	391	7.5	5.7	60	6	100	0	0	4	88	8.8	7.3	7.0
9950-5658	115	181	209	326	3.2	5.4	37	5	8	0	0	4	4	8.6	6.2	6.5
9950-5661	121	174	237	443	5.9	5.5	49	10	0	0	0	0	0	2.5	4.6	4.3
9950-5662	130	231	383	677	6.0	6.5	70	13	0	0	0	67	0	1.5	1.6	1.0
PBC275	121	202	241	494	5.8	6.6	73	3	0	0	0	13	0	7.8	5.2	5.0
9852-131	113	264	398	767	9.3	3.5	34	23	100	9	9	42	17	7.0	5.5	5.3
Andalus (ck)	115	515	672	513	14.5	5.5	88	6	100	0	0	4	8	8.3	6.0	5.5
Uranus (ck)	117	321	431	545	9.1	6.1	77	7	0	0	0	13	0	9.2	7.2	5.7
Mean	118	277	380	472	7.9	5.4	57	10								
CV%	3	30	23	26	5.9	5.0	13	26								
LSD (0.05)	5	139	146	207												

[1]DAS = days after sowing.
[2]Disease screening was carried out in separate greenhouse trials using Taiwan pathogen strains. PYY = potato virus Y; ChiVMV = chili veinal mottle virus; CMV = cucumber mosaic virus; BW = bacterial wilt; PB = phytophthora blight. Numbers are the percent symptomless plants after inoculation.
[3]BS = bacterial spot. Scores are diseased leaf area according to the Barrett-Horsfall scale and range from 0 (healthy) to 11 (100% disease). Resistant check PBC137 scored 1.8, 1.8, and 1.6 for races 1, 2, and 3, respectively.

Although the ISPN3 nursery was not evaluated under both cool-dry fall and hot-wet summer conditions at AVRDC, a comparison of three entries (9852-131, PBC271, and Andalus) when grown in the fall versus summer showed that total yield in the summer crop was less than half of the fall crop (Table 17). Previous research has shown that fruit weight is usually lower during summer while vegetative fresh weight increases. In this trial comparison, average fruit weight of summer fruit was about two-thirds that of fall-grown fruit, and vegetative fresh weight generally increased. The commercial hybrid variety Andalus displayed greater stability across the two environments than the two inbred lines, with the least reduction in fruit size and in total yield. Average number of fruit set by Andalus was reduced by 16% by summer production compared to the fall crop, while fruit set in the inbred lines was reduced by 30-40%.

In 2001, 30 non-AVRDC researchers requested sets of the entries of ISPN3. Of those, AVRDC received feedback from cooperators in Hong Kong, India, the Netherlands, South Korea, and Vietnam. Data received were incomplete and unreplicated in some cases, thus a thorough multi-location analysis is not possible. Average data for two important measurements, total yield and average fruit weight are listed in Table 18. While these data cannot support broad generalizations, it is clear that the summer planting at AVRDC is among the most stressful of all environments sampled, and our results are not strong predictors of varietal performance in other locations. Both average fruit size and total yield are depressed to uneconomic levels. Much of the difference in performance between locations can be interpreted on the basis of the amount of environmental stress encountered by the crop, mainly due to the cropping season.

Rank correlations of average fruit weight across the several trial locations were generally positively correlated, while results for total yield were highly variable (Table 19). In particular, yield results from the AVRDC trial produced low, but negative correlations with other locations. This may suggest that fruit size is a trait that is more stable across locations than is yield, or that fruit set shows a greater degree of genotype by environment interaction than average fruit size.

Preliminary yield trials

Two preliminary yield trials were conducted to identify sweet pepper lines adapted to the hot-wet summer season and to compare their performance in the cool-dry fall versus the hot-wet summer. The summer trial included 53 inbred lines, two inbred line checks (PBC271, PBC356) and two hybrid checks. It was sown 12 Mar., transplanted 26 Apr., and harvested once on 29 June 2001.

The best 31 lines (based on fruit size and weight, and plant total yield) from the summer trial were evaluated in a fall (cool-dry) trial that was sown 14 Aug., transplanted 24 Sept., and harvested four times beginning 17 Dec. 2001. Experimental design for both trials was randomized complete block design with two replications, 10 plants per plot, planted at a density of 30,000 plants per hectare. The plant pathology units at AVRDC, using standard protocols under laboratory and greenhouse conditions, conducted assays for disease susceptibility/resistance. Data from the best 10 entries (again based on plant yield, fruit size and

Table 17. *Performance of varieties grown at AVRDC in 2nd and 3rd International Sweet Pepper Nursery Trials, transplanted on 16 Oct. 2000 and 8 May 2001, respectively.*

	Average fruit weight (g)		Vegetative fresh weight (g)		Total yield (g/plot)		Harvest Index[1]	
	Fall	Summer	Fall	Summer	Fall	Summer	Fall	Summer
Variety	ISPN2	ISPN3	ISPN2	ISPN3	ISPN2	ISPN3	ISPN2	ISPN3
9852-131	52	34	390	767	822	397	0.68	0.34
PBC271	110	60	391	391	1154	371	0.75	0.49
Andalus	111	88	419	513	1013	673	0.71	0.57
Mean	108	57	426	472	915	380	0.71	0.47

[1]Total yield divided by the sum of total yield and vegetative fresh weight.

Table 18. *Average fruit weight and total yield of the 3rd International Sweet Pepper Nursery Trial, evaluated at AVRDC and by cooperators in five locations, 2001.*

	Average fruit weight (g)							Total yield (g/plant)						
Entry	AVRDC	Hong Kong	India	So. Korea	Nether-lands	Vietnam	Mean	AVRDC	Hong Kong	India	So. Korea	Nether-lands	Vietnam	Mean
9852-131	34	36	45	79	53	57	51	398	210	891	577	800	957	639
9852-174	66	70	89	164	196	123	118	513	228	483	729	1400	651	667
9852-190	51	60	50	136	90	80	78	429	213	783	876	ND[1]	1240	708
9950-5513	43	90	80	187	140	132	112	278	274	1033	744	ND	1052	676
9950-5558	34	44	52	72	67	56	54	396	142	717	652	940	489	556
PBC 271	60	ND	130	187	130	123	126	371	ND	900	546	910	686	683
9950-5658	37	76	112	102	118	95	90	209	243	1092	669	ND	959	634
9950-5661	49	76	78	159	160	125	108	237	215	758	764	1120	799	649
9950-5662	70	90	86	175	153	108	114	383	276	808	607	1080	796	658
PBC 275	73	104	82	185	134	129	118	241	196	708	696	950	670	577
Mean	52	72	80	145	124	103	96	345	222	976	686	1028	830	943

[1]ND = no data.

Table 19. *Spearman rank correlations among locations evaluating the 3rd International Sweet Pepper Nursery Trial entries, 2001.*

Country	AVRDC	Hong Kong	India	Nether-lands	South Korea	Vietnam	AVRDC	Hong Kong	India	Nether-lands	South Korea	Vietnam
AVRDC	1.00	0.64*	0.49	0.64*	0.68*	0.54	1.00	-0.26	-0.33	-0.45	-0.03	-0.18
Hong Kong		1.00	0.41	0.58*	0.70**	0.73**		1.00	0.46	0.16	-0.27	0.19
India			1.00	0.48	0.58*	0.38			1.00	-0.07	-0.16	0.79
Netherlands				1.00	0.58*	0.76**				1.00	0.36	0.11
South Korea					1.00	0.79***					1.00	0.39
Vietnam						1.00						1.00

*,**,*** Significant at 10%, 5% and 1% levels, respectively.

fruit weight) plus check varieties are presented in Table 20.

Mean total yield and mean fruit size of the fall trial exceeded those of the summer trial by over five times and three times, respectively. Higher temperatures and rainfall plus greater disease incidence in the summer trial resulted in substantial reductions in yield and quality. Inbred line 0007-2460 ranked first for total yield in both trials. The second highest-ranking line in the summer trial, 0037-7670, produced relatively large fruit in both seasons and displayed resistance to races 1-3 of the bacterial spot pathogen. The entries in this trial with the best combination of yield and disease resistance traits will be chosen for inclusion in the next cycle of the International Sweet Pepper Nursery series.

Cytoplasmic-genic male sterile pepper

Hybrid seed production is labor-intensive, particularly emasculation of flowers on female plants. Male sterility can be used to reduce the time needed to prepare the female flowers for pollination and thus reduce the amount of labor needed. Male sterility also increases the purity of the F_1 seed since no self-pollination takes place. Cytoplasmic-genic male sterility (CGMS) has been found in pepper and most researchers agree that a single nuclear gene, designated *rf1*, interacts with S (sterile) cytoplasm to produce sterility, and the restorer allele *Rf1* restores fertility. Plants with N (normal) cytoplasm are fertile regardless of whether they have the *Rf1* or *rf1* allele. Some reports indicate that CGMS can be unstable under different environmental conditions, depending on the genotype. Korean seed companies have used CGMS for hybrid

Table 20. *Yield, plant and fruit traits, and disease reactions of selected sweet pepper inbred lines and checks in summer and fall preliminary yield trials at AVRDC, transplanted 26 Apr. and 24 Sept. 2001, respectively.*

	Summer					Fall											
													Dis. resist.[2]		Dis. reactions[3]		
Entry	Total yield (g/plnt)	Vegtatve fresh wt. (g/plnt)	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Total yield (g/plnt)	Vegtatve fresh wt. (g/plnt)	Maturity (DAS)[1]	Fruit length (cm)	Fruit width (cm)	Fruit wt. (g)	Fruit no./plnt	Chi VMV	PB race1	BS race1	BS race2	BS race3
0007-2447	227	137	4.6	5.2	38	1070	260	118	9.4	7.9	164	12	40	5.3	NT	7.3	5.3
0007-2460	512	326	8.0	5.5	54	2067	571	128	10.1	7.0	110	43	NT[4]	50.0	7.5	NT	5.0
0007-2558	236	298	7.3	5.1	45	1389	418	116	9.9	6.3	106	21	0	33.2	8.3	7.3	6.8
0007-2559	197	150	6.9	4.5	36	1464	332	117	10.1	6.1	112	21	0	50.0	7.0	6.7	5.8
0037-7634	167	298	8.0	3.7	31	1183	291	124	11.1	5.0	79	23	0	41.7	4.0	4.8	3.8
0037-7641	126	185	10.2	3.1	22	1437	278	112	15.0	4.6	78	32	0	75.0	6.0	3.8	5.4
0037-7645	240	299	4.8	5.1	44	1330	363	117	9.2	8.9	221	11	0	0.0	5.7	5.5	4.8
0037-7655	191	148	8.1	3.9	34	1935	621	131	11.9	5.3	101	42	0	3.3	NT	7.0	7.3
0037-7670	374	271	6.0	7.2	101	1306	312	120	9.0	9.3	247	14	0	0.0	3.2	1.5	1.8
9950-5700	160	129	6.8	5.4	48	1240	334	115	9.6	7.6	137	13	0	8.3	6.3	5.7	4.8
PBC 271	128	175	7.2	4.9	33	1351	400	114	10.1	7.1	145	18	0	75.0	8.2	7.2	5.6
PBC 356	241	176	6.2	5.9	60	1504	508	128	10.5	8.4	205	15	0	16.7	3.2	3.5	2.8
Andalus	367	281	12.7	5.0	61	1564	411	116	17.7	6.3	193	17	0	0.0	6.3	6.2	5.8
Lucky Fortune	231	249	11.2	6.0	83	1454	352	123	15.0	7.4	184	13	0	0.0	5.8	6.3	3.0
Mean	206	182	6.8	4.8	41	1141	319	120	10.5	6.5	130	18					
CV (%)	43	44	14.9	12.8	25	21	22	5	6.0	6.0	15	18					
LSD (0.05)	316	105	2.0	1.3	21	560	170	18	1.2	0.8	4						

[1]DAS = days after sowing.
[2]Disease screening was carried out in separate greenhouse trials using Taiwan pathogen strains. ChiVMV = chili veinal mottle virus, BS = bacterial spot, PB = phytophthora blight. Numbers are the percent resistant plants after inoculation.
[3]BS = bacterial spot. Scores are diseased leaf area according to the Barrett-Horsfall scale and range from 0 (healthy) – 11 (100% disease). Resistant check PBC137 scored 1.8, 1.8, 1.6 for races 1,2,3, respectively.
[4]NT = not tested.

seed production with environmentally stable A-lines (male sterile parent lines). Assuming a single-gene system, of the six possible cytoplasmic-nuclear genotype combinations, only one is sterile (Table 21).

Commercial utilization of CGMS for hybrid seed production starts with the construction of isogenic lines incorporating the recessive *rf1 rf1* maintainer gene: one version (the A-line) carries the S cytoplasm, and is therefore sterile, while the other version (the B-line) contains the N cytoplasm, and is therefore fertile. Pollination of the sterile A-line by the male fertile B-line produces the next generation of male sterile seed, while the B-line is propagated via self-pollination.

In 1996, the AVRDC received five years of funding from the Seminis Company to transfer CGMS materials to selected chili and sweet pepper inbred lines. The CGMS materials were donated by Choong Ang Seed Co. under a restricted-use agreement. Each year the AVRDC pepper unit testcrossed 10 to 15 tropically adapted chili pepper lines to a Korean CGMS A-line to determine if they were maintainer B-lines or restorer R-lines. Based on testcross results, potential B-lines were backcrossed to the male sterile F_1 to begin the process of A-line conversion. From 1996 to 2001, 86 pepper lines were test-crossed to the male sterile source and then the F_1 were evaluated for male sterility. Of the 86 F_1, 40 were fertile, 28 were sterile, and 18 segregated for sterility. Six stable maintainer B-lines (Tumpang, Tit Paris, 9907-9611,

Table 21. *Cytoplasmic-nuclear genotypes.*

Cytoplasmic genotype	Nuclear genotype	Fertility	Line classification
S (sterile)	*Rf1Rf1*	Yes	R-line (restores fertility in progeny)
S	*Rf1rf1*	Yes	
S	*rf1rf1*	No	A-line (no viable pollen produced)
N (normal)	*Rf1Rf1*	Yes	R-line (restores fertility in progeny)
N	*Rf1rf1*	Yes	
N	*rf1rf1*	Yes	B-line (maintains sterility in progeny)

Arunalu, Kunja, and Cayenne Large Red Thick) were crossed to the source of male sterility and backcrossed five to six times to their respective maintainer lines (Table 22). The six cytoplasmic male sterile (CMS) A-lines and their respective maintainer B-lines have been in high demand from the AVRDC pepper breeding program. Since May 1999, 32 seed requests from 14 countries have been shipped, and may constitute the foundation of a hybrid pepper variety development and seed production program for the recipients.

Three of the maintainer B-lines and their respective CMS A-lines were crossed to restorer R-lines 9852-100 and 9852-110, and the F_1 hybrids were measured for yield and horticultural characters (Table 23). A randomized complete block design with three replications and generally 10 plants per plot was used. Contrasts of CMS A-lines and maintainer B-lines for horticultural characters indicated significant differences in the impact of the S vs. N cytoplasms in two of the three pairs, and across all three pairs in a combined analysis, particularly for fruit length and fruit weight (Table 24). Similarly, significant differences were detected between the two pollen parent lines in their impact on fruit length and fruit weight (Table 24, contrast [E1,2,3,4,5,6] vs. [E7,8,9,10,11,12]). While significant differences due to the pollen parent are to be expected, a noticeable influence of the cytoplasmic factor (outside of the male sterility) was a surprise. Potential causes of these anomalous differences may include:

- insufficient backcrossing to make the CMS A-line and maintainer B-line pairs more nearly isogenic;
- inadequate replication, randomization, or other experimental design limitation;
- genuine influence of the different cytoplasms on plant growth and development.

Table 22. *Conversion of maintainer B-lines to cytoplasmic male sterile A-lines, 1996-2001.*

Variety	B-line	A-line	Pedigree	Traits/Resistances[1]
Tumpang	PBC534	CCA 4261	Seungchon(cms)/Tumpang*5	CMV tol., 15 x 1.6 cm fruit size
Tit Paris	PBC380	CCA 4757	Seungchon(cms)/PBC380*6	12 x 1.2 cm fruit size
9907-9611	9907-9611	CCA 4758	Seungchon(cms)/9907-9611*6	ChiVMV tol., BW tol., good GCA
Arunalu	PBC483	CCA 4759	Seungchon(cms)/Arunalu*6	Vigorous, 8 x 0.8 cm fruit size
Kunja	PBC362	CCA 4916	Seungchon (cms)/Kunja*5	TMV res., high yield
Cayenne Large Red Thick	PBC292	CCA 4917	Suwon (cms)/Cayenne Large Red Thick*5	Tolerant to mites

[1]CMV = cucumber mosaic virus, ChiVMV = chili veinal mottle virus, BW = bacterial wilt, GCA = general combining ability, TMV = tobacco mosaic virus, GCA = good combining ability.

Table 23. *Horticultural characters of maintainer B-lines and CMS A-lines crossed to restorers 9852-100 and 9852-110.*

Code no.	Parent	Line cross	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Vegetative fresh weight (g/plant)	Marketable yield (g/plant)	Total yield (g/plant)
CCA4927	PBC380 × 9852-100	B × C	9.5	1.4	6.0	642	230	550
CCA4928	9907-9611 × 9852-100	B × C	9.7	1.2	4.8	1022	389	780
CCA4929	PBC483 × 9852-100	B × C	9.1	1.2	4.5	864	283	560
CCA4930	PBC380 × 9852-110	B × C	9.4	1.4	5.3	1195	295	630
CCA4931	9907-9611 × 9852-110	B × C	9.5	1.2	4.5	1424	262	598
CCA4932	PBC483 × 9852-110	B × C	8.6	1.1	4.2	1034	235	534
CCA4933	CCA4757 × 9852-100	A × C	8.0	1.4	4.6	760	281	584
CCA4934	CCA4758 × 9852-100	A × C	8.8	1.2	4.5	1008	233	501
CCA4935	CCA4759 × 9852-100	A × C	9.6	1.2	4.6	960	446	751
CCA4936	CCA4757 × 9852-110	A × C	8.5	1.3	4.7	977	247	532
CCA4937	CCA4758 × 9852-110	A × C	8.2	1.1	3.8	1062	271	540
CCA4938	CCA4759 × 9852-110	A × C	8.8	1.2	4.0	1346	300	584

Table 24. *Contrasts in horticultural characters between cytoplasmic male sterile A-line versus maintainer B-line when used as seed parent in hybrid combinations.*

Contrast	Fruit length (cm)	Fruit width (cm)	Fruit weight (cm)	Vegetative fresh weight (g/plant)	Marketable yield (g/plant)	Total yield (g/plant)
Contrast E1 vs E7	**	NS	**	NS	NS	NS
Contrast E2 vs E8	**	NS	NS	NS	**	**
Contrast E3 vs E9	NS	NS	NS	NS	**	**
Contrast E4 vs E10	**	*	*	*	NS	NS
Contrast E5 vs E11	**	*	*	**	NS	NS
Contrast E6 vs E12	NS	NS	NS	*	NS	NS
Contrast (E1,2,3) vs (E7,8,9)	**	NS	**	NS	NS	NS
Contrast (E4,5,6) vs (E10,11,12)	**	NS	**	NS	NS	NS
Contrast (E1,2,3,4,5,6) vs (E7,8,9,10,11,12)	**	NS	**	NS	NS	NS

^{NS}, *, ** Differences among means nonsignificant, and significant at 5% and 1% levels, respectively.

This experiment cannot distinguish among these sources, but the possibility that the cytoplasm has pleiotropic effect on hybrid performance should be considered, as it may influence the validity of combining ability studies which use fertile (N cytoplasm) parents to identify the most promising candidates for A-line conversion.

Project 2. Off-season onion and garlic

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

Project Coordinator: S Shanmugasundaram

High yielding onions 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 varieties for short-day, tropical conditions is the overall objective of this study.

Forty selections (20 red, 19 yellow, and one white) were evaluated along with one red and three yellow check varieties. A randomized complete block design with two replications was used. Each plot had 30 plants. Seeds were sown on 14 Sept. 2000. Seedlings were transplanted on 20 Nov. 2000 in plots of three rows on 1-m-wide beds with spacing between and within each row of 15 cm and 10 cm, respectively.

Six out of 20 red onion lines had significantly higher yields than the check variety, Red Creole (Table 25). All red onion lines matured in 125 to 135 days. Among the red onion lines, selections TA471(A)-N, AC724(A)-N and Red Creole-A-N appear promising for yield and quality characteristics, and therefore, seeds of these selections will be increased for multilocation testing.

Table 25. *Performance of high yielding, red onion lines and check variety at AVRDC, transplanted 20 Nov. 2000.*

Entry	Marketable yield (t/ha)	Marketable bulb no. (%)	Average bulb size (g)
TA471 (A)-N	101.0 a[1]	93	359 a
AC724 (A)-N	64.0 b	98	273 b
TA215-E-N	51.0 b	64	320 ab
Red Creole-A-N	47.0 b	78	244 bc
TA364-CST-C-N	45.0 b	72	220 bc
TA487 (A)-N	45.5 b	53	261 b
Red Creole (ck)	20.5 c	35	209 c
Mean of all red lines	37.0	65	210
CV (%)	23	18	13

[1]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

Six of 19 yellow onion lines produced similar yields as check varieties, Texas Grano 502 and Superex, and matured in 110 days, 10 days earlier than the check varieties (Table 26). None of the lines could match the yield of California 606. Selection AC835(A)-C appears most promising among the AVRDC lines and seed multiplication of the line is in progress.

White onion AC546(E)-C was the earliest maturing line (105 days) with a yield of 33 t/ha (81% marketable bulbs), but had small bulbs (180 g).

Fifteen new crosses were made among red onion lines to improve pungency and yield. Seven crosses were made between yellow and red onion lines to introduce early maturity genes into red onion.

Table 26. *Performance of selected high yielding, early maturing, yellow onion lines and check varieties at AVRDC, transplanted 20 Nov. 2000.*

Entry	Marketable yield (t/ha)	Marketable bulb no. (%)	Average bulb size (g)
AC835 (A)-C	91.5 b[1]	97	320 b
AC731 (A)-C	61.5 c	75	285 b
Yellow Granex-C-F-C	58.0 c	87	247 b
AC448-C-A-N	54.5 c	73	308 b
TA377-CST-G-N	48.5 c	88	208 c
AC713 (A)-C	47.5 c	86	392 a
California 606 (ck)	113.0 a	96	433 a
Texas Grano 502 (ck)	57.0 c	67	389 b
Superex (ck)	85.5 c	90	369 a
Mean of all yellow lines	51.5	76	293
CV (%)	19.5	15	17.1

[1]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

Improvement of storability in onion

Postharvest loss of onion bulbs is severe in the hot and humid conditions of the tropics. Therefore, improvement of storability in onion is one of the primary breeding objectives at AVRDC.

A total of 207 onion lines were planted during Oct. 2000. Mature bulbs were harvested, topped, and the healthy bulbs were kept in nylon net bags. The bags with bulbs were placed in a storage room under ambient conditions for three months, beginning on 19 Apr. 2001. Among them, 26 sib-mated lines were replicated twice with 30 bulbs per replication; 36 F_2 populations and 145 F_3 were without replication and number of bulbs varied from 50 to 150 and 30 to 180 bulbs per entry, respectively. The mean temperature and relative humidity in the storage room were 28±3 °C and 72±10%, respectively.

All 11 selected lines stored as well as popular storage variety Red Creole (Table 27). Seven onion lines had significantly better storability compared to the check variety California 606. Sib-mated lines AC448P(3)ST-3-A-C and AC429P(R5)ST-2-A-N had "good" storability (defined as <18% storage loss) and medium large bulbs. Cross combinations of OC210 (AC50 × Serrana), OC251 (Red Pinoy × Cebola Embrapa Brasil), and OC267 (Baswant × Red Pinoy) had good storability in F_2 tests (data not shown). Selections for good storability were made in these populations and will receive further purification.

Of the 145 F_3 lines tested, 30 promising entries with good storability were selected. These are: OC172-23-0, OC175(LR)-21-0, OC175(LR)-25-0, OC199-B-N, OC203-1-0, OC203-5-0, OC203-A-N, OC-206-7-0, OC208-1-0, OC211-B-N, OC211-4-0, OC211-D-N, OC215-4-0, OC215-7-0, OC215-13-0, OC235-2-0, OC238-4-0, OC239-5-0, ST3-CG-2, ST4BC1F1, ST4-NB-2, ST9-NB-3, ST9-NB-7, ST9-NB-8, ST9-0-2, ST12-NB-1, ST12-NB-2, ST14-0-2, ST27-NB-1. All these entries had improved storability with less than 25% storage loss following three months of storage under ambient conditions.

Table 27. *Promising sib-mated lines for good storability.*

Entry	Storage loss[1] (%)	Average bulb wt. (g)	Bulb color
AC448P(3)ST-3-A-C	14.5 f[2]	182 a-g	Yellow
AC429P(R5)ST-2-A-N	17.5 ef	250 a-d	Yellow
TA271P(2)ST-1-A-N	19.2 d-f	176 a-g	Yellow
ST(E)-N	19.7 d-f	162 d-g	Yellow
AC119-C-I-C	22.3 c-f	146 e-g	Red
AC446P(3)ST-2-B-N	23.1 c-f	182 a-g	Yellow
AC431P(2)ST-4-B-N	25.0 c-f	185 a-g	Red
ST(4)-0	27.6 b-f	148 e-g	Yellow
AC319P(1)ST-2-B-C	29.7 b-f	139 fg	Red
AC145-B-C	37.2 b-f	134 fg	Dark red
TA377-CST-G-N	31.2 b-f	228 a-e	Yellow
California 606	68.0 ab	269 a	Yellow
Red Creole	41.1 b-f	154 dg	Red
Mean of 26 entries	41.3	194	
CV (%)	38	18	

[1]Bulbs were stored for three months under ambient conditions with 28±3 °C and 72±10% RH.
[2]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

Yield improvement of garlic through virus elimination

Garlic is a vegetatively propagated crop and is highly susceptible to infection by viruses. The accumulation of viruses in cloves to be used for crop production retards plant growth and ultimately causes severe yield loss. In previous studies, AVRDC has refined its protocols for eliminating viruses from garlic lines via meristem-tip culture and documented the dramatic increases in yield possible through the use of virus-free planting material. The objectives of this research were to evaluate the yield potential of meristem-derived virus-free garlic planted in the open field; to track the patterns of virus reinfection as the garlic is grown without protection over several crop generations; and to evaluate the yield potential of meristem-derived planting material following successive generations of propagation under unprotected conditions.

Seven garlic varieties were rendered virus-free via meristem-tip culture, and were maintained in a 32-mesh screenhouse. These virus-free clones (designated VF-0), their original virus-infected clones, and the virus-free clones grown in the open field for one (VF-1), two (VF-2), or in some cases, three (VF-3) generations, were planted in the open field on 24 Oct. 2000 using a randomized complete block design 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. Samples of fifteen leaves were taken at random for each cultivar, and tested for the presence of five viruses (shallot latent virus [SLV], onion yellow dwarf virus [OYDV], leek yellow stripe virus [LYSV], garlic common latent virus [GCLV], and allexivirus) using an enzyme-linked immunosorbent assay (ELISA). Assay of original VF clones, maintained in nethouses, confirmed the virus-free status of all viruses except the allexivirus. Plots were harvested 6 Apr. 2001; fresh bulb yield per plot was determined, and converted into equivalent tons per hectare.

Yields of entries are presented in Table 28. All VF materials yielded higher in open field planting than non-VF checks, except for G29, which showed a rapid rate of re-infection and consequent severe yield reduction. For lines G180, G176 and G29, yields were maintained through successive generations as lines were propagated in the open. Declines in yields were noted for other lines. Significant differences on bulb yield were found as an effect of variety, generation, and the interaction of variety × generation, as corroborated in data regarding reinfection patterns.

ELISA for presence of viruses produced positive reactions for allexivirus in virtually all samples (data not shown). Testing the re-infection rate of four of the varieties (Table 29) indicated that LYSV and OYDV re-infected the VF garlic plants most rapidly, while SLV and GCLV reestablished themselves at much slower rates. This may be due to the relative absence of the virus or its vectors in the environment, or to the ability of the host to resist or retard establishment of the virus. Percentage virus infection of VF seed bulbs that were continuously planted in open field for four generations (VF-3) were generally higher than bulbs of the same line exposed only one year (VF-0), but they still had lower infection rate than the checks. Low sampling rates may be responsible for the absence of clear trends of re-infection across generations. Significant differences among varieties in susceptibility to virus re-infection could not be discerned.

Table 28. *Bulb yields (t/ha) of original materials, meristem-derived virus-free materials (VF-0), and successive generations propagated under open field conditions at AVRDC, transplanted 24 Oct. 2000.*

Entry	Original	VF-0	VF-1	VF-2	VF-3
G180	10.6 c[1]	16.9 a[z]	15.5 ab	14.6 b	17.3 a
G176	9.0 c	13.9 a	11.0 b	13.1 a	14.3 a
G54	7.2 c	11.4 a	10.1 ab	7.8 bc	–[2]
G29	7.9 b	5.8 c	12.7 a	12.6 a	–
TA275	1.7 b	5.2 a	3.6 ab	4.4 a	–
TA294	7.6 a	7.1 ab	4.0 b	4.6 ab	–
TA313	0.9 d	4.2 a	1.8 c	3.3 b	–

[1]Mean separation within rows by Duncan's multiple range test, $P \leq 0.05$.

[2]Not determined.

The present study confirms that it is possible to increase the yield of garlic through virus elimination, and thereby increase the income of farmers. Additionally, some of this yield advantage is retained through several generations of unprotected propagation. Erratic patterns of virus reinfection of garlic plants over several years of exposure to unprotected conditions illustrates the complex and somewhat unpredictable interactions among host genotype, virus, vector, and seasonal environment in reversing the virus-free status of the garlic crop.

Table 29. *Percentage of cloves with virus infection in original materials, meristem-derived virus-free materials (VF-0), and successive generations propagated under open field conditions at AVRDC, transplanted 24 Oct. 2000.*

		Virus infection (%)[1]			
Entry	Generation	SLV	GCLV	OYDV	LYSV
G180	Original	0.0	0.0	100.0	93.3
	VF-0	0.0	0.0	40.0	80.0
	VF-1	6.7	0.0	66.7	93.3
	VF-2	13.3	0.0	73.3	93.3
	VF-3	0.0	0.0	46.7	93.3
G176	Original	53.3	80.0	80.0	86.7
	VF-0	0.0	6.7	73.3	80.0
	VF-1	13.3	0.0	46.7	73.3
	VF-2	46.7	0.0	33.3	20.0
	VF-3	6.7	6.7	13.3	73.3
G29	Original	93.3	6.7	100.0	100.0
	VF-0	80.0	0.0	100.0	100.0
	VF-1	6.7	0.0	66.7	80.0
	VF-2	6.7	0.0	46.7	80.0
G54	Original	86.7	0.0	86.7	86.7
	VF-0	13.3	0.0	26.7	80.0
	VF-1	0.0	0.0	60.0	80.0
	VF-2	33.3	0.0	46.7	66.7

[1]SLV = shallot latent virus, OYDV = onion yellow dwarf virus, LYSV = leek yellow stripe virus, GCLV = garlic common latent virus.

Project 3. Legumes for crop diversification

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

Project Coordinator: S Shanmugasundaram

High yielding, MYMV-resistant mungbean lines for South Asia

Mungbean is one of the major pulses grown in South Asia. It is rich in protein and iron, and is easily digestible. The average yield of mungbean in South Asia is only 300-400 kg/ha with the major constraint being mungbean yellow mosaic virus (MYMV). Low yields of mungbean lead to reduced income for farmers and higher market prices for consumers, which in turn reduce the accessibility of this nutritious pulse to rural and urban poor.

AVRDC, in collaboration with researchers in Pakistan, has developed MYMV-resistant mungbean lines that yield up to 2.5 t/ha maturing in 65 to 70 days. Through South Asia Vegetable Research Network (SAVERNET), these lines are being evaluated in six strategic locations. The following is a summary of highlights for this project from 1997 to present.

A sub-regional consultation workshop was held at the Indian Agricultural Research Institute (IARI) from 7–11 Sept. 1997 in which 60 participants from six countries developed an implementation strategy for the project. This led to training at the Asian Regional Center of AVRDC for 16 senior scientists from six countries from 23–30 Mar. 1998. They agreed on methodology for implementing multilocation trials.

Sixteen varieties for summer and 17 varieties for *kharif* (rainy season) were subsequently evaluated in 17 locations in six countries. In three years, 64 trials were successfully conducted by partners (31 summer, 15 rainy seasons, and 18 dry seasons). The increase in yield of test entries over the local check was 1– 373%. Some of the entries matured in only 46–55 days compared to local checks requiring 70–83 days to mature. Entries ML267, ML613, NM92 and VC6372(45-8-1), NM94, and VC6368(46-40-4) were consistently MYMV-resistant/tolerant across locations.

The analysis of variance in these trials showed a highly significant genotype x environment (GxE) interaction. Summer trials and the rainy season trials were analyzed using additive main and multiplicative interaction (AMMI) analysis to understand the GxE interaction components. Photothermal variations and presence of MYMV appeared to play a major role in GxE interaction during the summer, when MYMV is most active. Locations such as Bhutan, Islamabad in Pakistan, and Sri Lanka had very little MYMV. Ishurdi in Bangladesh as well as Punjab and Pantnagar in India were hot spots for MYMV. Based on this interaction analysis, adaptations of specific varieties for different locations were identified. Indian varieties formed one group; AVRDC/Pakistan varieties formed another group.

In Bangladesh, Bangladesh Agricultural Research Institute and Bangabandhu Sheik Mujibur Rahman Agricultural University have released two new varieties, BARIMUNG 5 (NM92) and BU MUG 1 (VC6372[45-8-1]). Nearly 10 tons of seeds of both varieties have been produced and extended to farmers.

In India, IARI has released Pusa Vaishal, also called Pusa Bold (NM92). Seeds of this release are being multiplied for farmer adoption in northwest India. In Tamil Nadu, farmers are already growing Pusa Bold (NM92) and 5 tons of seeds were produced for feeding trials by Avinashilingam Deemed University in Coimbatore, India. Furthermore, Punjab Agricultural University has submitted applications for the release of NM94; they have planted 20 ha of this release for seed multiplication.

In supporting studies, a socio-economic survey was completed in Bangladesh, India, and Nepal. The major findings of the study include: farmers with irrigated fields adopted improved varieties and technologies faster than farmers with rainfed fields; yields with irrigation were substantially higher than without; the price of mungbean increased over time faster than rice; mungbean is predominantly a summer and kharif season crop in northern India, Bangladesh and Pakistan, whereas in southern portions of this region it is cultivated in summer, kharif and dry seasons; and mungbean can be incorporated into wheat-rice cropping systems. Other supporting research reported that MYMV isolates from Bangladesh and northern India showed very little variation.

Plans are underway to expand production of the MYMV-resistant, early maturing lines to 1 million additional ha in the Indo-Gangetic Plains by 2005.

Effect of temperature and daylength on total biomass, yield and seed size of vegetable soybean

Temperature and daylength are two major environmental factors that determine the growth and development of soybean. Their influences on flowering as well as pod and seed development have previously been studied. However, their influences on total biomass production, yield and seed size in vegetable soybean have not been investigated. Since vegetable soybeans can be grown year-round in the tropics and subtropics, information on these factors would be valuable.

Two genotypes, Kaohsiung No. 1 (KS#1) and Kaohsiung No. 5 (KS#5), the two most popular cultivars in Taiwan, were used. They were evaluated in spring, summer and autumn seasons in 1998 and 2001; and in spring and autumn seasons in 1999 and 2000. The plot size was 5 m x 2 m and the harvested plot size was 5 m x 1 m, except in Autumn 2001 when the plot size was 2 m x 2 m and the harvest plot size was 2 m x 1 m. Plant population density was 400,000 plants/ha for spring and summer trials, and 600,000 plants/ha in autumn.

Observations were made on days to first flower (R_1) and days to maturity ($R_{6.5}$). At $R_{6.5}$ growth stage (vegetable soybean stage), the following data were collected from five randomly selected plants: pod length and pod width of two-seeded pods, 100-green bean weight, total biomass, total green pod weight, and graded pod weight. About 250 g of graded pods from each harvested plot was used to determine the dry matter, protein, oil and sugar by using near infrared spectrophotometry (NIRS). The pod color was visually rated using a color chart. Daily means of air temperatures, soil temperatures (10 and 30 cm below surface), and solar radiation levels were gathered from AVRDC weather station records. Daylength was determined for the Tainan area according to Astronomical Almanac 1985 (published by Central Weather Bureau in Taiwan).

Agronomic data (dry matter and pod color), air temperatures, and daylengths were collected for all trials. However, oil, protein, and sugar content data were collected only for five seasons (three seasons in 1998 and two seasons in 1999).

Correlation parameters were estimated using Pearson correlation coefficients. Air and soil temperatures were highly correlated, therefore, it was decided to use only air temperatures to study the relationship with other traits.

The range of solar radiation over this study was 154 to 8857 W-hour/m^2/day. The range of daily mean air temperatures was 18.0–31.4 °C, and the range of daylength was 10.7–13.6 hours.

The cumulative solar radiation, daylength, and mean temperature for three growth periods (whole crop [from sowing to harvest], pre-flowering, and post-flowering) were used to determine correlations with vegetable soybean traits. Similarly, the average solar radiation, daylength, and temperature for the above listed three growth periods were used to determine correlations with vegetable soybean traits.

For those traits where the correlations for KS#1 and KS#5 were statistically similar, the data for the two genotypes were pooled and an overall correlation was determined (Tables 30, 31 and 32). For the other traits for which the correlations for KS#1 and KS#5 were statistically different, either for cumulative or for average daylength, temperature or solar radiation, the results for KS#1 and KS#5 are given separately (Table 33).

Increased levels of solar radiation led to an increase in total biomass, total pod yield and graded pod yield, but a decrease in the number of pods/500 gm (Table 30). It also led to paler pod color. Higher cumulative solar radiation levels prior to flowering significantly increased the days to flowering.

Data presented in Table 31 shows that daylength (both cumulative or average) was positively correlated to total biomass, total pod yield, and graded pod yield. Longer daylength also delayed flowering and maturity, in general.

Daylength was negatively correlated to the number of pods/500 gm, indicating that individual pods were heavier as daylength was increased. After flowering, pod length significantly increased as cumulative or average daylength increased (data not shown). Longer daylength was also correlated to lower sugar contents (Table 31).

For cumulative temperature, the graded pod yield increased with increased temperature for all three periods. However, total pod yield increased only with increased temperature during the pre-flowering period. Days-to-maturity was prolonged with higher post-flowering temperature (Table 32).

However, the relationships with average temperature were different. An increase in post-flowering average temperature significantly increased

Table 30. *Correlations between solar radiation[1] and vegetable soybean traits in genotypes KS #1 and KS #5, AVRDC, 1998–2001.*

Growth period	Graded pod yield	Total pod yield	Total biomass	Days to flower	Days to maturity	Pod no./ 500 g	Pod length	Pod width	Sugar	Pod color[2]
					Cumulative					
Whole crop	0.48*	0.64**	0.83**	0.33	0.50*	-0.62**	0.27	-0.21	-0.19	0.64**
Pre-flowering	0.39	0.60**	0.73***	0.48*	0.52*	-0.66**	0.27	-0.02	-0.19	0.57*
Post-flowering	0.49*	0.59**	0.80***	0.14	0.41	-0.50*	0.23	-0.36	-0.16	0.61**
					Average					
Whole crop	0.43	0.53*	0.76***	0.22	0.22	-0.46*	0.07	-0.34	0.01	0.58*
Pre-flowering	0.26	0.34	0.45*	-0.17	0.33	-0.35	-0.15	-0.19	-0.03	0.79***
Post-flowering	0.47*	0.58**	0.83***	0.45*	0.13	-0.47*	0.23	-0.36	0.03	0.31

[1]Range of solar radiation during the study was 145–8857 W-hour/m^2/day.
[2]Pod color rated on 1–6 scale with 1 = very dark green-yellow and 6 = pale green-yellow.
*,**,*** Differences significant at $P \leq 0.05$, 0.01 and 0.001, respectively.

Table 31. *Correlations between daylength[1] and vegetable soybean traits in genotypes KS #1 and KS #5, AVRDC, 1998–2001.*

Growth period	Graded pod yield	Total pod yield	Total biomass	Days to flower	Days to maturity	Pod no./ 500 g	Sugar
				Cumulative			
Whole crop	0.65**	0.84***	0.78***	0.60***	0.83***	-0.68***	-0.62*
Pre-flowering	0.54*	0.71***	0.73***	0.95***	0.49*	-0.54*	-0.48
Post-flowering	0.45*	0.56*	0.46*	-0.08	0.78***	-0.49*	-0.43
				Average			
Whole crop	0.76***	0.81***	0.79***	0.49*	0.50*	-0.37	-0.65**
Pre-flowering	0.59**	0.46*	0.36	-0.29	0.23	0.10	-0.52*
Post-flowering	0.71***	0.83***	0.86***	0.77***	0.54*	-0.56**	-0.54*

[1]Range of daylength during the study was 10.7–13.6 hours.
*,**,*** Differences significant at $P \leq 0.05$, 0.01 and 0.001, respectively.

the graded pod yield, total pod yield, and total biomass. Higher average temperature prior to flowering or for the whole period resulted in earlier flowering (Table 32).

Longer cumulative daylength both for the whole period and prior to flowering, and longer average daylength at post-flowering increased pod length only in KS#5 (Table 33).

Higher cumulative air temperatures, in general, reduced pod widths, and significantly so during the post-flowering and whole growth periods of KS#5. Higher cumulative temperatures at pre-flowering reduced sugar content in KS#1 (Table 33).

Higher average temperatures during the post-flowering and whole periods decreased pod width. Higher average temperatures during the pre-flowering stage reduced pod weight but increased pod width in KS#5. Higher average temperatures generally reduced sugar levels, and significantly so during the post-flowering period for KS#1 (Table 33).

A significant correlation between cumulative daylength for the whole growth period and protein content was observed ($r^2 = 0.515$, $P \leq 0.05$). But for oil content, the correlation was only significant for the average daylength for the pre-flowering period. The above was for the pooled data for both genotypes. Individual genotypes had no relationship.

Although the average temperature (post-flowering) was significantly correlated with graded pod yield, at temperatures between 20.4 °C and 29.6 °C, the correlations for the two genotypes were insignificant. Therefore, it appears that the critical temperatures were either below 20.4 °C and above 29.6 °C (Figures 4 and 5).

Table 32. *Correlations between air temperature and vegetable soybean traits in genotypes KS #1 and KS#5, AVRDC, 1998–2001.*

Growth period	Graded pod yield	Total pod yield	Total biomass	Days to flower	Days to maturity
			Cumulative		
Whole crop	0.51*	0.38	0.21	-0.39	0.44
Pre-flowering	0.61**	0.47*	0.21	-0.17	0.30
Post-flowering	0.45*	0.34	0.20	-0.45*	0.46*
			Average		
Whole crop	0.39	0.12	-0.04	-0.62*	-0.07
Pre-flowering	-0.01	-0.26	-0.41	-0.90***	-0.25
Post-flowering	0.81***	0.60**	0.48*	0.02	0.23

[1]Range of air temperature during the study was 18.0–31.4 °C.
*,**,*** Differences significant at $P \leq 0.05$, 0.01 and 0.001, respectively.

Table 33. *Correlations between daylength and air temperature[1] on vegetable soybean traits in genotypes KS#1 and KS#5, AVRDC, 1998–2001.*

	Daylength						Air temperature									
	Pod length		Pod width		Pod color[2]		Pod no./500g		Pod length		Pod width		Sugar		Pod color	
Growth period	KS#1	KS#5	KS#1	KS#5	KS#1	KS#5	KS#1	KS#5	KS#1	KS#5	KS#1	KS#5	KS#1	KS#5	KS#1	KS#5
									Cumulative							
Whole crop	0.50	0.72*	0.20	-0.30	0.39	0.58	0.05	0.06	0.01	-0.14	-0.26	-0.65*	-0.64	-0.54	0.67*	0.28
Pre-flowering	0.46	0.86**	0.10	-0.15	-0.20	0.09	0.20	0.29	0.08	-0.11	-0.21	-0.62	-0.86**	-0.69	0.31	-0.08
Post-flowering	0.29	0.22	0.19	-0.30	0.78*	0.76*	0.00	-0.03	-0.01	-0.15	-0.26	-0.63*	0.54	-0.45	0.73*	0.41
									Average							
Whole crop	0.42	0.44	-0.23	-0.62	0.38	0.37	0.38	0.50	-0.25	-0.60	-0.51	-0.69*	-0.42	-0.23	0.49	-0.09
Pre-flowering	0.05	-0.25	-0.46	-0.76*	0.70*	0.27	0.55	0.66*	-0.37	-0.80**	-0.32	-0.34	-0.15	0.04	0.40	-0.08
Post-flowering	0.47	0.69*	-0.09	-0.43	0.12	0.30	-0.04	0.05	0.04	-0.07	-0.56	-0.90***	-0.82*	-0.67	0.45	-0.09

[1]Ranges of daylength and air temperature during the study were 10.7–13.6 hours and 18.0–31.4 °C, respectively.
[2]Pod color rated on 1–6 scale with 1 = very dark green-yellow and 6 = pale green-yellow.
*,**,*** Differences significant at $P \leq 0.05$, 0.01 and 0.001, respectively.

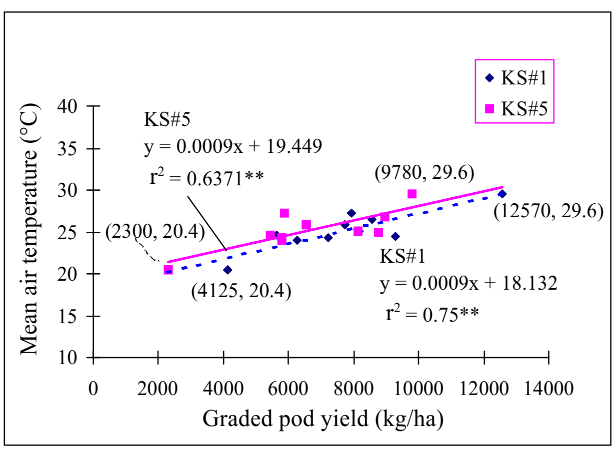

Figure 4. *Correlations between graded pod yield with average temperature of post-flowering stage for KS#1 and KS#5, AVRDC, 1998–2001.*

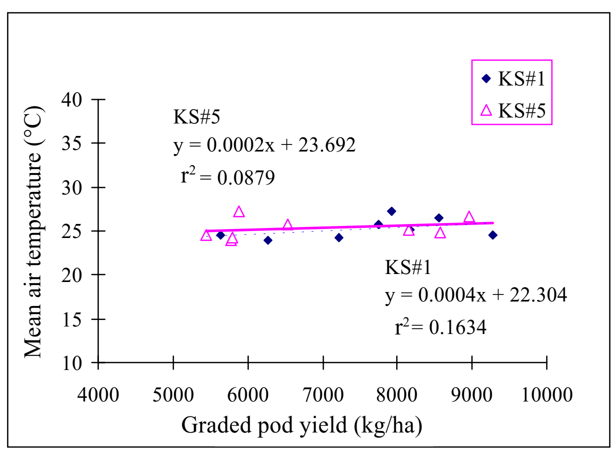

Figure 5. *Correlations between graded pod yield for KS#1 and KS#5 when average temperatures were 20.4 to 29.6˚C during post-flowering stage, AVRDC, 1998–2001.*

Program II

Year-round vegetable production systems

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

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

The objectives of Program II are to:

- collect and improve technologies—including crops and production practices—for peri-urban and homestead production systems;
- develop cost-effective and safe means of controlling vegetable pests, with reduced reliance on pesticides;
- develop a better understanding of 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

One of the major thrusts of AVRDC is development and transfer of technologies for year-round production of vegetables. Emphasis is being placed on technologies for tomato production during the hot-wet season and on improving cultural practices for year-round leafy vegetable production. Considerable effort is being devoted to use of organic fertilizers as a source of nutrients for vegetables and at the same time provide a means of recycling organic municipal and farm wastes.

Project Coordinator: LL Black

Effects of rain shelter, grafting, and variety on yield of summer tomato

Low yields of tomato during the hot-wet season are attributed to unfavorable conditions that include abiotic stresses (e.g., high temperatures, flooding, and physical impact of heavy rain on plants and soil), as well as biotic stresses (especially bacterial wilt [BW]). The potential of reducing seasonality in tomato production and increasing farm income seems to be promising if the submarginal production during the humid summer months can be enhanced.

In recent years, field trials at AVRDC have evaluated various combinations of improved crop management practices for increasing production of summer tomato. These practices involved choosing appropriate planting dates and utilization of crop management practices such as heat-tolerant and disease-resistant varieties, rain shelters, grafted plants, and mulches. The objectives of this study were to compare two promising varieties as well as to evaluate AVRDC's evolving grafting and rain shelter technologies. This year's trials included evaluation of shelters with and without netting enclosures along sides.

Two AVRDC heat-tolerant tomato varieties were compared. CL5915-206D is indeterminate, immune to tomato mosaic virus (ToMV), and has an intermediate level of BW resistance. CHT501 F_1 is determinate, immune to ToMV, and has a lower level of resistance to BW. Tomato seedlings were transplanted to the field on 10 July 2001 at the AVRDC headquarters research farm in Taiwan.

Plots consisted of raised beds that were 30 cm high, 1.4 m wide (2.4-m row spacing), and 5 m long. Twenty plants per plot were transplanted in double rows with spacings of 80 cm between rows and 50 cm between plants in the row. There were three rain shelter treatments, i.e., shelter with open sides, shelter with sides enclosed by netting, and no shelter. Each shelter was 5 m long, 2.4 m wide and 2.4 m high with an arched top. The frames were constructed from 1.25 cm (inside diameter) galvanized pipe. The arched top was covered with ultraviolet-resistant clear polyethylene film. For the enclosed shelters, 32-mesh white nylon net was used for the sides. There were two grafting treatments for both varieties: non-grafted plants and plants grafted onto eggplant rootstock, Surya (EG203). Surya is resistant to BW and tolerates flooding.

Plant beds were covered with silver polyethylene mulch with a layer of rice straw on top. For the indeterminate variety CL5915-206D, side branches were pruned regularly and two main stems of each plant were allowed to develop on a bamboo trellis. For the determinate variety CHT501, only lower branches were pruned and four or more stems were allowed to develop. The branches were supported on a suspended horizontal 12 x 12-cm mesh net trellis. Each flower cluster was also treated once with 15 ppm of 4-chlorophenoxyacetic acid (Tomatotone). Weekly applications of insecticide/fungicide mixes were made to manage pests and diseases. Plots were arranged in a randomized complete block design with four replications.

Rainfall was relatively low during the cropping season compared to a 10-year average for this location. Cumulative rainfall during this period (12 July to 30 Oct.) was 978 mm, most of which occurred in September (Figure 6). There was a single rainfall episode on 18 Sept. during which the field was flooded with water over the bed tops for more than 24 hours. Plant survival after flooding was significantly higher in grafted than non-grafted plants of both varieties (Table 34). The effect of rain shelter on plant survival was not significant, except for non-grafted CL5915-206D, which had less survival under enclosed shelters compared to open side shelters and no shelter. About 30% of the non-grafted CL5915-206D plants survived following flooding, whereas none of non-grafted

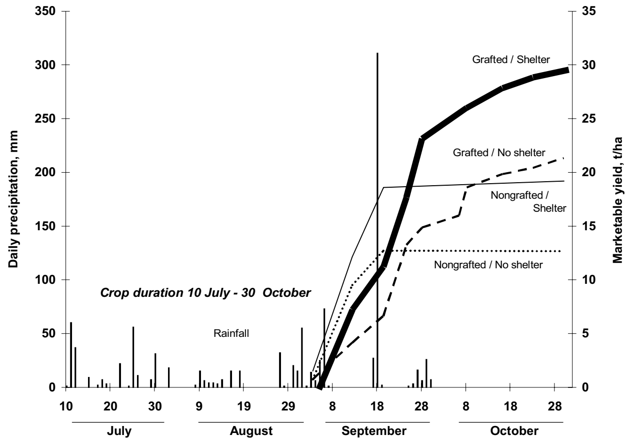

Figure 6. *Effect of rain shelter and grafting on marketable yield of* CHT501, *AVRDC, 2001.*

CHT501 plants survived following flooding regardless of shelter treatment (Table 34). The interaction between tomato variety and grafting was highly significant ($P \leq 0.01$) indicating that the degree of survival is influenced by both factors.

Grafting tomato onto eggplant rootstocks resulted in higher marketable yield than non-grafted plants of both tomato varieties (Table 34). Yields for grafted plants were significantly increased in both the open side and closed side rain shelters. However, before the onset of flooding, non-grafted tomato produced higher yield than grafted plants (Figure 6). This is consistent with previous observations that in the absence of flooding and BW, non-grafted tomato outyields tomato grafted onto eggplant rootstock. Since BW did not occur in this planting, the benefit of grafting was not evident until after the mid-September flood that killed all of the non-grafted CHT501 and 70% of non-grafted CL5915-206D plants.

Marketable yield was significantly influenced by variety, shelter, and grafting. Both grafted and non-grafted plants of the determinate tomato CHT501 produced significantly higher yields than the indeterminate CL5915-206D under all shelter treatments (Table 34). For both varieties, yields of grafted plants were greater than non-grafted plants. The combined effect of grafting and rain shelter was significant in increasing tomato yield as indicated by the higher yields on grafted plants grown under rain shelters. The benefits of grafting and rain shelters are, therefore, evident in tomato production during the hot-wet season in the lowland tropics.

Yields of selected vegetables grown under protective shelters during the cool-dry season

The use of protective structures enhances hot-wet vegetable production in the lowland tropics. To increase the cost effectiveness of these structures year-round, we would like to use them to grow warm season vegetables during the cool-dry season. The objectives of this study were to determine yield of selected vegetables under plastic rain shelters during the cool-dry season and to evaluate the effects of single and combined crop management technologies (raised beds, rain shelters and netting) on yield of summer vegetables grown during the cool-dry season.

Two trials were conducted during the cool-dry season, 2001. The first trial evaluated the yield of cucumber, snow peas, Chinese kale, and lettuce grown with and without shelters and with two irrigation systems (drip vs. furrow). The second trial evaluated the effects of single and combined crop management technologies on yield of okra and yardlong bean.

Study I

The first trial was conducted in a field previously planted with summer tomato under plastic rain shelter

Table 34. *Effects of grafting and rain shelters on plant survival and yield of tomato, AVRDC, transplanted 10 July 2001.*

	Plant survival (%)				Marketable yield (t/ha)			
	CL5915-206D		CHT501		CL5915-206D		CHT501	
Rain protection[1]	Grafted	Non-grafted	Grafted	Non-grafted	Grafted	Non-grafted	Grafted	Non-grafted
RS	99 a[2]	46 b	95 a	0.0 c	13.9 c	4.0 d	29.5 a	18.8 bc
RS + net	100 a	16 c	91 a	0.0 c	16.4 bc	3.0 d	34.0 a	13.9 c
Open	96 a	38 b	90 a	0.0 c	6.6 d	0.5 d	21.3 b	12.8 c

[1]RS = rain shelter with plastic-covered roof and open sides; RS + net = rain shelter with plastic-covered roof and mesh netting along sides; open = no shelter.

[2]Mean separation within row and/or column by Duncan's multiple range test at $P \leq 0.05$.

and no shelter. Crops were planted on raised beds which were 30 cm high, 2.4 m wide (bed top 1.1-1.2 m) and 6 m long. Each crop was planted in double rows on the bed. Row spacing was 80 cm for cucumber and snow peas, 30 cm for lettuce, and 20 cm for Chinese kale. Plant spacings within rows were 50 cm for cucumber, 25 cm for snow peas, 40 cm for lettuce, and 15 cm for Chinese kale. The rain shelter was made of galvanized pipe frame 4.8 m wide, 6 m long, and 2.3 m high. There were two beds per shelter. The tops were covered with a UV-resistant clear polyethylene.

Two irrigation schemes were used to apply water to the crops, i.e, drip irrigation and furrow or ditch irrigation. All crops were transplanted on 21 Dec. 2000. Cucumber and snow peas were supported by a bamboo trellis. Weekly applications of insecticide/ fungicide mixtures were made to manage insect pests and foliar diseases. The 16-treatment combinations were laid out in randomized block design with three replications. The main plot treatments consisted of two irrigation methods (drip vs. furrow) and the subplot treatments were two shelter levels (shelter vs. open).

Chinese kale. There were small differences in marketable yield between rain shelter and open field and between drip and furrow irrigation (Table 35). Mean yield in open field was slightly higher than that in rain shelter, suggesting that rain shelters provide no benefit during the cool-dry season for Chinese kale. Under rain shelter, yield with furrow irrigation was higher than drip irrigation. In open field conditions, the drip-irrigated crop yielded higher than the crop under furrow irrigation. Overall, mean yield with furrow irrigation was slightly higher than drip irrigation, but drip irrigation may have potential for dry season vegetable production in terms of reduced and more efficient water use.

Lettuce. Marketable yield was slightly higher under rain shelter compared to open field (Table 35). Under rain shelter, yield with furrow irrigation was higher than drip irrigation, but in the open field, the type of irrigation had little effect. The mean yield with furrow irrigation was 2.0 t/ha higher than drip irrigation.

Cucumber. The overall mean yield of cucumber was similar between rain shelter and open field, indicating that rain shelter provided no advantage (Table 35). Mean yield was slightly higher (3 t/ha) with furrow irrigation in both rain shelter and open field treatments.

Snow peas. Yield was higher in open field than under rain shelter (Table 35). Under rain shelter, yield with furrow irrigation was 4 t/ha higher than drip irrigation, but in the open field, yields were similar. Overall, mean yield was slightly higher with furrow irrigation.

These results indicate that yields of the vegetables evaluated in this study may be slightly reduced if grown under rain shelters during the cool-dry season. Differences in yield due to irrigation (drip vs. furrow) were small suggesting that drip irrigation can be used to increase water use efficiency. In this study, total irrigation water use was nearly three times higher (41 m^3) with furrow irrigation compared to 14 m^3 with drip irrigation.

Table 35. *Yield of cucumber, snow peas, lettuce, and Chinese kale under rain shelters (RS) and in the open field (OF) with drip and furrow irrigation, AVRDC, transplanted 21 Dec. 2000.*

Shelter	Irrigation	Cucmbr Total yield (t/ha)	Sn. peas Total yield (t/ha)	Ch. kale Mktble yield (t/ha)	Lettuce Mktble yield (t/ha)
Rain shelter	Drip	56	10	16	16
	Furrow	61	14	19	21
	RS mean	59	12	17	19
Open field	Drip	59	18	21	16
	Furrow	61	17	19	15
	OF mean	60	17	20	15
	Drip mean	58	14	18	16
	Furrow mean	61	15	19	18

Study II

The second study evaluated the effects of single and combined crop management technologies for cool season (off-season) production of okra and yardlong bean. The trial was established in a field previously planted with summer tomato. Treatments consisted of two raised beds (30-cm and 40-cm) and three rain shelters (rain shelter with open sides [RS], rain shelter with side netting [RS+Net], and open field [OF]). Raised beds were 2.4 m wide and 5.0 m long. There was a single bed under each shelter. The rain shelters were made of galvanized pipe frame structure; 5.0 m long, 2.4 m wide, 2.4 m high with tops covered with UV-resistant clear polyethylene. Material used to enclose the sides of RS+Net treatment was 60-mesh nylon net.

Okra was transplanted 15 Feb. 2001 and harvested 29 Mar. to 13 June 2001. Yardlong bean was transplanted 23 Feb. 2001 and harvested 1 May to 11 June 2001. Both okra and yardlong bean were planted in two rows per bed. Plant spacing was 50 cm within rows and 60 cm between rows. Insect pests and diseases were managed by weekly spraying of insecticide/fungicide mixtures. Treatment factors consisted of raised beds, rain shelters, and netting for each crop. The average maximum air temperature in the RS+Net treatment was about 4-5 °C higher than the RS and OF treatments. Average minimum temperature was about 1 °C higher.

Okra. In both low and high beds (30 and 45 cm), total fruit weight was higher in the RS+Net treatment compared to the RS and OF treatments (Table 36). Yield in open field was higher than rain shelter (RS) in 30-cm bed. Overall, mean yield was slightly higher in 45-cm bed than in 30-cm bed. With a small yield difference, the high beds may not provide economic advantage due to high labor requirement in preparing and maintaining the beds. The RS+Net treatment appears to provide the greatest benefit to okra. Presumably, the effect of the side netting is due to reduced insect infestation and increased temperatures in the enclosed structures.

Yardlong bean. Marketable pod weight was highest in the RS+Net treatment followed by OF and RS treatments, respectively (Table 36). Overall, mean yield was higher in 30-cm bed compared to 45-cm bed which is the opposite of results observed with okra.

Results of this study show little effect of bed height on yields of okra and yardlong bean during the cool season, and suggest that any benefit would likely be offset by the cost of building and maintaining the higher beds. On the other hand, the use of 60-mesh nylon net enclosed shelters resulted in higher yields of both okra and yardlong bean in comparison with open-sided shelters and no shelters. The yield increase is believed to be due to protection against insect pests and elevated temperatures inside the net enclosed shelters. Net enclosed shelters will be evaluated further during the coming cool season to more clearly identify the basis for the observed yield increase.

Table 36. *Yield of okra and yardlong bean in low and high beds under rainshelters and open field, AVRDC.*[1]

		Okra		Yardlong bean	
Bed	Shelter[2]	Total fruits[3]	Total yield (t/ha)	Mktble pods[3]	Mktble yield (t/ha)
30 cm	RS	154	16	237	64
	RS + N	199	23	313	88
	OF	171	19	303	79
	Bed mean	174	19	284	77
45 cm	RS	156	20	193	52
	RS + N	212	28	257	69
	OF	176	19	236	69
	Bed mean	181	23	230	64
	Shelter mean				
	RS	155	12	215	58
	RS + N	217	26	285	79
	OF	173	19	269	74

[1]Okra was seeded 19 Jan. 2001, transplanted 15 Feb. 2001, and harvested 29 Mar.–13 June 2001. Yardlong bean was seeded 6 Feb. 2001, transplanted 23 Feb. 2001, and harvested 1 May–11 June 2001.
[2]RS = Rainshelter; RS+N = Rainshelter + Net, OF = open field.
[3]Data presented on square meter basis.

Use of liquid and solid nutrient supplements to enhance efficacy of organic fertilizers

Organic fertilizer is the principal fertilizer source in many developing countries. Fertilization technologies need to be developed for these farmers so as to improve vegetable production from the standpoint of both sustainability and profitability.

Vegetable crops grown using organic fertilizer on an N equivalent basis to inorganic fertilizer generally result in reduced plant growth and yields. Previous studies at AVRDC have shown that the use of liquid NPK supplements as starter solutions can boost early growth of cherry tomato, cabbage, and leafy vegetables grown with organic fertilizers. But the effects of starter solution on both inorganic and organic fertilizer treatments were more obvious for early growth than the final yields. Hence, additional liquid NPK supplements or solid inorganic fertilizers that are sidedressed at later stages may be useful. This study set out to develop balanced organic-inorganic fertilization practices, including liquid supplemental fertilizers and times of application that improve the performance of crops grown principally with organic fertilizers. Combinations of liquid NPK supplements and inorganic sidedressings were evaluated.

Crops selected in the study included three types of vegetables: cherry tomato (*Lycopersicon esculentum*) as a long duration crop, head cabbage (*Brassica oleracea* cvg. *capitata*) as a mid-duration crop, and pak-choi (*Brassica rapa* cvg. *chinensis*) as a short duration crop. All experiments were arranged in randomized complete block design with four replications. Organic fertilizers were banded at 10 cm below the surface of beds as a basal application before transplanting or sowing. 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 within Tables 37-41.

For cherry tomato and cabbage, transplants were placed 45 cm apart in twin rows planted on 1.5-m-wide raised beds. Seedlings of cherry tomato line CHT 154 were transplanted on 13 Mar. and 7 Aug. 2001, and harvested beginning on 10 May and 25 Oct., respectively. Seedlings of cabbage varieties Hsia-Chiu (Summer-autumn) and Hsia-Kuang (Summer-glory) were transplanted on 8 Nov. 2000 and 7 June 2001, and harvested on 10 Jan. and 21 Aug. 2001, respectively. Initial growth responses were evaluated using dry weights of tops (leaf and stem) and roots at 12 days after transplanting for common cabbage and 3 weeks after transplanting for cherry tomato. Fruit or head weight was measured at harvest.

For pak-choi, raised beds were 1-m-wide with four rows of plants per bed; in-row spacing was 6.7 cm and the spacing between the rows on the beds was 10 cm. Seeds of local cultivars were sown on 4 Apr. 2001 and harvested on 3 May. At harvest, 30 plants from each plot were sampled and evaluated for plant height, fresh weight, and dry matter determination.

Cherry tomato

The addition of liquid starter solutions to plants fertilized with chicken manure compost (CM) significantly increased leaf dry weight at 3 weeks after transplanting (WAT) compared to CM alone, CM with a basal standard inorganic (SI) application, or the SI fertilizer check (Table 37).

For marketable yields of first three harvests, doubling the amount of CM could increase fruit yield

Table 37. *Effects of chicken manure and inorganic fertilizer treatments on dry weight and yields of cherry tomato, AVRDC, transplanted 13 Mar. 2001.*

	Leaf dry weight at 3 WAT[1]		Marketable yield			
			Harvests 1-3		Harvests 1-6	
Fertilizer treatment	(g/plant)	Index[2]	(t/ha)	Index[2]	(t/ha)	Index[2]
CM[3]	11.1 b[4]	103	19.9 de	96	38.6 de	96
2CM	10.3 b	96	23.5 b-d	114	43.9 a-d	110
CM + Basal	9.9 b	92	16.9 e	82	37.4 e	93
CM + Side 3 WAT[5]	11.0 b	102	19.9 de	96	41.0 c-e	102
CM + Side 9 WAT	9.1 b	85	21.6 cd	105	41.9 b-e	105
CM + St4[6] + Side 3 WAT	16.8 a	156	26.2 ab	127	46.5 ab	116
CM + St4 + Side 9 WAT	14.7 a	137	26.0 ab	126	45.5 a-c	114
CM + St5 + Side 3 WAT	16.7 a	156	27.7 a	134	46.3 a-c	116
CM + St5 + Side 9 WAT	17.1 a	159	27.4 ab	133	48.1 a	120
CM + St5 + Side 3,9 WAT	16.6 a	155	24.6 a-c	119	43.9 a-d	110
CM + St5 + St5 3,9 WAT	15.6 a	146	27.8 a	135	47.7 a	119
Standard inorganic (ck)[7]	10.7 b	100	20.6 de	100	40.1 de	100

[1]WAT = weeks after transplanting.

[2]Percentage of standard inorganic treatment.

[3]Composted chicken manure (CM) application equivalent to 1x and 2x the rate of N applied as inorganic solid fertilizer (i.e., 17.5 and 35 t/ha of CM, respectively).

[4]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.

[5]Starter fertilizer (St) was liquid compound fertilizer #4 (6N–5.2P–5K) or #5 (4.5N–3.9P–7.5K), diluted and applied after transplanting at a rate of 160N–138P–133K mg in 50 ml water per plant (equivalent to 4.7N–4.1P–3.9K and 4.7N–4.1P–7.9K kg/ha).

[6]Side = sidedressing; applied at 60N–25.8P–49.8K kg/ha, at either 3 or 9 weeks after transplanting.

[7]Standard inorganic fertilizer comprised a basal application of 90N–38.7P–74.7K kg/ha; and 1st, 3rd sidedressings of 60N–25.8P–49.8K kg/ha, at 3 and 9 WAT; and 60 N kg/ha as 2nd and 4th sidedressings at 6 and 12 WAT.

by 14%. However, yields for all treatments without starter solutions were statistically similar and less than yields for treatments using starter solutions.

Data from six harvests showed that when CM was supplemented with a starter solution and either one sidedressing (9 WAT) or two sidedressings (3 and 9 WAT), yields were increased.

Liquid fertilizer #5 as a starter usually produced slightly better effects than liquid fertilizer #4. This might be because #5 contains twice the amount of K and that the N component is mainly in the form of ammonium.

The summer trial aimed to confirm the best combination of organic fertilizer with liquid or solid supplements on the growth and yield of cherry tomato. For treatments where pig manure compost (PM) and CM were used, adding a starter solution immediately after transplanting resulted in 100% and 94% greater top dry weight at 3 WAT (Table 38). These dry weight values were 62% and 76% higher than those of the SI fertilizer check.

For the treatments in which organic fertilizer was combined with starter and liquid supplements or combined with a SI sidedressing, cumulative marketable fruit yields of first 3 harvests were greater than the yields of plots with either organic fertilizer or SI alone. The highest yields from six harvests were achieved when PM was combined with starter and solid inorganic sidedressing at 9 WAT or when CM was applied with starter and solid inorganic sidedressing at 3 WAT. Two sidedressings did not improved yields compared to one sidedressing.

Common cabbage

Common cabbage is a vegetable crop that requires large quantities of nutrients (120–250 kg N/ha) within a 2–2.5 months period. The initial N availability in soil may influence much of the early growth, which subsequently affects the head yield. According to studies carried out in previous years, application of CM or PM equivalent to 1x the rate of N as inorganic fertilizer was not sufficient for common cabbage. Hence, organic fertilizer in the autumn trial was increased to double dosage.

Adding starter solution to the SI fertilizer check resulted in 27% more dry weight 12 days after transplanting and the highest yield overall (Table 39). The double-rate applications of PM and CM led to early growth that was similar to that of the respective SI checks, but such effects could not persist to the

Table 38. *Effects of liquid starter supplements and inorganic sidedressings on dry weight and yields of cherry tomato, AVRDC, transplanted 7 Aug. 2001.*

Fertilizer treatment	Leaf dry weight at 3 WAT[1] (g/plant)	Leaf dry weight at 3 WAT[1] Index[2]	Total marketable yield: Harvests 1-3 (t/ha)	Harvests 1-3 Index[2]	Harvests 1-6 (t/ha)	Harvests 1-6 Index[2]
PM[3]	2.43 b[4]	62	14.7 e	98	31.4 abc	114
PM+St5[5] + Side 9 WAT	6.25 a	162	21.1 ab	140	35.0 a	126
PM+St5 + Side 3,9 WAT	–[6]	–	18.8 a-c	125	31.4 a-c	114
PM+St5 + St5 3,9 WAT	–	–	18.2 b-d	121	31.7 a-c	115
CM	2.73 b	70	16.4 c-e	109	26.6 d	96
CM+St5 + Side 3 WAT	6.79 a	176	22.2 a	147	34.9 a	126
CM+St5 + Side 3,9 WAT	–	–	20.5 ab	136	32.5 ab	118
CM+St5 + St5 3,9 WAT	–	–	20.4 ab	135	30.3 b-d	110
Standard inorganic (ck)[7]	3.90 b	100	15.1 de	100	27.7 cd	100

[1]WAT = weeks after transplanting.
[2]Percentage of standard inorganic treatment.
[3]Composted pig manure (PM) and chicken manure (CM) applications were equivalent to 1x the rate of N applied as inorganic solid fertilizer (i.e.,11.8 and 14.0 t/ha as PM and CM, respectively).
[4]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.
[5]Starter fertilizer (St) was liquid compound fertilizer #5 (4.5N–3.9P–7.5K), diluted and applied after transplanting at a rate of 160N–138P–133K in 50 ml water per plant (equivalent to 4.7N–4.1P–7.9K kg/ha for one application).
[6]Not determined.
[7]Standard inorganic fertilizer comprised a basal application of 90N–38.7P–74.7K kg/ha; and 1st, 3rd sidedressings of 60N–25.8P–49.8K kg/ha, at 3 and 9 WAT; and 60N kg/ha as 2nd and 4th sidedressings at 6 and 12 WAT.

mid-growing period nor to the final harvest. SI basal fertilizers added to CM or PM plots did not significantly enhance initial growth, but did significantly increase yield to the degree that their yields were similar to those of the SI check plot. The starter solutions significantly improved yields of the organically-fertilized plots, but yield levels were still far below the SI check. These results indicate that starter solutions and especially SI basal fertilizers are necessary for improving yields of common cabbage when grown using organic fertilizer as principal nutrient sources.

The double-rate applications of CM or PM were not economical as evaluated by yield increment. In the subsequent trial conducted during Summer 2001, the application amounts of organic fertilizer were back to 1x the N rate as inorganic fertilizer. Applications of either SI basal or starter fertilizers accelerated the initial growth, measured at 19 days after transplanting (DAT), of CM plots by nearly 30%. Similar results were true for starter application with PM.

As it did in the Autumn 2000 trial, application of CM alone reduced yield compared with SI fertilizer check (Table 40), in this case by 54%. But when starter and SI sidedressing supplemented the CM, yields increased 43% over CM alone, thus most of the original 54% yield loss incurred by using CM was recuperated. For the treatment of adding starter and two liquid NPK supplements as sidedressings with CM, the yield increased by 24% compared to CM alone. Similar trends were evidenced in PM-treated plots. Although the yields were still lower than the SI check, yields of CM and PM plus starter solution plus one sidedressing (27 DAT) reached yields that were 89 and 78%, respectively, of the yields for the SI check. And these treatments, along with all treatments with organic fertilizer, had significantly less internal rot than inorganic-only treatments. Therefore, in summary from these two trials, the recommended balanced organic-inorganic fertilization practice for common cabbage is banded application of 1x the N rate (240 kg N/ha) of organic fertilizer, combined with a starter solution after transplanting, and then a SI sidedressing of 60N–0P–33.2K kg/ha at about 25 DAT.

Pak-choi

Leafy vegetables have unique growth patterns compared to other vegetables. Nearly 85-90% of their total dry biomass accumulates during the last third of the growth period. Hence, application of liquid supplements before or during their fast growth stage may be beneficial to yield improvement. Based on results obtained in 2000, the optimum application time of liquid supplements would be during the second phase of the growth period just before growth rate was steeply increased.

Table 39. *Effects of organic fertilizer and starter on growth and yield of common cabbage, AVRDC, transplanted 8 Nov. 2000.*

Fertilizer treatment	Leaf dry weight at 12 DAT[1] (g/plant)	Index[2]	Leaf dry weight at 34 DAT (g/plant)	Index[2]	Yield (t/ha)	Index[2]
2CM[3]	2.76 b[4]	91	18.6 cd	50	21.4 c	72
2CM + Basal[5]	2.84 b	93	35.7 b	95	28.3 b	96
2CM + Starter[6]	3.33 ab	109	24.4 c	65	22.8 c	77
2PM	2.76 b	91	13.4 d	36	14.0 d	47
2PM + Basal	2.88 b	94	32.3 b	86	27.5 b	93
2PM + Starter	3.32 ab	109	20.7 cd	55	21.3 c	72
Standard inorganic + Starter	3.87 a	127	46.4 a	124	34.3 a	116
Standard inorganic (ck)[7]	3.05 b	100	37.4 b	100	29.5 b	100

[1]DAT = Days after transplanting.
[2]Percentage of standard inorganic treatment.
[3]Composted chicken manure (CM) and pig manure (PM) applications were equivalent to 2x the rate of N applied as inorganic solid fertilizer (i.e., 21.6 and 14.7 t/ha of CM & PM).
[4]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.
[5]Basal application of 60N–38.7P–49.8K kg/ha.
[6]Starter fertilizer was inorganic liquid compound fertilizer #4 (6N–5.2P–5K), diluted and applied after transplanting at a rate of 240N–206P–199K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg/ha).
[7]Standard inorganic fertilizer comprised a basal application of 60N–38.7P–49.8K kg/ha, and sidedressing of 60N–0P–33.2K at 13, 22 and 34 DAT.

Table 40. *Effects of organic fertilizer, starter and inorganic liquid supplements on initial growth and yield of common cabbage, AVRDC, transplanted 7 June 2001.*

Fertilizer treatment	Leaf dry weight at 19 DAT[1] g/plant	Leaf dry weight at 19 DAT[1] Index[2]	Yield (t/ha)	Yield Index[2]	Internal rot incidence (%)
CM[3]	4.35 c[4]	56	18.5 e	46	0.0 b
CM + Basal	6.56 b	85	26.9 d	66	0.0 b
CM + Starter[5]	6.59 b	85	19.8 e	49	0.0 b
CM + Starter + Side 27 DAT	6.70 b	87	36.1b	89	8.8 b
CM+ Starter + LF 27,40 DAT[6]	6.36 b	82	28.6 cd	70	6.3 b
PM	4.65 c	60	15.9 e	39	0.0 b
PM+ Starter + Side 27 DAT	6.78 b	88	31.7 c	78	0.0 b
PM + Starter + LF 27,40 DAT	6.96 ab	90	25.2 d	62	0.0 b
Standard inorganic + Starter	8.24 a	106	41.0 a	101	50.0 a
Standard inorganic (ck)[7]	7.75 ab	100	40.6 a	100	56.3 a

[1]DAT = Days after transplanting.
[2]Percentage of standard inorganic treatment.
[3]Composted chicken manure (CM) and pig manure (PM) applications were equivalent to 1x the rate of N applied as inorganic solid fertilizer (11.6 and 7.3 t/ha of CM and PM).
[4]Mean separation within columns by Duncan's multiple range test, $P \leq 0.05$.
[5]Starter fertilizer was inorganic liquid compound fertilizer #4 (6N–5.2P–5K), diluted and applied after transplanting at a rate of 240N–206P–199K mg in 50 ml water per plant (equivalent to 7.2N–6.2P–6K kg/ha).
[6]Inorganic liquid 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 27 and 40 DAT.
[7]Standard inorganic fertilizer comprised a basal application of 60N–38.7P–49.8K kg/ha, and sidedressings of 60N–0P–33.2K at 19, 27 and 40 DAT.

In the spring trial, yield from the PM treatment was only 71% of that grown with SI fertilizer (Table 41). However, various applications of liquid supplements from 5 to 20 days after sowing (DAS) increased fresh yield. Highest yields were obtained when liquid supplements were applied either 10 DAS or at both 5 and 20 DAS. These yield levels were boosted to levels similar to those grown with SI fertilizers, at least statistically. Because this trial was conducted in spring, the growing period was shorter than that in summer. Therefore, the 10 DAS application of liquid supplements coincided with the time period just prior to the rapid growth phase of pak-choi.

Increasing liquid supplements to four applications did not improve yields. Adding liquid supplements to the SI fertilizer check at 10 or 15 DAS had no effect on yields.

Based on results from this and other trials, the recommended organic-inorganic fertilization practice for pak-choi is organic fertilizer banded or broadcasted on surface of bed, mixed well in the top 10 cm of soil, followed by one or two liquid supplements prior to the fast-growing period, approximately 10-20 DAS.

Table 41. *Effects of organic fertilizer and liquid supplement applications on pak-choi , AVRDC, sown 4 Apr. 2001.*

Fertilizer treatment	Fertilization (DAS)[1]	Fresh matter yield (t/ha)	Index[2]	Dry matter yield (t/ha)	Index[2]
1.5PM[3]	None	25.4 e[4]	71	1.22 c	72
1.5PM + LF[5]	5	28.3 de	79	1.43 bc	84
1.5PM + LF	10	31.0 a-e	86	1.42 bc	84
1.5PM + LF	15	29.3 c-e	81	1.35 bc	80
1.5PM + LF	20	28.9 de	80	1.40 bc	83
1.5PM + LF	5,10	27.4 de	76	1.30 c	77
1.5PM + LF	5,15	30.3 c-e	84	1.41 bc	83
1.5PM + LF	5,20	31.7 a-d	88	1.45 bc	86
1.5PM + LF	10,20	29.5 c-e	82	1.36 bc	81
1.5PM + LF	5,10,15,20	30.5 b-e	85	1.39 bc	82
Std. inorganic (ck)[6]	None	36.0 ab	100	1.69 a	100
SI + LF	10	36.5 a	101	1.69 a	100
SI + LF	15	35.0 a-c	97	1.60 ab	94

[1]DAS = days after sowing.
[2]Percentage of standard inorganic treatment.
[3]Amount of pig manure (PM) applied equivalent to 1.5x times of N applied as inorganic solid fertilizer (i.e., 9.2 t/ha).
[4]Mean separation within columns by Duncan's multiple range test, $P \leq .05$.
[5]Starter or liquid fertilizer (LF) was inorganic liquid fertilizer #5 (4.5N–3.9P–7.5K), diluted and applied at a rate of 356N–306P–591K mg 296 ml water/m^2 (equivalent to 3.6N–3.1P–6K kg/ha for one application).
[6]Standard inorganic fertilizer comprised a basal application of 60N–38.7P–49.8K kg/ha; and sidedressings of 50N–0P–16.6K kg/ha at 10 and 20 days after transplanting.
[7]SI = standard inorganic.

Conclusion

These fertilizer studies on three different vegetable crops show that a small amount of inorganic fertilizer solution as a starter, basal, and/or well-timed sidedressing may help plants overcome the shortage of nutrients released by organic fertilizers during periods of active plant growth. This judicious and combined use of inorganic and organic fertilizers may assist farmers to maximize profits, recycle animal wastes, and reduce pollution risks.

Expert system for composting and utilization

Composts were major sources of nutrients supplied to the crops in the early 20th century. However, due to the development of the chemical fertilizer industry, the use of composts gradually declined in crop production. In recent years, increasing concerns over the environment and soil sustainability have prompted greater interest in composting as a way of recycling wastes back to soil.

Types of wastes used for composting were relatively limited in the past. Composting was made by combining raw materials by trial and error or by blending raw materials that were available on the farm. Today, types of waste materials generated from agricultural production and processing have become much more diversified. Also, their quantities are in such huge amounts that they may become pollutants in the environment. Associated risks such as the spread of human diseases, plant diseases and weed seeds, as well as contamination of heavy metals further complicate matters. Extensive research studies in recent years have improved composting technology to a more science-based and environment-friendly process.

Composting is enhanced through the establishment of conditions that encourage the growth of the microorganisms. The most desirable conditions include mixes of raw materials to provide a carbon to nitrogen ratio (C:N) of 25:1 to 30:1, oxygen levels greater than 5%, moisture at 50-60%, and temperatures above 55 °C. To achieve rapid and good quality composting, it is useful to develop composting formulations based on science-based data. Due to great diversity in compositions of raw materials, the characteristic data are not always available at hand.

Therefore, the objectives of this study are to integrate information on organic waste composting and to establish databases for utilization of agricultural wastes. An expert system for calculating compost formulations, monitoring composting processes, and determining maturity of composts is being established. A main feature of the system is an user-friendly query menu to allow non-specialists, extensionists, and farmers to easily access information for composting and organic fertilization recommendations. Users can select types of raw wastes from databases and the formula is automatically calculated based on the C and N content. Formulation and monitoring on factors such as temperature, moisture, aeration, and maturity, will ensure a high-quality composted product.

Software programs MS Visual FoxPro and MS Access were selected for database management. These programs are efficient in sorting ability and facilitate user-friendly menus that increase applicability. Visual Basic is the language for the database/query system interface, and MS Windows is the platform for the expert system.

The conceptual flow chart of the expert system is shown in Figure 7. Major components of the system include the following:

Database for integrating information on composting

This component is further divided into three sub-databases:

Organic wastes and materials. Data are searched from national and international references, research reports, publications, books and analytical reports. Types of waste material in the database include crop and livestock production wastes, food processing wastes, fish and meat processing wastes, municipal wastes and kitchen wastes. The organic materials include crop residues, green manures, disposable peat moss and media, straws, sawdusts, papers, and agricultural processing by-products (e.g., soybean meal, bagasse, bone powder, bark, fallen leaves and tree trimmings). Main fields are compost properties (bulk density, C:N ratio, moisture content), nutrient contents (C, N, P, K, Ca, Mg, heavy metals) and sources of information. To date, more than 250 records of waste material have been collated in the database.

Composting technologies. Data are divided into six sections: handling of raw materials; formulating compost recipes; mixing and pile formation methods;

monitoring composting processes (e.g., watering, aeration); detection of compost maturity; and curing, drying and storing composts. Illustrations are included in the database to make the composting processes easily understandable.

Organic fertilizers. Types of composts include waste media compost, chicken manure compost, pig manure compost, cow manure compost, bagasse compost, and garbage compost. Main fields selected for this database are nutrient contents (C, N, P, K) and mixing ratios of raw materials.

Database of nutrient requirements and fertilizer management for vegetables

Three sub-databases are included in this category. The first is a collection of references related to organic fertilization for major vegetables. The second is the utilization of compost other than as fertilizer, e.g., using composts for container or potting media, soil amendment, or plant disease controller. The third database includes nutrient-releasing factors from composts for better estimation of the actual amounts required for application. More than 300 records of reference have been put in the database.

Compost formulation system

This is a query system that allows users to select types of waste materials from the database or key in names of farm wastes. After materials are selected, the system will develop a compost formula for maximum efficiency. The query system is being connected to the composting technology database to provide guidelines for composting.

The program is calculated on a dry weight basis, but if the rough bulk density is known, it can be converted from dry weight to volume or fresh weight. Amounts of water needed for composting is also calculated. For use in the developing countries where computers are not available, a simple booklet with compost formulation based on locally available materials is being designed from this system.

For validating the composting expert system, based on pre-set conditions, eight compost formulas have been developed and tested. Actual C and N contents were closely related to the values predicted. By maintaining good aeration and moisture conditions during processing, temperature was easily maintained above 70 °C, and no offensive odors were detected.

A program for developing organic fertilizer recommendations is planned as the final goal of the expert system.

In conclusion, the establishment of an expert system for composting will increase efficiency of composting, result in high quality composts, and provide teaching tools for researchers and extensionists. This will lead to greater recycling of agricultural wastes and expanded cultivation of organically-grown vegetables.

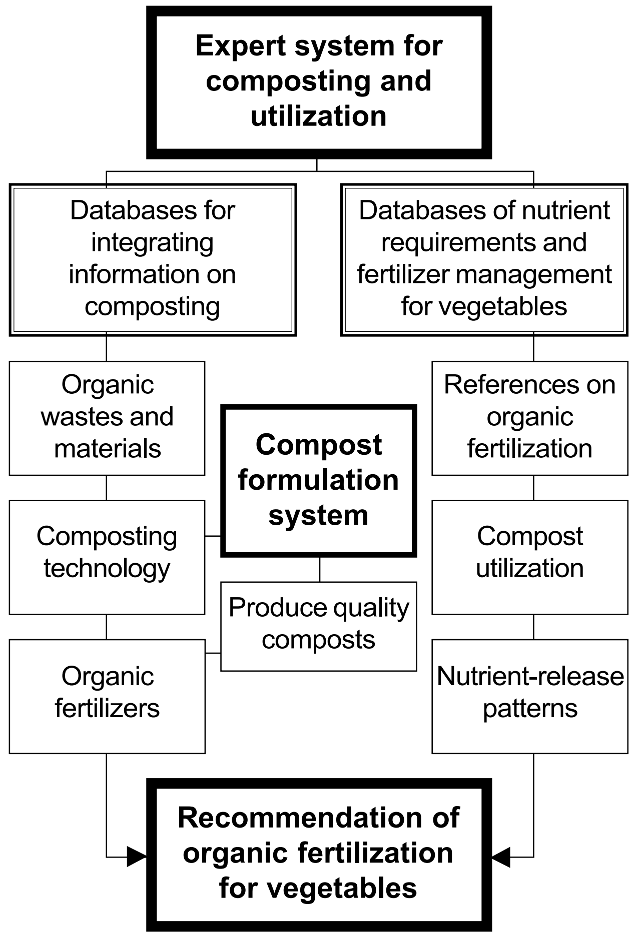

Figure 7. *Conceptual flow chart of the expert system.*

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 integation 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

Insect pest problems of leafy vegetable production under nethouses

Leafy vegetables are popular vegetables in Southeast Asia and, because of their perishable nature, are traditionally grown near urban markets. These vegetables are grown intensively, season after season, on the same piece of land. To produce these vegetables continuously, especially during the rainy season, peri-urban farmers in the tropics are now resorting to growing these vegetables under protective structures, especially nethouses. If managed diligently, nethouses can reduce pest problems, and therefore, reduce pesticide use under these structures. However, as it is practiced now, there is very little reduction in pesticide use. AVRDC has recently initiated research on IPM of leafy vegetables under nethouses. Initial research, as reported here, is focused on monitoring pest species and understanding their modes of entry inside nethouses.

Two permanent nethouses, each measuring 35 m long, 21 m wide and 2 m high, with infrastructure of 6-cm-diameter galvanized iron tubings, were constructed over two parcels of land located in adjacent fields separated by 30 m including a 5-m-wide farm road. Both structures were covered on all sides and top with 32-mesh nylon netting. The entry of each structure was equipped with two double doors, which also used 32-mesh netting (Figure 8). In the larger of the two double doors, two 3-m sliding doors were maintained opposite to each other with a distance of 3 m between them. The door passage led one directly from outside straight into the planted area of the nethouse. This pathway was used only twice during each cropping cycle: once for the entry of a tractor to prepare the land for planting and once at harvest to transport the produce. The other double door with two 1.5-m-wide sliding panels was constructed at a 90 degree angle to the larger double door. Its pathway did not directly open into the planted area. This door was used for entry and exit of the personnel for daily operation and maintenance of the nethouse.

While covering the iron infrastructure on all sides with nylon net, the amount of net used to cover the 2-m-high walls on all sides was intentionally maintained at 2.3 m. The excess 30-cm portion of the net was buried in soil to tightly seal the nethouse from the outside. For irrigation, water was brought inside the nethouse via buried pipes, thus preventing insects entering through the irrigation system. Before erecting the structures, the land was flooded for 1 week under 20 cm of standing water to kill soil-inhabiting stages of insects.

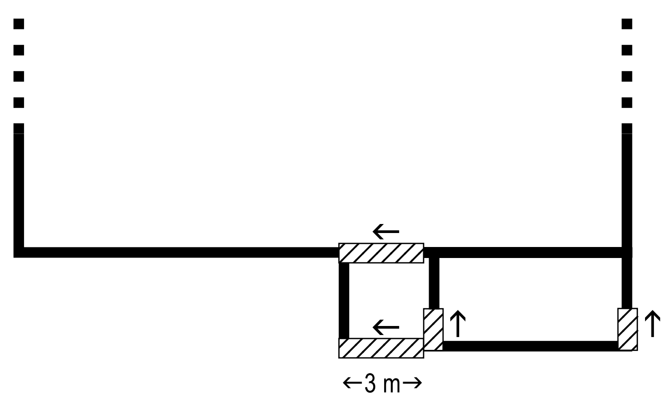

Figure 8. *Schematic diagram of nethouse opening. Arrows indicate directions that doors (indicated by slanted boxes) slide. Actual dimension of entire nethouse is 35 m long x 21 m wide.*

Nets were inspected almost daily to check their integrity; holes wider than 0.8 mm were repaired promptly. After each crop cycle, nets were washed by pressurized water to remove any dust clogging the net. This assured minimum reduction in sunlight penetration inside the nethouses.

Two short-duration leafy crucifers, Ethiopian kale (*Brassica carinata*) and pak-choi (*Brassica rapa* cv. group *chinensis*) and four similar duration non-crucifer leafy species, vegetable amaranth (*Amaranthus* spp.), kangkong (*Ipomoea aquatica*), loose-leaf lettuce (*Lactuca sativa* var. *crispa*), and spinach (*Spinacia oleracea*) were cultivated inside the nethouse. At each season, one nethouse was planted to two crucifers and another nethouse to two non-crucifers. During subsequent seasons the nethouse used previously for crucifer was planted to noncrucifers and visa versa. The same two species of the crucifers were grown throughout the year, but for non-crucifers, amaranth and kangkong were grown during hot-wet summer months and lettuce and spinach during cool-dry winter months. All crops were directly seeded and grown using traditional cultural practices, with the notable exception that no pesticide was used in controlling insect pests or diseases. Well-decomposed and finely chopped compost was applied to both parcels once during summer.

Crops were monitored for insect damage observed on a weekly basis. At harvest, plants were uprooted and yield data were recorded.

Only two insect species, striped flea beetle (SFB), *Phyllotreta striolata*, and common armyworm (CAW), *Spodoptera litura*, were observed attacking the crop inside the nethouse. SFB attacked only crucifers, whereas CAW larvae fed on both crucifers and non-crucifers. The 32-mesh net normally should prevent entry of adults of both pest species inside the nethouses. However, we observed that SFB adults were crawling through tiny gaps between two adjacent pipes supporting the sliding doors and attacking the crucifers inside. Subsequently we closed the gaps with plastic sheets and eliminated the entry of SFB adults in all subsequent crop cycles.

CAW adults did not enter the nylon nets physically, however, we noticed that adults were laying eggs on the top of the net and individual eggs or first instar larvae were falling on the vegetables grown underneath and initiating infestation. Toward the end of the season, the adults developing from these immature stages could be caught in traps baited with CAW sex pheromone. At this time we also found egg masses of CAW on the inner side of the nylon net walls. These egg masses were always located on the northeast section of the net. This is the predominant wind direction throughout much of the year in southern Taiwan. All such egg masses were promptly destroyed.

Each crop cycle lasted about five weeks and we spent an additional 10 days of crop-free period to clean the nets and prepare land for next cropping. We did not notice any reduction in crop yield, which we assume to be due to effective crop rotation that also minimized incidence of any damaging disease epidemic. Due to heavy rains accompanied by typhoons, most of our planting operations between June to October were delayed considerably. We could grow only four successful crop cycles inside the net throughout 2001.

In conclusion, we found that using 32-mesh nets for nethouses erected on pest-free soil (flooding land for seven days before construction), and maintaining the integrity of nets prevented damage by all insect pests except CAW. Subsequent research will focus on devising ways to combat this pest, especially on preventing oviposition of CAW on netting without entailing additional construction costs.

Intentional flooding for control of soil-inhabiting striped flea beetle and common armyworm

Striped flea beetle (SFB) and common armyworm (CAW) are serious pests of leafy vegetables grown in open fields and in nethouses. Because of the imminent health hazards associated with consumption of pesticide-tainted leafy vegetables, use of chemical pesticides to combat these insects is discouraged. Very few commercial biological pesticides are effective in combating these pests. Eggs, larvae and pupae of SFB and pupae of CAW can persist in the soil where these pests damaged the immediate preceding crop. This study evaluated the possibility of flooding the land after harvest to kill SFB and CAW and reduce their damage to the subsequent crop. The experiment also aimed at determining the minimum duration of flooding to get effective control of these pests, so as to enable one to adopt this technique without wasting time between successive crops.

SFB was raised on potted radish plants in a greenhouse by procedure described in *AVRDC Report 2000*. Since larvae and pupae develop in soil and are difficult to obtain from soil without injuring the insect, we used SFB eggs for this research. CAW was raised on a commercially available artificial diet in laboratory. Its pupae were used for this test.

For SFB, two different flooding methods and four treatments overall were followed. Treatment A involved flooding of naked eggs. Eggs collected from laboratory culture were dipped 3 cm in water for 24, 48, 72 and 96 hours. After each dipping interval, eggs were placed on soil at the base of a potted radish plant. The plants were maintained in a greenhouse and the number of adults emerging from each pot was recorded.

The other three treatments involved flooding eggs in situ. Fresh eggs were transferred onto soil at the base of potted radish plant and the pots were placed in a water trough. Water was maintained constantly 3 cm above the soil surface for 0, 12, 24, 36, and 48 hours. After each treatment interval, the plants were taken out and maintained in greenhouse (treatment B). In one set of this test, after a suitable interval when pupae would have been formed, eight days, we sifted through the soil and counted the number of pupae developed in each pot (treatment C). In the second set we allowed the adults to come out from soil and recorded their number (treatment D).

For CAW, fresh pupae were placed 2-3 cm below soil surface in several 15-cm-diameter clay pots. These pots were placed in a water trough. Water was maintained 3 cm above the soil surface for 0, 12, 24, 36, and 48 hours. After each flooding interval, water was drained and clay pots were maintained under greenhouse conditions until all CAW adults emerged.

The data were analyzed by analysis of variance and means were compared by the test of least significant difference (LSD).

Results of the effect of flooding on the emergence of SFB adults from eggs and subjected to flooding in two different manners are summarized in Table 42. For treatment A, drowning naked SFB eggs in water for up to four days did not significantly affect their development compared to eggs that were not drowned in water at all. The differences among the treatments can be explained by handling damage, as naked eggs are extremely fragile.

For treatment B, placing eggs on soil immediately before flooding and flooding the eggs for 36 hours practically killed all eggs; very few adults emerged when eggs were flooded in this manner. We suspect chemicals from flooded soil had accelerated egg mortality. When eggs were allowed to remain on soil adjacent to a crucifer stem for eight days before initiating flooding, nearly complete pest mortality was observed at 24 hours and longer flooding duration.

Among treatments C and D, lower survival rates can be attributed to physical damage caused when eggs were sifted out of the soil. There was no difference whether we searched for pupae in soil or waited for adults to come out to judge SFB survival. This

Table 42. *Effect of duration of flooding on the development of striped flea beetle eggs into adults.*

Duration of flooding (hours)	Egg survival and development (%)
A. Naked eggs flooded and placed on soil (adults recorded)	
0	12.00 ± 11.25
24	17.13 ± 6.19
48	23.63 ± 4.06
72	15.38 ± 5.19
96	28.00 ± 8.75
LSD (0.05)	7.84
B. Eggs were placed on soil and flooded immediately (adults recorded)	
0	19.00 ± 15.50
12	14.63 ± 6.81
24	10.25 ± 2.75
36	0.50 ± 0.75
48	0.75 ± 1.13
LSD (0.05)	17.57
C. Eggs were placed on soil for eight days and then flooded (pupae recorded)	
0	3.38 ± 2.84
12	0.38 ± 0.75
24	0.00 ± 0.00
36	0.13 ± 0.25
48	0.00 ± 0.00
LSD (0.05)	2.11
D. Eggs were placed on soil for eight days and then flooded (adults recorded)	
0	2.75 ± 1.26
12	3.25 ± 1.89
24	0.13 ± 0.25
36	0.00 ± 0.00
48	0.00 ± 0.00
LSD (0.05)	1.50

indicates that pupa to adult transformation is not affected by flooding. The flooding seems to affect the larval stage more than egg or pupal stages.

Results of the mortality of CAW pupae due to flooding are presented in Table 43. A mere 24-hour flooding caused over 88% mortality of CAW pupae. Mortality increased over 95% when flooding was extended by another day. With such a high mortality of pupal stage—normally the most sturdy of the four life stages of CAW—it is unlikely that CAW will pose a serious threat to leafy vegetable production if farmers utilize flooding with additional standard field sanitation practices, such as monitoring and prompt destruction of egg masses.

From this study it is concluded that flooding soil for up to 48 hours causes heavy mortality of soil-inhabiting immature stages of SFB and CAW. In production areas where pesticide use is discouraged, flooding soil for up to 48 hours will help to manage the pest safely and economically.

Table 43. *Effect of duration of flooding on mortality of common armyworm pupae.*

Flooding duration (hours)	Mortality (%)
0	23.20 ± 7.41
12	65.15 ± 9.41
24	88.38 ± 7.93
36	85.70 ± 5.09
48	95.53 ± 4.48
LSD (0.05)	10.87

Influence of temperature on parasitism of diamondback moth by *Diadromus collaris*

Diadromus collaris is a specific parasitoid of diamondback moth (DBM), *Plutella xylostella*, attacking the pupal stage of the pest insect. Activity of this parasitoid is especially important in biological control of DBM because it parasitizes pupae, which are not attacked by any other parasitoid species in the tropics and subtropics. *D. collaris* activity thus complements, and does not compete with biological control achieved by other species of larval parasitoids. However, *D. collaris* is confined to cooler highlands in the tropics, where, with the availability of larval parasitoids like *Diadegma semiclausum*, damage caused by DBM is not as serious as in the lowlands. We are, therefore, searching for a suitable high temperature-tolerant, pupal-parasitizing species, which will complement activities of larval parasitoids already established in the Asian lowlands. This will help in controlling DBM and reduce pesticide use.

In this respect, in 2000 we introduced a strain of *D. collaris* from USDA's European Biological Control Laboratory (EBCL). EBCL collected these specimens from Uzbekistan at the height of summer when temperatures were over 35 °C. It was thought that any *D. collaris* surviving at such high temperatures could be tolerant to high temperatures in tropical lowlands. We conducted laboratory experiments to study the effect of temperature on the parasitism of DBM pupae by *D. collaris*.

Fresh pupae of DBM and fresh adults of *D. collaris* were collected from AVRDC's rearing facilities. Both pupae and the parasitoid adults were held at 20, 25, 30, and 35 °C for four hours to acclimatize them at these temperatures. One hundred DBM pupae, placed on cabbage leaves in each of three acylic jars (15 cm in diameter, 30 cm long) were then exposed to two pairs of mated *D. collaris* adults and held at specific temperature for two days after which adults were discarded and pupae maintained at 26±2 °C until parasitoid or DBM adults emerged from them. This was done at each of four temperatures (20, 25, 30 and 35 °C). Temperatures below 20 °C are not common in tropical lowlands and above 35 °C are not suitable for crucifer cultivation, hence we used this practical temperature range in this study.

The extent of parasitism of DBM by *D. collaris* at various temperatures is shown in Table 44. The level of parasitism was moderate and at par between 20 and 30 °C. Parasitism was reduced drastically at 35 °C. Although the level of parasitism at 30 °C was at par with 20 °C, proportionately more male than female *D. collaris* adults emerged at 30 °C (71% male) than at 20 °C (58% male). This implies that at temperatures above 30 °C, the current level of parasitism will not be sustainable due to predominance of males. Therefore, this strain of *D. collaris* is not suitable for high temperatures commonly found in tropical lowlands. Other pupal parasitoids that can survive at temperatures over 30 °C must be identified.

Table 44. *Survival of* Diadromus collaris *and its parasitism of diamondback moth (DBM), as effected by temperature.*

Temp. °C	*D. collaris* adults emerged Females	Males	Total	DBM adults emerged	Parasitism (%)
20	12.3 ± 7.6	17.6 ± 6.4	30.0 ± 3.6	70.0 ± 3.1	30.0 ± 3.6
25	10.0 ± 2.7	26.6 ± 1.5	36.6 ± 4.0	63.3 ± 4.0	36.7 ± 4.0
30	9.6 ± 3.8	23.6 ± 2.5	33.3 ± 5.0	66.7 ± 5.0	33.3 ± 5.0
35	0.0 ± 0.0	1.3 ± 1.2	1.3 ± 1.2	98.6 ± 1.2	1.3 ± 1.2
LSD (0.05%)					7.77

IPM of eggplant fruit and shoot borer in South Asia

AVRDC is conducting a collaborative project on the integrated pest management (IPM) of eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis*, in South Asia. Collaborators include scientists of Bangladesh Agricultural Research Institute (BARI), Gujrat Agricultural University of India, Indian Institute of Vegetable Research (IIVR), Horticultural Crop Research and Development Institute (HORDI) of Sir Lanka, and Natural Resources Institute (NRI) of the United Kingdom (UK). The project is funded by the Department for International Development, UK.

The proposed IPM involves prompt destruction of insect-damaged shoots, use of pheromone traps to capture male EFSB moths, and conservation of natural enemies, especially a wasp parasitoid *Trathala flavo-orbitalis*. It also involves a long-term activity of breeding eggplant cultivars resistant to this pest.

Trapping and shoot-cutting studies

A protocol for utilization of sex pheromone traps was developed at BARI and GAU. It included determining the most effective trap design, height of traps in the field, distance between traps, and persistence of pheromone lure in the field. These experiments were conducted by BARI and GAU on farmers' fields and by IIVR on farmers' fields and experimental farms.

The result of this research showed that pheromone traps should be maintained slightly above crop canopy, installed at a grid of 10 m throughout treatment fields, and several trap designs were deemed suitable. This protocol was used in experiments reported herein. Plot size and shape varied between 0.08 and 0.5 ha depending upon the landholdings of individual farmers. Experiments were done in both contiguous as well as on scattered eggplant fields. Three replications were used for both treatment (pheromone trap + cutting damaged shoots) and check (no pheromone or removal of damaged shoots) plots. The distance between plots varied from 50 to over 100 m. Locally available and suitable traps were used: BARI scientists used water trough pheromone traps, IIVR scientists used Helicoverpa-type traps, and GAU scientists used delta-type traps.

Two tests were conducted each at BARI and IIVR and one at GAU. The first of the two tests in Bangladesh was undertaken on a five-month-old crop that was being sprayed by the farmer, yet fruit infestation was still 50% or higher. Soon after introduction of pheromone traps and initiation of excising of pest-damaged shoots, the EFSB damage to fruit declined over the remaining four weeks from 56.1% to 26.4% (Figure 9). In check plots, where the farmer continued his routine pesticide spraying, the

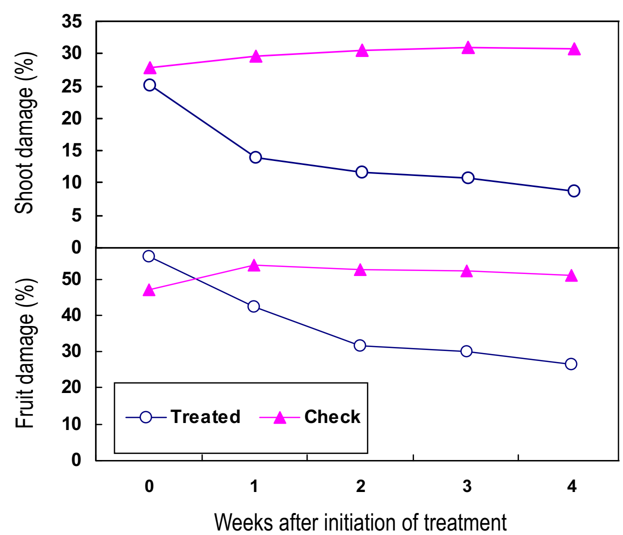

Figure 9. *Infestation of shoots (a) and fruits (b) by eggplant fruit and shoot borer in treated (pheromone traps and damaged shoots removed) and check plots with treatment initiated on five-month-old plants, Jessore, Bangladesh.*

pre-treatment damage of 47% increased slightly to over 51.2%. Shoot damage in the check plot remained between 29 and 30% but in treatment plots it declined from 27.2% to 14.0%.

For the second test in Bangladesh, where we introduced the pheromone + cutting treatment within three weeks after transplanting, the initial low infestation of both shoot and fruit did not differ between treatment and check plots. However, after five weeks of treatment, pest damage to fruit declined from 30% to 20% whereas it remained steady or increased from 25% to 43% in the check plots, a damage level comparable to the average eggplant grower in Jessore district. In the same plots, damages to shoots declined from a high of 7% to 1% in treatment plots but remained above 6% in check plots (Figure 10).

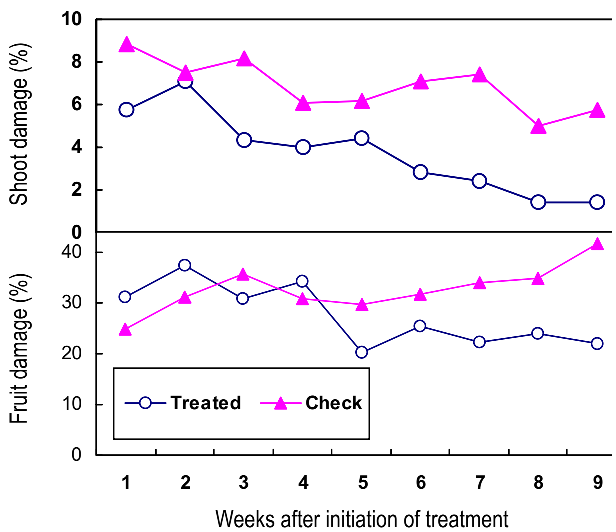

Figure 10. *Infestation of shoots (a) and fruits (b) by eggplant fruit and shoot borer in treated (pheromone traps and damaged shoots removed) and check plots with treatment initiated three weeks after transplanting, Jessore, Bangladesh.*

Two experiments at IIVR, one on farmers' fields and one at the IIVR experimental farm, were planted in Aug. 2001. The plot size was 0.08 ha each, and there were three replications. At both locations, there was significant reduction in fruit damage in the pheromone-treated field. As a result of reduction in pest damage, there was consequent increase in marketable yield (Table 45). Large numbers of EFSB adults were trapped in the pheromone traps, up to 484 per week, especially during November to December.

At GAU on farmers' fields, pheromone-baited traps were erected in the field soon after transplanting and maintained until final harvest. This led to significant reduction in EFSB damage to fruit and significant increase in marketable yields (Table 46).

This experiment was conducted in Sri Lanka but similar pheromone-baited traps failed to attract significant numbers of *L. orbonalis* male adults.

Table 46. *Effect of sex pheromone-utilized mass trapping of adults and prompt cutting of damaged shoots on EFSB damage to fruit and marketable yield in Gujrat, India.*

Treatment	Damaged fruits (%)	Yield (t/ha)
Pheromone + cutting	14.64 ± 0.38	23.57 ± 1.59
Check	31.25 ± 1.78	16.41 ± 0.73
t	12.97**	4.09*

*, **Significant at $P \leq 0.05$ or 0.01, respectively, using Student's *t* test.

Parasitism studies

In Bangladesh, the parasitism of EFSB by *T. flavo-orbitalis* was monitored in routinely-sprayed farmer fields and nearby non-treated experimental fields at two different locations. The two locations have histories of different levels of pesticide use (seven sprays per week in Jessore and one spray per week in Rangamati). Infested fruits and shoots, 30 fruits and

Table 45. *Effect of pheromone-utilized mass trapping and prompt cutting of damaged shoots to control eggplant fruit and shoot borer ,IIVR experimental farm and farmers' fields in Adalpura, India, transplanted Aug. 2001.*

	Damaged fruits (%)		Yield (t/ha)	
Treatment	IIVR	Adalpura	IIVR	Adalpura
Phermone + cutting	22.86 ± 2.22	24.55 ± 2.81	19.92 ± 1.16	19.58 ± 1.57
Check	39.94 ± 3.23	34.37 ± 2.66	14.45 ± 0.97	16.11 ± 1.34
t	6.16**	3.58*	5.11**	2.38[NS]

[NS], *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01 respectively, using Student's *t* test.

40 shoots, respectively, each were collected from July 2001 to Mar. 2002 from these fields and maintained in laboratory until EFSB larvae emerged as adults. In fields where pesticides were not used, parasitism ranged from 10 to over 20%. In Jessore, where eggplant is grown throughout the year and pesticide use is intensive, no parasitism was found when farmers' crops were surveyed. In Rangamati, some parasitism was observed even on farmers' fields. This is due to the moderate level of pesticide use in Rangamati area. In general, parasitism of EFSB larvae in shoots was higher than in fruits.

At IIVR, *T. flavo-orbitalis* is the predominant parasitoid of EFSB. A weekly monitoring of parasitism from damaged fruits at an experimental farm where pesticide use is restricted, indicated higher level of parasitism of EFSB in October and March (average 8%) but low during traditionally cooler months after November. During cooler months, IIVR scientists found another unidentified parasitoid.

In Gujarat, parasitism levels were much higher, peaking at over 38% of EFSB larvae in September. The parasitism remained relatively high there in October but reduced drastically in cooler November-December.

At the AVRDC-Asian Regional Center site in Thailand, a greater diversity of parasitoid species was found as compared to South Asia. So the occurrence and extent of parasitism in Thailand was monitored throughout the year on crops transplanted once every three months. Parasitism was high during July to early December and dropped drastically after first week of December. During August the parasitism exceeded 48% of the EFSB larvae. *T. flavo-orbitalis* was the predominant parasitoid species. Other species of common occurrence were *Pristomerus testaceus*, *Elasmus corbetti*, and *Bracon chinensis*. Their occurrence was not consistent hence we could not record their contribution to the overall parasitism of EFSB. *T. flavo-orbitalis* occurs in all areas of South Asia where eggplant is grown, but its parasitism of EFSB is still not high enough to give adequate control of the pest. Some of the species found in Thailand are worth exploring in the future for their utility in South Asia to boost overall parasitism.

Host-plant resistance

Fifty-eight breeding lines from crosses made by AVRDC plant breeders were screened for resistance to EFSB at GAU. These lines were selected earlier at AVRDC for their least pest damage and good fruit quality and yield. These entries were planted in non-replicated bservational plots in August 2001 and screened for EFSB damage at five weekly harvests. Pest damage ranged from 0 to 50% of fruits. GAU staff selected 13 lines that showed the least damage. These lines were either damage-free during all five observations or had no more than 10% fruits damaged during a single harvesting period. These lines will be screened at AVRDC for EFSB resistance again during summer 2002 and lines with most consistent resistance, good fruit quality, and high yield will be selected for further tests elsewhere.

Oviposition and feeding attractants for eggplant fruit and shoot borer

Eggplant fruit and shoot borer (EFSB), a damaging pest of eggplant in south and southeast Asia, is specific to eggplant. Adults lay eggs on eggplant foliage and the hatching larvae feed on eggplant fruits and tender shoots. If not controlled in a timely and effective manner, over 50% of fruits can easily succumb to pest damage. Excessive use of insecticides is common and EFSB is developing resistance to many chemicals. The development of an alternative, safe, and sustainable control measure is badly needed.

Host-plant specificity of EFSB to eggplant indicates that this insect utilizes certain host-specific signals, most likely mediated by host-plant chemicals, for finding eggplant for oviposition and feeding. Genetic manipulation of eggplant to alter production of these chemicals, thus making the host less susceptible, provides an interesting possibility in managing EFSB. In 2000–2001, preliminary tests were conducted to characterize the nature of these host-plant chemicals.

Oviposition preference

In a 20 m x 20 m parcel of land, enclosed on all sides with 2-m-high nets, eight potted eggplants in each of pre-flowering (three weeks after transplanting), full-flowering, and fruiting stages, were placed at random. Laboratory-reared adults of EFSB were released in the center at sunset and allowed to fly out and lay eggs on the potted eggplants. EFSB adults preferred to lay eggs on eggplant in flowering and fruiting stages, compared to plants in pre-flowering stage (Table 47). On average, the number of eggs laid on flowering or fruiting plants were seven to eight times higher

Table 47. *Influence of plant growth stage on the preference of eggplant fruit and shoot borer for egg laying on eggplant.*

Plant growth stage	No. eggs laid/plant
Pre-flowering	2.50 ± 2.56
Flowering	17.17 ± 9.92
Fruiting	21.00 ± 8.07
LSD (0.05)	7.95

compared to plants in pre-flowering stage. The preference of pest adults for post-flowering stage is possibly due to the presence of fruit (preferred by larvae over shoots for feeding) or flowers which soon produce fruit. The attraction of EFSB to chemicals emanating from plants in flowering or fruiting stage was suspected.

Oviposition attracting chemicals

Freshly excised leaves or flowers, depending on treatment, from flowering plants were placed in an 800-ml glass beaker and hexane was poured to cover the plant part completely. The beaker was covered with a glass petri dish on the top and the entire set up was quickly placed in a household microwave oven. The oven was run for 1 min. The plant parts were removed from hexane promptly. This microwave radiation selectively heated the tissues and resulted in leaching of oviposition-attracting chemicals from the tissue to move into the surrounding hexane solution. This hexane extract was dried over anhydrous sodium sulfate to remove water and then concentrated by flash-evaporation to 1 ml.

Aliquots of extracts from tissues were bioassayed for oviposition attraction activity. A 4-m-long, 30-cm-diameter, cylindrical clear plastic "I tube" was used in studying oviposition activity of the leaf or flower chemicals. Both open ends of the tube were closed using 32-mesh nylon net. A filter paper coated with microwave-assisted extract of leaves or flowers was attached to the inner sides of the nylon net at one end of the tube and a filter paper coated with hexane alone was attached at the other end of the tube. Two pairs of mated EFSB adults were placed in the center of the tube late in the afternoon and the whole tube was covered with a dark cloth. Fans on both sides ran at equal but low speed, blowing air from over the filter papers inside the tube containing EFSB adults. The following morning, nets were removed from both ends and the number of eggs laid on the net and filter papers were recorded. In four tests with leaf extract, the number of eggs laid on the net and filter paper coated with hexane extract of foliage and hexane solvent alone were 123±30 and 8.50±8.24, respectively. The difference in the number of eggs laid was highly significant ($P \leq 0.01$). Similarly, flower extract attracted 90.25±10.63 eggs while its blank attracted 1.25±1.50 eggs. This difference was also highly significant ($P \leq 0.01$).

In a similar study, instead of extracting leaves or flowers with hexane, flowering branches of eggplant were placed in an airtight clear acrylic chamber. The air inside the chamber was sucked from over the flowering branch and continuously passed through a 30-cm column of hexane to absorb the volatile chemicals. The hexane was concentrated and bioassayed for EFSB egg laying activity in a similar manner as described above. The hexane extract of plant volatile had 100.75±9.54 eggs and hexane alone has 11.00±3.37 eggs. The difference in the number of eggs laid in these two treatments was highly significant ($P \leq 0.01$).

During 2002, these plant extracts will be purified to isolate and identify chemicals within these extracts that are responsible for attracting EFSB for egg laying. In addition, efforts will be made to isolate and identify chemicals that are responsible for EFSB larval feeding on eggplant fruits and shoots.

Timing of insecticide application for control of onion thrips

Onion thrips, *Thrips tabaci*, a highly polyphagous and cosmopolitan insect, is a damaging pest of onion during relatively cooler and drier periods of the year. During the past four years, AVRDC has conducted a series of tests to understand the characteristics of thrips' damage to onion crops. From this work it was concluded that the onion crop remains tolerant to the pest during early growth but later becomes susceptible when bulbs start enlarging, a few weeks before the crop is ready for harvest. This period is the most vulnerable time for pest damage and suitable control measures are essential at this stage if one is to avoid yield loss.

Currently, farmers use chemical insecticides routinely throughout the season to control this pest.

This not only wastes chemical but such pesticide use early in the season unnecessarily kills natural enemies, which exacerbates the pest problem later in the season. Since finding practical techniques for sustainable control of thrips without the use of pesticides is not feasible, AVRDC has been working to determine the optimal timing of pesticide applications to control the pest with minimum quantity of pesticides.

A trial was arranged using randomized complete block design and four replications. Plots were 3 m x 3.3 m. Five-week-old onion seedlings of variety California 606 were transplanted in each plot on 26 Oct. 2000. The treatments were defined by the dates that spraying was initiated, namely either 4, 6, 8, or 10 weeks after transplanting (WAT). The check plot was left untreated. Treated plots were sprayed weekly using profenofos and carbosulfan in rotation. Plots were monitored weekly for damage. 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. Pest damage results in loss of chlorophyll and browning of damaged plant part. 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 measured at harvest time. There was a significant correlation between increases in damage ratings and reductions in final yields (r^2=0.89, $P \leq .05$).

Plots that were initially sprayed 4, 6, or 8 WAT suffered significantly less thrips damage than plots initially sprayed 10 WAT or not sprayed at all ($P \leq .05$) (Figure 11). There was no difference in damage ratings among the plots where spraying was initiated at 4, 6, or 8 weeks after transplanting.

For the autumn-winter crop in southern Taiwan, the period of 10 weeks after transplanting coincides with bulb enlargement. 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 variety used. Any spraying done before this time could be harmful to the environment, natural enemies of thrips, farmer health, and farmer profits.

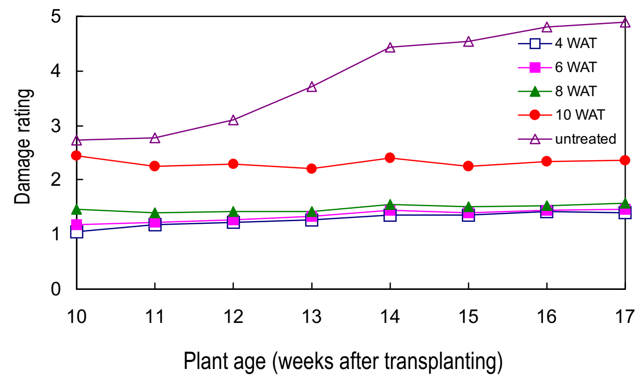

Figure 11. *Effect of initiation of pesticide sprays at various weeks after transplanting (WAT) on the damage of thrips to onion.*

Role of *Pythium* in sudden death of flooded tomato plants

Tomato production in lowland areas of tropical and subtropical countries during the hot- wet season faces a number of constraints, and yield is generally quite low compared to that in the cool season or from highland production areas. High temperatures reduce fruit set, heavy rainfall directly damages aerial plant parts, soil waterlogging reduces plant vigor, and short periods of soil flooding can result in sudden death of tomato plants.

Soil flooding for periods of 2 to 3 days can cause wilting, chlorosis of the lower leaves, leaf epinasty, adventitious root development, and reduced stem and root sizes of tomato plants. In greenhouse studies conducted a few years ago at AVRDC, it was shown that the severity of flooding-induced symptoms increased with increasing temperatures during the flooding period, but generally most of the plants survived even at the higher temperatures. Similar observations were made in field studies, except that during hot weather the tomato plants often wilted and died soon after flooding. It is generally held that damage to tomato caused by soil flooding is due to a reduction of oxygen in the root zone which inhibits aerobic respiration by the roots and sets off a cascade of metabolic changes. Increasing temperatures reduce oxygen concentrations in water and increase the oxygen demand by roots; thus it has been speculated that relatively short periods of flooding at high temperatures could be directly responsible for death of tomatoes by depriving the root system of oxygen.

The question is—why do tomato plants often die following flooding at high temperatures in the field but not in pot studies in the greenhouse? One chief difference noted was that greenhouse studies were done using steam sterilized soil which suggested that there might be a biological component responsible for tomato death in the field soils that was being eliminated by sterilization.

In summer tomato trials at AVRDC in recent years, we have been observing the occurrence of a stem rot, caused by *Pythium aphanidermatum*, in scattered plants following heavy rains that did not result in soil flooding. This organism is known to have a high temperature optimum (35 to 40 °C), and it is also known that temperature greatly influences infection and subsequent damage that it causes to its plant hosts. Temperatures of 30 to 35 °C are considered to be most favorable for disease development, while at lower temperatures damage is much less or negligible. The pathogen has a very fast growth rate and is a prolific producer of zoospores. It is often cited as the causal agent of root diseases and wilting of a number of vegetable crops grown in hydroponics systems. *P. aphanidermatum* is a well-known pathogen of tomato that has been shown to cause damping-off, stem rot, root disease, and fruit rot.

Taking all of these factors into consideration, we began to suspect that *P. aphanidermatum* might play a role in the death of flooded summer tomatoes. Therefore, we conducted a greenhouse test on tomatoes grown in 40-liter plastic tubs. Tomato plants were transplanted into *P. aphanidermatum*-infested and non-infested steam sterilized soil. The plants were watered daily to maintain good soil moisture without flooding. None of the plants in the non-infested tubs died after transplanting. About 10% of the plants in the *P. aphanidermatum*-infested tubs died during the first two weeks, but the remaining plants grew normally without any disease symptoms. After two months, tubs were flooded for 48 or 72 hours. Wilting and chlorosis of lower leaves of the tomato plants occurred in all of the flooded tubs. However, wilting of plants in the *P. aphanidermatum*-infested tubs was much faster and all of the plants died, whereas the plants in non-infested tubs recovered from the wilting soon after the flood water was removed. Root systems from the various treatments were washed and observed; roots that were most severely damaged were those taken from the flooded, pythium-infested tubs. Most of the cortical tissue on the roots in this treatment was dead and sloughing off.

Based on our preliminary results, we believe that *P. aphanidermatum* (and perhaps other oomycetes) is involved in the sudden death of flooded tomatoes in the summer. Further research will be conducted to confirm these results.

An enriched-PCR method for detecting *Ralstonia solanacearum* from soil and water samples

Bacterial wilt caused by *Ralstonia solanacerum*, a soil-borne pathogen, is the most important disease for tomato production in the lowland tropics during hot and wet seasons. The pathogen is able to survive in soils and is carried along water. A sensitive detection method is essential in finding the origin of initial inoculum, which is important for designing an effective integrated management package. The most commonly used detection method for *R. solanacearum* is direct plating on selective media such as modified selective media (SM-1). However, the best sensitivity is at the 100-cell level depending on the kinds of microorganisms in the samples. Specific primers of *R. solanacearum* have been identified and used in detection. The sensitivity could be at 10 to 100-cell level with pure cultures, but decreased to 10^6-cell level when detecting from infested soils. This decrease was mostly due to the presence of polymerase chain reaction (PCR) inhibitors. Several reports indicated that enriching the pathogen population using selective media could enhance the sensitivity of PCR methods for soil and water samples. Thus, the objective of this study was to determine whether a pre-enrichment treatment with selective media could increase the sensitivity of PCR to detect the pathogen from soil and water samples.

Soil samples used for this study were collected from AVRDC farm (AVRDC), Kuan-tien in Tainan (KT1, KT2, KT3), and Chung-lin in Hsinju (CL1, CL2, CL3) counties. The pH values of the soil samples were measured after diluting with 0.01 M $CaCl_2$ in the ratio of 1 to 2 (w/v). To determine the efficacy of enrichment method, soils artificially infested with *R. solanacearum* Pss4 (race 1, biovar 3) were prepared by mixing individual soil samples with bacterial suspensions of different densities in the ratio of 10 to 1 (w/v). For enrichment, 1 ml of soil suspension (10 g infested soil in 90 ml sterile water) was added into 9 ml liquid SM-1 medium. The culture was incubated at 30 °C with 160 rpm, and samples were taken every 24 hours for detection. The detection methods included direct plating on SM-1 or PCR with AU759/760 primer pair, which is specific to different strains of *R. solanacearum* regardless of their biovar and origin. For template preparation, 5 ml of bacterial suspension or enriched cultures was placed in a 50-ml tube, covered with two drops of mineral oil, and placed into boiling water bath for five minutes and processed through standard PCR steps with 60 °C as the annealing temperature. A 281-bp specific band indicating the presence of the pathogen was checked by electrophoresis. Water samples were collected from two ground wells of KT1 and KT2 and canal water at KT3. Identical processes were made as the soil samples to determine the efficacy of the enrichment method.

To determine the period required for enrichment, growth of Pss4 strain in SM-1 cultures was monitored at 30 °C over time. When Pss4 suspension was added into the SM-1 media, it took three to four days to reach maximum growth no matter the starting concentration, and then gradually declined (Figure 12A). The Pss4-infested AVRDC soil samples showed similar results, except that no growth decline was observed even until seven days after incubation (Figure 12B). During these two experiments, it was possible to detect the pathogen from the enriched cultures by PCR method using AU759/760 starting at one day after incubation. Therefore, we conclude that the enrichment period need not be longer than four days.

Several soil and water samples were collected to test the efficacy of this enrichment method. The pH values of the soil samples collected were 7.4 for KT1, 6.5 for KT2, 5.9 for KT3, 4.8 for CL1, 6.0 for CL2, and 4.1 for CL3. By adding different amounts of bacterial cells, the results showed that the sensitivity of the enriched-PCR method could be at the 10-cell level for detecting the pathogen from soil and water samples after enriching for two to three 3 days (Table 48). We are verifying the effectiveness of the enriched-

Table 48. *Detection of* Ralstonia solanacearum *from water or soil samples by enriched-PCR method with AU759/760 specific primers.*

	Cell levels		
Sample[1]	1	10	100
KT1 soil	+ (3)[2]	+ (2)	+ (2)
KT2 soil	+ (2)	+ (2)	+ (2)
KT3 soil	- (2)	+ (3)	+ (3)
CL1 soil	- (3)	+ (3)	+ (3)
CL2 soil	+ (3)	+ (2)	+ (2)
CL3 soil	- (3)	+ (2)	+ (2)
KT1 groundwater	+ (2)	+ (2)	+ (2)
KT2 groundwater	+ (2)	+ (2)	+ (2)
KT3 canal water	+ (2)	+ (2)	+ (2)

[1]Water or soil samples were infested with Pss4 suspensions to prepare samples with different theoretical initial density at the 10^0, 10^1, or 10^2 cell level.
[2]+ or – indicated the presence or absence of the 281-bp band, and the values in the parentheses were the days of enrichment applied to individual samples.

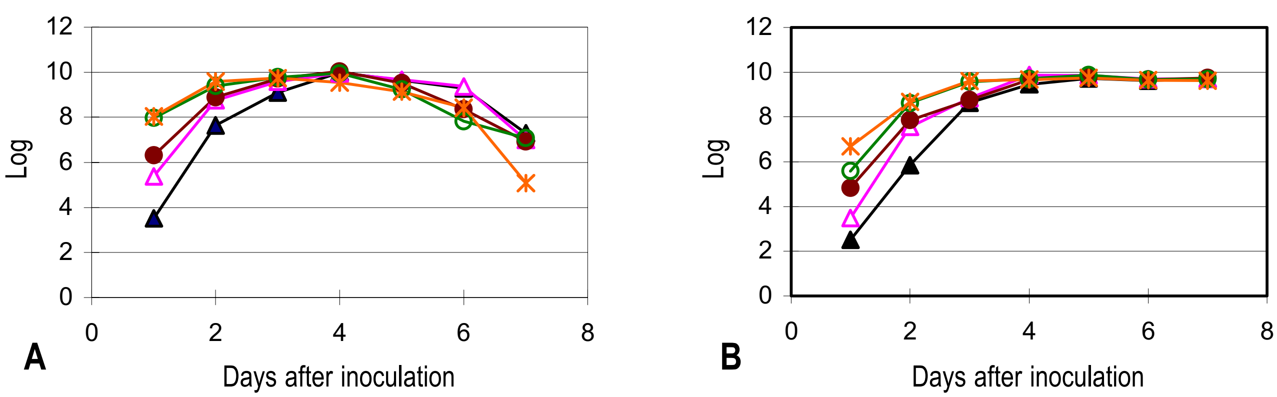

Figure 12A, B. *Population change of* Ralstonia solanacearum *Pss4 strain when incubating in SM-1 broth with different initial inoculation densities in water suspension (A) or in artificially infested AVRDC soil suspension (B). Line symbols indicate the theoretical initial density as ▲ for 1-cell level, △ for 10-cell level, ● for 100-cell level, ❍ for 1000-cell level, and * for 10,000-cell level.*

PCR method by testing additional soil and water samples from fields with or without known bacterial wilt history. Moreover, a sampling scheme needs to be developed for collecting soils from production fields for correlating the detecting results with real disease incidence.

Survey of viral diseases of solanaceous crops in Asia

Knowledge of the prevalence of virus diseases on solanaceous crops in Asia will help to understand the epidemiology and assist in developing effective control methods. In 2001, disease surveys were conducted on pepper, tomato, eggplant and weeds in 10 countries for the presence of nine viruses: cucumber mosaic virus (CMV), chili veinal mottle virus (ChiVMV), potato virus Y (PVY), tomato mosaic virus (ToMV), pepper mild mottle virus (PMMV), broad bean wilt virus (BBWV), watermelon silver mottle virus (WSMV), pepper veinal mottle virus (PVMV) and whitefly-transmitted geminiviruses.

On tomato, the most prevalent viruses were the whitefly-transmitted geminiviruses, with 57% of the 453 samples testing positive (Table 49). This was followed by CMV (14%) and ToMV (12% [all in Taiwan]) (Table 50). ChiVMV was not identified in any tomato samples.

On pepper, BBWV, ChiVMV, CMV, geminiviruses, and PMMV were the most prevalent viruses, encountered in 26%, 25%, 16%, 13% and 12% of the tested samples respectively. BBWV was present on the pepper crop only in China, Laos and Vietnam (Table 50).

Although sample numbers are relatively low, it was interesting to note that the incidence of geminivirus infection in eggplant was high (58% of samples), especially in China (100%) and Malaysia (100%) and Thailand (83%) (Table 49). This should be considered in IPM practices for this crop in the region.

Table 49. *Geminivirus survey of major solanaceous crops and weeds in Asia, 2001.*

Country	Plant	Samples tested	No. and (%) of positive samples
Bangladesh	Tomato	119	88 (74)
	Pepper	48	0
China	Tomato	3	3 (100)
	Pepper	3	2 (67)
	Eggplant	3	3 (100)
Cambodia	Tomato	9	3 (33)
	Pepper	6	0
	Eggplant	2	0
	Weed [1]	1	0
India	Tomato	72	37 (51)
	Pepper	43	4 (9)
	Weed [2]	19	5 (26)
Indonesia	Weed [3]	5	1 (2)
Laos	Tomato	8	4 (50)
	Pepper	22	0
	Weed [4]	9	7 (78)
Malaysia	Tomato	8	1 (17)
	Pepper	22	4 (67)
	Eggplant	2	2 (100)
	Weed [5]	10	2 (20)
Myanmar	Eggplant	7	5 (71)
	Weed [6]	22	0
Nepal	Tomato	46	0
Pakistan	Tomato	13	7 (54)
	Pepper	10	10 (100)
	Weed [7]	1	0
Philippines	Tomato	65	40 (62)
	Pepper	5	0
Sri Lanka	Tomato	43	14 (33)
	Pepper	2	1 (50)
Taiwan	Tomato	40	38 (95)
	Weed [8]	6	4 (67)
Tanzania	Tomato	9	7 (78)
Thailand	Tomato	13	13 (100)
	Pepper	8	0
	Eggplant	6	5 (83)
	Weed [9]	7	2 (29)
Vietnam	Tomato	7	3 (43)
	Pepper	12	0
	Eggplant	6	0
	Weed [10]	5	0
TOTAL	Tomato (14 countries)	453	259 (57)
	Pepper (11 countries)	165	21 (13)
	Eggplant (6 countries)	26	15 (58)
	Weed (10 countries)	66	21 (32)

Positive samples noted by (+): [1]Unknown weed. [2]*Acalypha* sp., *Ageratum conyzoides* (+), *Ageratum* sp., *Croton bonplandianum* (+), *Croton* sp. (+), *Malvastrum coromandelianum, Malvastrum* sp., *Parthenium* sp.. [3]*Ageratum conyzoides* (+), *Hyptis rhomboidea.* [4]*Ageratum houstonianum* (+), *Ageratum* sp., unknown weed (+). [5]*Ageratum conyzoides*(+), *Ageratum* sp., *Asystasia intrusa, Mikania micrantha, Paspalum conjugatum.* [6]*Ageratum* sp.. [7]Unknown weed. [8]*Ageratum* sp. (+). [9]*Cleome viscosa, Euphorbia geniculata, Paspalum foetida, Ramacardens calyptocarpusvialis, Zinnia elegans* (+), *Passiflora* sp., and Compositae family (+). [10]Unknown weed.

Table 50. *Survey of virus infection of tomato, pepper, and ageratum in selected countries in Asia, 2000-2001.*

Country	Crop	Samples tested	Virus-positive samples[1]							
			CMV	ChiVMV	PVY	ToMV	PMMV	BBWV	WSMV	PVMV
Bangladesh	Pepper	156	33	42	–[2]	–	–	–	–	–
	Tomato	17	0	–	0	0	–	–	–	–
Cambodia	Pepper	1	1	0	0	0	0	0	0	–
	Tomato	1	1	–	0	0	–	–	0	–
China	Pepper	47	26	22	–	–	20	36	–	–
India	Pepper	30	0	0	0	–	–	–	–	–
Laos[3]	Pepper	21	0	12	0	0	0	6	2	0
	Tomato	8	2	0	0	0	0	0	2	0
Philippines	Pepper	5	0	0	0	0	0	–	0	0
	Tomato	11	4	–	–	–	–	–	0	–
Taiwan	Pepper	278	76	63	6	1	32	0	–	–
	Ageratum	50	6	0	0	0	0	–	–	–
	Tomato	175	12	0	2	25	0	0	–	–
Thailand	Pepper	8	–	5	–	–	7	–	–	–
	Tomato	12	12	–	12	–	–	–	–	–
Vietnam	Pepper	7	0	2	0	0	0	2	1	0
	Tomato	3	0	0	0	0	0	0	0	0

[1]CMV = cucumber mosaic virus, ChiVMV = chili veinal mottle virus, PVY = potato virus Y, ToMV = tomato mosaic virus, PMMV = pepper mild mottle virus, BBWV = broadbean wilt virus, WSMV = watermelon mosaic virus, PVMV = pepper veinal mottle virus.

[2]Not tested.

[3]Ageratum, two papaya, two summer squash and five weeds from Laos were also tested and found negative for all viruses.

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

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

Nutrient content of the Center's principal crops 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

Comparative analysis of the vegetable sector in Cambodia, Laos, and Vietnam

Socioeconomic surveys were conducted to provide insights into various aspects of vegetable production, marketing, and consumption in the region. This survey, the largest of its kind in history, contacted about 1600 vegetable farm families in remote areas of Laos, Cambodia, and northern and southern Vietnam, and collected production-related data for more than 5500 parcels. A multi-disciplinary team was organized on each site to execute the survey in collaboration with the AVRDC Socioeconomic Unit.

The characterization of farmers in the region suggests that vegetable farmers are resource poor to start with. However, they generally have slightly higher education levels than other farmers and they invest resources to improve drainage of their lands—an important requirement for vegetable cultivation. Vegetable farmers are better connected with the market, therefore, they earn more off-farm income which enables them to take the risks inevitable in vegetable cultivation (Table 51).

The synthesis of the four reports revealed tremendous variation in vegetable production practices in the region (Table 52). A profitable networking approach can be built upon this variation to benefit vegetable farmers in each location by learning from the experience of other locations. As major vegetables grown at each site vary, researchers at one site can focus on the major commodities produced at their own site, and learn from the research on other major vegetables at other sites.

It is furthermore concluded from the synthesis of the location reports that there is great potential to improve the vegetable seed and seedling industry in

Table 51. *Farm and household characteristics of vegetable farmers compared to non-vegetable farmers in Cambodia, Laos, and Vietnam.*

Character	Cambodia	Laos	Vietnam (northern)	Vietnam (southern)
Larger family size	No	No	Yes	No
Bigger house size	No	No	Yes	No
Higher % of farmers owning water pumps	No	No	No	No
Higher % of irrigated land	No	No	No	No
Higher % of light soils	No	No	No	No
Higher % of land plowed by tractor	No	No	No	No
Smaller farm size	Yes	Yes	No	Yes
Better education of household head	Yes	Yes	No	Yes
Higher off-farm income	Yes	–[1]	Yes	Yes
Higher percentage of well drained land	No	Yes	No	Yes

[1]Not determined.

Table 52. *Management practices used (% of total parcels) on vegetable cultivation in Cambodia, Laos and Vietnam.*

Practice	Cambodia	Laos	Vietnam (northern)	Vietnam (southern)
Transplanting	46	43	45	44
Mulching	4	8	27	4
Staking in fruit veg.	21	27	100	70
Raised bed	55	0	100	99
Pesticide treatment	84	57	93	92
Fertilizer application	91	88	95	100
Manure application	26	26	80	53
Irrigation	88	80	95	97
Weeding	84	42	99	70

the region, which can boost vegetable production levels as a whole. This is because a large proportion of seed used in these countries is uncertified, and seedling production practices are not fully developed.

The building of modern farm-level irrigation channels in Cambodia and northern regions of Vietnam can save labor that is currently tied up in manual irrigation, and can also boost vegetable production. To build such infrastructure in these regions, where vegetable plots are so small, cooperation is required among farmers. This can be built on the existing commune structure that still loosely and informally exists in rural communities. In Laos, on the other hand, vegetable fields need to be properly prepared to facilitate irrigation operations.

The level of mechanization in land preparation varies across site, as well as input use intensity (Table 53). Cross-location synthesis revealed that high capitalization (i.e., greater use of machinery) in vegetable production does not necessarily lead to lower unit output cost. This is evidenced by the higher unit output cost in southern Vietnam and Laos (where capitalization is high) compared to unit output cost in northern Vietnam (where capitalization is low). Similarly, higher input use (such as fertilizer and pesticide) also do not reduce the unit output cost, unless they are properly used and supplemented with proper irrigation, marketing, and transport infrastructure. There remains much to learn from farmers' strategies to produce vegetables at low cost under their own constraints.

Table 53. *Mechanization, input use, yield, and economics of vegetable production per cropping season in Cambodia, Laos, and Vietnam.*

Input/yield	Cambodia	Laos	Vietnam (northern)	Vietnam (southern)
Land preparation (% of land prepared)[1]				
Tractor	3.5	30	8	31
Animal	95	21	78	5
Hand	0.5	41	13	8
Fertilizer (nutrient kg/ha)	148	91	350	534
Manure (t/ha)	1.7	1.3	9.6	7.6
Number of pesticide sprays	6.2	1.5	2.4	7.9
Number of irrigations	50	21	5	31
Labor (labor days/ha)	437	223	468	297
Yield (t/ha)	10.5	10.6	18.5	25.2
Economics of vegetable production				
Total cost (US$/ha)	1081	669	721	1355
Net return (US$/ha)	452	696	908	1151
Unit output cost (US$/t)	140	94	79	70

[1]The percentages by sources in each source may not add up to 100, as the remaining percentage of parcels was not given these operations.

Marketing as an institution need to be established on modern lines throughout this region, especially in northern Vietnam and Laos, where most of the retail selling of vegetables is done by the farmers themselves. As a first step, cooperative marketing through communes should be encouraged. This can relieve family labor that is currently tied up in self-retailing, and can provide vegetable farmers access to a large number of consumers living in other regions. In cities, an efficient wholesale marketing infrastructure for vegetables needs to be established. The transportation infrastructure should be improved, especially in Cambodia and Laos.

Vegetable production is input intensive and requires a significant amount of cash resources. This limits vegetable cultivation to only those farmers who can commit these resources. Development of cost reducing technologies, instead of searching for high-cost sophisticated ones, should be an important objective of vegetable research and development programs in the region. Moreover, formal financial institutions need to be strengthened to overcome this constraint.

Although most farmers in the region apply pesticides, insect problems persist. Notwithstanding that vegetable farmers and their families are relatively better educated, they have poor knowledge about vegetable insect pests and diseases. Therefore, integrated pest management (IPM) training on diagnosing insect pests and diseases and taking appropriate control measures can reduce production costs as well as lead to the production of safe vegetables for consumers.

The relatively small differences between the dry and wet season yields of vegetables (Table 54) suggests that there exists:

- regions within the respective countries which can produce high yields during the hot-wet season;
- vegetable crops which give high yields during the hot-wet season; and
- farm-level technologies to mitigate excessive moisture and heat stresses.

To mitigate seasonality of vegetable production, researchers may look to southern Vietnam where relatively little seasonality in vegetable production is noticed. We need to learn more about farmers' strategies of supplying vegetables during the hot-wet season before suggesting high-cost technologies. Moreover, connecting suitable vegetable growing

Table 54. *Seasonal yield of vegetables by survey site.*

	Dry 1 season			Dry 2 season			Wet season		
Site	Months	Observation (number)	Yield (t/ha)	Months	Observation (number)	Yield (t/ha)	Months	Observation (number)	Yield (t/ha)
Cambodia	Nov.–Jan.	420	11.1 a[1]	Feb.–Apr.	112	9.1 b	May–Oct.	133	9.6 b
Laos	Oct.–Jan.	244	11.6 a	Feb.–Apr.	71	9.8 b	May–Sept.	103	8.9 b
Vietnam (northern)	Oct.–Dec.	569	19.4 a	Jan.–Apr.	125	16.0 b	May–Sept.	432	18.0 b
Vietnam (southern)	Oct.–Dec.	177	22.1 b	Jan.–Mar.	378	26.9 a	Apr.–Sept.	517	25.0 a

[1]Mean separation within rows at $P \leq 0.10$.

regions in the highlands with less suitable growing regions in the lowlands through infrastructure development can be another strategy to mitigate seasonality in regional vegetable supplies.

The role of vegetables in diets and types of vegetables consumed vary across the survey sites. The nutrient deficiency is clearly related with the level of vegetable consumption (Table 55). For example, the farmers with greatest nutrient deficiencies for vitamins A, C and iron in this study were those living in Cambodia, the location where farmers consume relatively less vegetables.

Promoting vegetable cultivation on small farms can be an important tool to alleviate poverty and nutrient deficiency. First of all, shifting resources from cereals to vegetables itself improves farm resource efficiency (Table 56). Vegetable cultivation also improves managerial skills of farmers, which when applied to non-vegetable crops like cereals, further improves resource use efficiency and their productivity. The resultant higher total farm income both from cereals and vegetables leads to the consumption of better quality food, thus improving their nutritional status.

When all these benefits are added with higher per ha income from vegetable cultivation and off-farm incomes, the overall farm and non-farm earnings of vegetable farmers exceed many times of the earnings of non-vegetable farmers. Thus vegetable production can lead to healthy, wealthy, and busy farmers, with diversified production and income sources.

Table 56. *Resource-use efficiency in vegetable and rice cultivations in Cambodia, Laos, and Vietnam.*

			Vietnam	
Characteristic	Cambodia	Laos	(northern)	(southern)
Return of land use (US$/ha/day)				
	5	12	11	12
Benefit-cost ratio				
Vegetables	96	170	127	106
Rice	53	54	19	43
Labor productivity (US$/day/person)				
Vegetables	4	6	3	8
Rice	2	7	1	4
Fertilizer productivity (US$/kg nutrient)				
Vegetables	17	27	6	8
Rice	7	16	2	3
Irrigation productivity (US$/US$ water)				
Vegetables	8	11	24	21
Rice	21	42	8	15

The AVRDC along with its national partners can play a role in the development of vegetable sector in Cambodia, Laos, and Vietnam through the following means:

Table 55. *Types of vegetables consumed and nutrient deficiency by site in Cambodia, Laos, and Vietnam.*

	All vegetables	Consumption (% share)			Nutrient deficiency[1]		
Site	(g/capita/day)	Fruit	Root and stem	Leafy	Viitamin A	Vitamin C	Iron
Cambodia	154	58.1	8.3	33.6	39	11	32
Laos	161	32.7	48.4	18.9	36	-1	23
Vietnam (northern)	240	12.1	7.6	80.3	-27	-57	0
Vietnam (southern)	223	32.5	4.2	63.3	-5	-35	8

[1]Negative values indicate a nutrient surplus.

- catalyze the development of vegetable research and development networks in the region;
- help to identify and prioritize the regional issues in the vegetable sector;
- understand farmers' strategies to avoid seasonal stresses, and help national programs to develop low-cost/stress-tolerant technologies for small-scale farmers;
- understand farmers' strategies to produce vegetables at low unit output costs, and help national programs in developing appropriate technologies for mass adoption;
- help national programs to understand vegetable market functions for the purpose of developing modern marketing institutions;
- train farmers on pest control strategies that reduce unnecessary pesticide use and produce safe vegetables;
- train farmers and private industry personnel in seed and seedling production; and
- train farmers on appropriate irrigation methods according to the availability of water.

Research and development of vegetables in South and Southeast Asia: a guideline for setting priorities

Historical data on vegetable and cereal production in South and Southeast Asia have been updated from statistical bureaus of respective countries through national collaborators in the region. Data on area, production, and yields of individual vegetables and cereals were completed for the period 1981-2000. The macro-level data were supplemented with the perceptions of the policymakers regarding various vegetable related issues from Southeast Asia.

The trend analysis of vegetable production suggests that it is a booming sector in South and Southeast Asia. During 2000, these regions produced nearly 100 million tons of vegetables from 9.2 million ha. During the 1980s and 1990s, vegetable production in these regions had almost tripled at the rate of 4.9% per annum. Major increases in production came from yield improvement, which increased at the rate of 3.2%, while increases in area were about half of that. In Southeast Asia alone, the overall vegetable sector amounted to US$10.8 billion, which is about one-third of the size of the cereal sector (Table 57). The importance of vegetables in the overall agriculture economy has significantly increased in terms of area, economic value, and employment during the past two decades. Now the vegetable sector is a key component of agriculture and cannot be ignored in agricultural policy planning.

Despite improvements in vegetable supplies, their availability remains far below the recommended level of 73 kg per capita per annum. Retail prices of vegetables have increased due to the economic crisis in Southeast Asia and shifting of vegetable production to remote areas, among other factors. This rise in prices has reduced the access to vegetables, which has aggravated the micronutrient deficiency problem, especially among the poor. Hence, there are nutritional and development reasons to improve the vegetable sector in South and Southeast Asia.

Improving the vegetable sector is a complex challenge as there are more than 50 widely consumed vegetable species, each with their own production

Table 57. *Status of vegetable sector in South and Southeast Asia.*

	South Asia		Southeast Asia		Overall	
Parameter	Estimate for 2000	Annual growth rate (%) (1980-2000)	Estimate for 2000	Annual growth rate (%) (1980-2000)	Estimate for 2000	Annual growth rate (%) (1980-2000)
Production (million t)	77.7	5.2	22.6	4.0	100.0	4.9
Area (million ha)	6.7	1.7	2.4	1.4	9.2	1.6
Yield (t/ha)	11.5	3.4	9.3	2.6	10.9	3.2
Per capita availability (kg/year)	54.7	3.3	44.2	2.1	51.8	3.0
Value of vegetables (billion US$)	–	–	10.8	3.8[1]	–	–
Ratio of vegetable to cereal value (%)	–	–	32	3.7[1]	–	–
Ratio of vegetable area to cereal area	5.4	2.4[1]	4.7	1.8[1]	5.2	2.2[1]

[1]Annual growth rate for 1991-2000.

constraints. The challenge is further magnified since only meager resources are currently allocated for vegetable research. Under this scenario, efficient research and development strategies need to be designed to deliver the technological innovation for various environments.

In terms of area, chili pepper is the major vegetable grown in South and Southeast Asia. Tomato, onion/shallot, and cabbage are other important vegetable crops in both regions. Eggplant and gourds are especially important in South Asia and yardlong bean is a prominent crop in Southeast Asia.

Food consumption surveys in Cambodia, Laos, and Vietnam show that leafy vegetables contribute 52% of the total vegetable consumption, followed by fruit types at 37%, and stem and root types at 10%. On the other hand, fruit types are the major vegetables consumed in South Asia (56%), followed by root and stem (22%) and leafy types (22%). Therefore, these demand structures should be kept in view while allocating research funds for the two regions.

A survey conducted with the representatives of vegetable policymakers from the Association of Southeast Asia Nations (ASEAN) showed that the upland intensive system is the major supplier of vegetables in the region (Table 58). The hot-dry and hot-wet seasons emerged as the largest contributors in total vegetable production (Table 59). Priority areas for research and development were germplasm improvement, followed by technology improvement, development of seed and seedling industries, and transfer of low pesticide production techniques (Table 60). The policymakers want researchers to focus on the hot-wet season in researching these issues (Table 61). Although major supplies of vegetables are coming from the upland intensive system, more attention was demanded for peri-urban systems (Table 62).

Albeit consumers were willing to pay higher prices for "safe" vegetables, they seem to be indifferent between vegetables grown organically (free of any chemicals) versus vegetables grown using integrated pest management (having allowable pesticide residue). Member nations were of the view that their vegetable growers are more interested in information about available varieties, seed sources, optimum levels of input use, and control measures for major diseases of the vegetables. On-farm training and demonstration plots are anticipated as relatively more efficient methods of transferring information from research

Table 58. *Distribution of vegetable supplies (% of total production) by production system in Southeast Asia.*

Crop	Peri-urban lowland	Rice-based lowland	Upland intensive	Home garden
Bean sprouts	54.4	32.6	3.0	10.0
Carrots	1.8	3.9	92.5	1.8
Chili	7.9	47.5	44.0	0.6
Cucurbits	25.4	35.4	34.7	4.5
Eggplant	25.8	40.6	29.5	4.0
Garlic	2.6	46.7	48.8	1.9
Heading brassicas	10.8	9.3	74.9	4.9
Kangkong	51.1	26.2	11.3	11.4
Leafy brassicas	34.5	20.2	30.2	15.1
Okra	10.0	30.0	50.0	10.0
Onion and shallot	7.4	51.6	40.5	0.5
Other fruit types	40.4	16.8	29.2	13.6
Other leafy types	34.7	8.5	30.8	26.0
Other legumes	26.5	35.5	32.6	5.4
Other root types	31.9	11.1	29.6	27.3
Radish	25.5	27.0	39.5	8.0
Sweet pepper	18.9	13.1	64.3	3.7
Tomato	19.2	16.0	52.4	12.4
Vegetable soybean	40.0	60.0	0.0	0.0
Overall	21.3	29.0	40.7	9.1

Table 59. *Percent distribution of vegetables supplies by ecology in Southeast Asia.*

Vegetable	Hot-wet (%)	Hot-dry (%)	Cool-wet (%)	Cool-dry (%)
Bean sprouts	22.4	65.0	9.4	3.2
Carrots	25.5	9.5	30.0	35.0
Chili pepper	25.3	54.6	10.9	9.2
Cucurbits	33.3	36.7	17.8	12.2
Eggplant	36.7	24.8	14.2	24.3
Garlic	2.1	37.7	2.3	57.9
Heading brassicas	24.3	16.9	26.0	32.8
Kangkong	50.1	35.2	7.4	7.3
Leafy brassicas	42.1	23.2	6.0	28.7
Okra	50.0	20.0	0.0	30.0
Onion and shallot	20.2	49.7	10.8	19.3
Other fruit types	28.6	11.5	1.6	58.3
Other leafy types	33.4	21.9	18.9	25.8
Other legumes	29.2	21.2	27.5	22.1
Other root types	23.8	26.2	22.1	27.9
Radish	10.2	13.9	19.8	56.1
Sweet pepper	12.8	0.8	39.7	46.7
Tomato	18.0	39.5	16.8	25.7
Vegetable soybean	90.0	0.0	0.0	10.0
Overall	26.9	32.7	16.3	24.1

Table 60. *Prioritization of research themes, by vegetable, in Southeast Asia.*[1]

Vegetable	Germplasm collection, utilization	Varietal improvement for Productivity	Quality	Disease resist.	Post-harvest tech.	Pesticide reducing tech.	Improved tech.	Seed, seedling business	Socio-economic research	Exploit inform. tech.	Training	Enhance consumer awareness
Indigenous veg.	9	9	7	14	7	5	13	10	9	6	5	7
Tomato	4	10	10	15	9	7	8	16	3	4	4	9
Eggplant	9	10	11	10	7	10	11	10	4	8	5	6
Chili pepper	10	9	12	8	5	8	14	12	4	7	7	5
Sweet pepper	7	21	7	10	5	8	13	11	1	8	2	9
Okra	20	15	0	0	0	5	15	5	0	15	0	25
Cucurbits	9	7	5	20	6	7	17	8	1	8	8	4
Other fruit types	2	44	21	15	2	0	1	10	1	1	2	3
Vegetable soybean	0	50	30	10	0	0	0	0	0	0	10	0
Other legumes	6	23	9	7	1	14	20	7	1	5	5	2
Onion and shallot	12	8	9	8	19	1	12	15	2	6	4	3
Garlic	7	16	16	12	3	3	12	11	3	7	5	4
Carrots	3	9	11	12	11	10	7	10	5	6	6	11
Radish	7	26	25	9	6	1	9	8	1	2	2	3
Other root types	6	6	8	22	8	6	11	13	6	4	4	7
Leafy brassicas	4	24	16	3	10	24	4	5	1	5	4	1
Heading brassicas	0	18	13	13	10	24	7	5	1	4	4	1
Kangkong	9	13	13	8	6	13	6	9	5	6	4	8
Other leafy types	4	27	16	4	6	28	2	2	3	4	1	3
Bean sprouts	5	31	6	4	6	6	18	0	3	3	15	3
Overall	7	15	12	11	7	10	10	10	3	6	5	5

[1]Source: Survey of representatives of vegetable policymakers from the Association of Southeast Asian Nations, 2001.

Table 61. *Prioritization of vegetable research and development issues by seasons in Southeast Asia.*[1]

Research & development areas	Hot-wet	Hot-dry	Cool-wet	Cool-dry
	—(Priority score in percentage)—			
Varietal improvement for:				
Productivity	47	22	14	17
Quality	45	21	13	21
Resistance	48	20	16	16
Technology improvement	43	26	14	17
Seedling industry	42	24	14	20
Post-harvest technology	47	24	15	14
Low pesticide technology	46	19	15	20
Information technology	47	18	16	19
Training	48	22	16	14
Indigenous veg. collection	48	23	15	14
Socioecon. & policy research	40	20	18	22
Overall	46	23	16	16

[1]Source: Survey of representatives of vegetable policymakers from the Association of Southeast Asian Nations, 2001.

Table 62. *Prioritization of vegetable research and development issues by production system in Southeast Asia.*[1]

Research & development areas	Peri-urban lowlands	Rice-based lowlands	Upland intensive	Home garden
	—(Priority score in percentage)—			
Varietal improvement for:				
Productivity	50	21	25	4
Quality	55	19	21	5
Resistance	56	18	23	9
Technology improvement	49	22	23	16
Seedling industry	53	16	23	8
Post-harvest technology	47	21	24	8
Low pesticide technology	49	22	23	6
Information technology	48	22	21	9
Training	50	19	25	6
Indigenous veg. collection	44	16	25	15
Socioecon. & policy research	51	21	16	12
Overall	50	20	23	8

[1]Source: Survey of representatives of vegetable policymakers from the Association of Southeast Asian Nations, 2001.

station to farmers' fields. The local national agricultural research and extension systems (NARES) desired greater capacity and involvement in varietal testing trials, germplasm exchange, and collaborated adaptive-research trials. Regarding involvement of private sector in research and development activities, it was widely desired to allow the private sector to gain access to AVRDC technology, but the nature of this partnership remained undecided. In their planning activities, ASEAN member countries are seriously lacking in many types of information that are considered necessary for successful planning.

It is suggested that production of major vegetables can be increased by making various nations specialized in producing certain vegetable crops through tri-party collaboration between AVRDC and ASEAN member countries. Linking favorable vegetable producing zones with consumption centers and developing stress-tolerant technologies were suggested to reduce seasonality in vegetable supplies. Awareness about benefits of using safe vegetables should be created among consumers through electronic media. Besides maintaining area and production data for different vegetables, other information such as investment and efficiency parameters, comparative advantage, production costs and marketing margins, trade flow and trade constraints should be maintained on regular basis so that it is readily available to the policymakers, when needed.

Methodologies for impact assessment in vegetable and mungbean research

The objective of this research project is to quantify the development impact of vegetable and mungbean research. Earlier research has shown that the *indirect* effects of agricultural research, such as improved education, productivity and employment, are probably larger than *direct* effects, which take into account only price reductions and increased supply of agricultural crops. Based on data collected during a one-year feeding trial with mungbeans and supplemented with secondary consumption data from the National Sample Survey Organization (NSSO), this study sets out to answer the following questions:

- How large are the effects of insufficient micronutrient intake (particularly iron and vitamin A) on labor productivity in poor rural households?
- What are the determinants of micronutrient demand? Does demand increase with enhanced availability (lowered prices, enhanced supply) and higher incomes?
- What is the impact of enhanced iron availability through daily mungbean supplementation on health and productivity of children?

Effects of insufficient micronutrient intake on labor productivity of poor rural households

The extent of productivity losses due to insufficient micronutrient intake is estimated using wages as a proxy for marginal productivity. The regression itself is based on a two-stage least square (2SLS) regression approach. A 2SLS approach first regresses each of the endogenous variables on all of the exogenous variables in the system, in order to calculate the estimated values of the endogenous variables. In the second stage, the estimated values are used as regressors in an ordinary least square regression. This approach is used to overcome the problem of *simultaneity*. That is, the nutrition and health status of a person may affect the level of wages and simultaneously the wage level affects the money available in households for food expenditure and therefore the nutrition and health status.

The micronutrients under investigation were iron and vitamin A, as well as interactions between iron and vitamin C. Iron and vitamin C were analyzed together because of the possible importance of vitamin C in the bioavailability of iron. Nutrition surveys show that rural Indian laborer households currently consume inadequate amounts of calories, iron, and vitamins A and C in their diets, but too much fat (Table 63).

For each micronutrient or interaction term under consideration, the semi-log wage takes the following

Table 63. *Mean and recommended intakes of rural Indian laborer households.*[1]

Nutrient[2]	Mean intake	SD	Recomm.	% of recomm.
Calories (kcal)	2254	557.5	2400	94
Iron (mg)	17	8.7	29	59
Vitamin A (µg)	326	281.3	600	54
Vitamin C (mg)	50	34.9	60	83
Fat (g)	26	14.1	20	130

[1]Source: National Sample Survey Organization, 50th round. N = 5800 agricultural laborer households.
[2]Per adult equivalent.

forms:

$$\ln W_{hh} = a + b\hat{N}_i + cZ_{hh} + dX_{hh} + gA_{hh} + e$$

where *i* indexes the individual; *hh* indexes the household; *N* is (estimated) nutrient intake in the respective unit; *Z* is a vector of time-invariant control variables at the household level, including schooling and gender of the household head and schooling of the spouse, and household composition; *X* is a vector of time-variant control variables (season, age of household head, and age squared); *A* denotes assets at household level (amount of land owned by the household, in hectares, and a dummy that indicates whether the household earns any income from interest and dividends); and *e* is the error term.

Table 64 presents the results in a summarized form (variables other than micronutrient intake are not shown). The regressions have relatively high R-squares around 0.5. Iron intake taken by itself does not show a significant impact on the wage level. However, the interaction term iron x vitamin C intake is significant at the 1% level, with an elasticity of 0.074, indicating that if intake rises by 10%, productivity rises of 0.74% can be expected.

Multiplying this by the average intake gap up to recommended levels that poor rural households experience (41%), this signifies average productivity loss of 3% due to the deficient intake of iron and vitamin C. Similarly, for vitamin A intake the elasticity on wages is 0.075, resulting in average productivity losses (or lower wages) of 3.5%.

Lifting current average deficient intake levels up to recommended levels indicates that average total household productivity increases would be in the range of 3% to 3.5%. The results demonstrate that policy interventions that aim at enhancing micronutrient intake are not merely ends in themselves. They can be regarded as investments in improved productivity and higher household incomes. Enhancing micronutrient intake will contribute significantly to overall economic growth and development. This will particularly benefit the landless poor, who are dependent on wage income as a source of livelihood.

However, the question remains how enhanced micronutrient intake, particularly for iron and vitamin A, can best be achieved, and how micronutrient intake will respond to economic growth and development. The study finds that Vitamin A intake responds positively to price reductions in vegetables. Channeling more resources into the production of leafy green as well as yellow vegetables, for instance through technology development, can therefore be regarded as one significant contribution to the reduction of vitamin A deficiencies. Also, more effort should be undertaken to enhance the availability of vegetables rich in micronutrients during the summer months, since intake is particularly low then. Promoting home gardening is another way to enhance the intake of vitamins A and C.

While the prospect of reducing vitamin A deficiencies is rather positive, overcoming iron deficiency in India remains a challenge. Iron intake depends more on overall dietary patterns and cultural beliefs (particularly vegetarianism) than is the case with vitamin A. While supplementation of iron has proved efficacious, it is difficult to supervise, particularly so in regions where infrastructure is missing. Following a food-based approach by increasing both the access to foods rich in iron (such as certain pulses and vegetables) and promoting a change in their way of preparation may therefore be a more preferable and sustainable solution. The feasibility of this approach is explored in the following study.

Table 64. *Summarized regression results measuring impact of micronutrient intake on productivity.*[1]

	Iron intake		Vitamin A intake		Iron x Vitamin C	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
Nutrient intake (*1000)	1.572	0.889	0.231**	0.057	0.098**	0.016
Elasticity	0.027		0.075**		0.074**	
Output change (%) if intake rises to recommended level	1.107		3.450**		3.034**	
R-square	0.478		0.488		0.511	
Regression SE	0.387		0.383		0.375	

[1]Source: National Sample Survey Organization, 50th round. N = 5800 agricultural laborer households.
**Significant at $P \leq .01$.

Impact of the consumption of iron-bioavailability-enhanced mungbean dishes on nutrition and health status of children

Previous research at AVRDC had focused on low-cost, easy-to-prepare dishes with high iron bioavailability based on the use of mungbeans, a highly nutritious pulse. One way of enhancing the bioavailability of certain micronutrients is to combine foods that, when eaten together, increase the bioavailability of these micronutrients. A well-known example of this is the effect that ascorbic acid has on non-heme iron obtained from plant sources. Ascorbic acid promotes non-heme iron absorption by reducing ferric iron to the ferrous state, which is more soluble with pH present in the duodenum and small intestine. Also, vitamin A or its precursor beta-carotene prevents the detrimental effect of phytates on iron absorption and thus improves iron absorption. Adding vegetables such as cabbage, tomatoes, onions or carrots to pulses such as mungbean can thus increase the absorption rates of iron.

In order to analyze the prospects of promoting a plant-based, high iron-bioavailability diet, AVRDC recently conducted a one-year feeding trial in cooperation with Avinashilingam Deemed University in Coimbatore, India. The objective of this feeding trial was to test whether the daily supplementation of children with iron-enhanced mungbean preparations would show an improvement in biochemical parameters related to nutrition.

A total of 225 school children aged 10 to 12 participated in the feeding trial from Oct. 1999 to Oct. 2000. The trial included three treatment groups and one control group. One treatment group (TR) received a traditional preparation of mungbeans with a low iron bioavailability. One treatment group (IR1) received a mungbean preparation with a high iron bioavailability based on ascorbic acid, and one treatment group (IR2) received a mungbean preparation with a high iron bioavailability based on beta-carotene. The control group did not receive any supplementation. All preparations were standardized in regard to protein, calorie and iron content. Table 65 shows preparation costs and in vitro bioavailability of one portion of daily supplementation.

Table 66 shows how supplementation affected the prevalence of anemia among girls and boys. All girls remained anemic after supplementation. No girl showed hemoglobin levels of 10 g/dl or more after supplementation. However, the percentage of girls that could be classified as moderately anemic after supplementation and severely anemic before supplementation was largest for both groups that received the bioavailability-enhanced mungbean preparation. In the control group, the percentage of severely and moderately anemic girls did not change over the period.

Fewer boys than girls are "severely" anemic (hemoglobin level less than 7 g/dl) before

Table 65. *Cost and in vitro iron bioavailability of mungbean supplementation, India.*

Group	Dish	Cost (INR)[1,2]	In vitro iron bioavailability (%)
TR	Sundal	14.9	7.7
	Masiyal	14.7	5.8
IR1	Cabbage kootu	14.7	13.1
	Tomato masiyal	15.9	12.4
IR2	Carrot sundal	14.5	12.2

[1]INR = Indian rupee; 48.4 INR = 1 US dollar.
[2]Source: Purushotaman (2001) and own calculation based on average unit prices of food items in the 50th National Sample Survey Organization, 1995.

Table 66. *Anemia prevalence[1] for 225 children before and after supplementation with mungbean dishes, India, 1999–2000.*

	Before			After		
	Severe	Moderate	Mild	Severe	Moderate	Mild
Girls						
TR[2,3]	10	14	0	10	15	0
IR1[4]	13	12	0	6	19	0
IR2[5]	11	14	0	5	20	0
Control	16	21	0	16	21	0
Boys						
TR	7	18	0	2	23	0
IR1	6	19	0	1	21	3
IR2	8	17	0	1	21	3
Control	9	29	0	7	31	0

[1]Degree of anemia is defined by hemoglobin level. Severe = <7%, moderate = 7 to <10%, and mild = 10 to 11% g/dl.
[2]TR: Received a traditional preparation of mungbeans with low iron bioavailability.
[3]There was no initial measurement for one girl receiving this treatment.
[4]IR1: Received a preparation of mungbeans and cabbage or tomato for a high iron bioavailability based on ascorbic acid.
[5]IR2: Received a preparation of mungbeans and carrot for a high iron bioavailability based on beta-carotene.

supplementation, and after supplementation some of them have hemoglobin levels that classify them as "mildly" anemic. This is true for about 15% of the boys in both groups receiving bioavailability-enhanced mungbean preparations.

Therefore, while supplementation did not overcome anemia completely, it greatly improved body iron stores of children.

A regression analysis using the absolute change in hemoglobin levels as the dependant variable, and the initial hemoglobin level, thebody-mass index, age, and sex as control variables, indicates that the two groups receiving bioavailability-enhanced recipes experienced the largest increase (Table 67). On average, over the year their hemoglobin levels rose by 0.8 g/dl, while the group receiving traditionally prepared recipes experienced an increase of only 0.3 g/dl. Girls experienced a slightly lower rise in hemoglobin levels than boys did.

Table 67. *Regression analysis evaluating the effects of supplementation on hemoglobin level of 225 children, India, 1999-2000.*

	Co-efficient	SD	t-value
Constant	0.371	0.249	1.490
Initial hemoglobin level (g/dl)	-0.014	0.008	-1.768
Initial body-mass index	1.86E-04	0.005	0.039
Supplementation			
Member of TR[1] (yes = 1)	0.336	0.022	15.585
Member of IR1[2] (yes = 1)	0.771	0.023	33.068
Member of IR2[3] (yes = 1)	0.794	0.022	35.924
Sex (girls = 1)	-0.073	0.017	-4.323
Age	-0.023	0.022	-1.028
R^2	0.905	0.113	
F-value	305.119		

[1]TR: Received a traditional preparation of mungbeans with low iron bioavailability.
[2]IR1: Received a preparation of mungbeans and cabbage or tomato for a high iron bioavailability based on ascorbic acid.
[3]IR2: Received a preparation of mungbeans and carrot for a high iron bioavailability based on beta-carotene.
Dependent variable: Absolute change in hemoglobin level after supplementation.

The analysis shows that enhancing iron bioavailability through modified preparations of local dishes is a cost-effective way of improving the iron status of population groups at risk. Dishes with a higher in vitro iron bioavailability do not incur higher costs of preparation than traditional dishes. Promoting dishes with a higher iron bioavailability based on mungbeans appears to be a viable strategy to enhance body iron stores in regions where diets are predominantly vegetarian and the inclusion of animal products into diets is not feasible. Opportunities to promote the modification of existing preparation practices, i.e. through nutrition education and local media, should be used to reach a large number of households.

Approaches that aim at changing consumption practices are only one of several components of a food-based approach to increase intake of micronutrients. Using nutrition education and mass communication technologies are additional means of reaching this goal. Other components of such a strategy include a focus on improved production technologies for vegetables. Studies have shown that diversity in consumption increases when production of vegetables increases. In terms of further research it would be desirable to know more about the cost-effectiveness of such programs for improving the iron status of population groups at risk, particularly when considering the effect on productivity. Due to the large number of iron deficient persons in India, and the large and negative effect on productivity of individuals, it can be expected that food-based approaches to improve the iron status of people will generate good results at a relatively low cost.

Quality evaluation of lipoxygenase-null vegetable soybean lines at vegetable and grain stages

Soybean seed is rich in protein and oil and, in combination with cereals, provides a balanced diet that meets most human nutritional requirements. Increased human consumption of soybean could help to alleviate malnutrition in many developing countries. Soybean seed can be consumed at either the immature stage (R_6, vegetable soybean) or mature stage (R_8, grain soybean), depending upon utilization. However, acceptance of soybean has been limited in certain areas where people reject the unique soybean flavor often referred to as "beany flavor," which is mainly governed by lipoxygenase isozymes. Lipid peroxidation was also one of the factors limiting soybean consumption. Several lipoxygenase-null grain soybean lines were developed and reported to have a reduced beany flavor and increased oil stability. The AVRDC Legume Unit has developed lipoxygenase-null vegetable soybean lines using AGS292 as the recurrent parent. The objectives of this study were to evaluate its improved progeny for contents of major- and micro-constituents, beany flavor, and protein recovery rate of soybean milk.

Four lines of the triple null genotype *lx1lx1lx2lx2lx3lx3:* GC96019-6, GC96019-9, GC96019-10, and GC96019-11 (isozyme group L0); five lines with the genotype *lx1lx1lx2lx2Lx3Lx:* GC96019-86, GC96019-96, GC96020-51, GC96020-54 and GC96020-57 (isozyme group L3); and AGS292, *Lx1Lx1Lx2Lx2Lx3Lx3* (isozyme group L123) were planted in four replications using randomized complete block design at AVRDC in Mar. 2001. Seeds were harvested at R_6 and R_8 stages. Two lines each from L0 and L3 isozyme groups were selected for evaluation of beta-carotene, vitamin C, folic acid and isoflavone contents. Eight vegetable and grain soybean lines harvested in Spring 2000 were selected to test the relation of soybean milk protein recovery to seed size.

Composition of dry matter, protein, oil, sugar, starch, fiber, and boiled seed texture (presented as hardness and expressed by the grams of force required to break the seed) were evaluated using near infrared spectroscopy (NIRS). Vegetable soybeans were blanched, frozen, dried at 45 °C for two days, and ground into a fine powder, before subjecting to nutritional quality evaluation. Grain soybeans were directly ground into powder for NIRS analysis.

Folic acid content was measured by microbiological assay using *Enterococcus hirae.* Isoflavone and beta-carotene analyses were performed by high pressure liquid chromatography (HPLC) with reversed phase column. Ascorbic acid content was determined by colorimetry using 2,4-dinitrophenylhydrazine.

Head-space flavors were analyzed with gas chromatography (GC) and the intensity of beany flavors was expressed as a value of total peak areas. Soymilk (seeds:water, 1:9 w/w) was prepared from mature seeds with 100-seed weights ranging from about 10 to 40 g. Protein content determination was carried out by the Kjeldahl method. Protein recovery rate was expressed by the protein content of milk extracted against protein content of seeds used.

Data were analyzed using analysis of variance procedures. The varietal effect was partitioned using orthogonal contrasts to compare different isozyme groups.

No statistically significant differences in nutritional qualities were found between L123 and Group L0 and between L123 and Group L3 at the same harvest stage or between two harvest stages stages (Table 68). However, significant differences in protein and oil contents were detected among lines within Group L3 at both vegetable and grain stages (data not shown). Folic acid content was over four times greater in seeds at grain stage compared to the vegetable stage for all isozyme groups. The three groups showed similar amounts of folic acid in their grain stage seeds. Soybean has been reported to be rich in folic acid. In spite of a lower concentration at R_6 stage, vegetable soybean is still a good folic acid source comparing with other vegetables (e.g., folic acid contents range from 10 µg/g in cabbage to 130 µg/g in spinach). Contents of vitamin C and beta-carotene were similar levels among groups at the vegetable stage.

Table 68. *Comparison of soybean isozyme groups for seed qualities at vegetable (R_6) and grain (R_8) stages.*

	L123		L0		L3	
	Vegetable	Grain	Vegetable	Grain	Vegetable	Grain
NIRS analysis[1] (%)						
Dry matter	29.8	93.8	29.6	94.5	29.6	94.4
Protein	39.6	39.1	39.6	39.1	39.5	38.8
Oil	24.1	23.3	23.8	23.4	24.1	23.7
Sugar	12.1	–[2]	12.2	–	11.7	–
Starch	8.5	–	8.9	–	9.1	–
Fiber	5.8	–	5.8	–	5.8	–
Hardness (g)	17.4	–	17.2	–	17.1	–
Folic acid (µg/100g)	89 ± 3	459 ± 26	105 ± 20	481 ± 91	112 ± 26	486 ± 55
Beta-carotene (mg/100g)	0.22	–	0.19	–	0.19	–
Vitamin C (mg/100g)	29	–	30	–	28	–

[1]Near infrared spectrophotometry done on dry weight basis.
[2]Not tested.

Isoflavone contents were similar among isozyme groups within stages (Table 69). Isoflavones accumulated continuously during seed maturation. Contents of daidzin and genistin, the glycoside isoflavones, were about two times greater at the fresh grain stage compared to the vegetable stage. Daidzin and genistin contents increased after one year of storage, to about two times those of the fresh grain stage and four times of the vegetable stage. This trend was not detected for daidzein and genistein.

In taste testing, the beany flavors of soymilk made from L0 and L3 lines were less than that made from the L123 line. Flavor intensities of L0 and L3 were weaker than that of L123. Beany flavors are mainly produced when making soybean milk. Heat treatment is generally applied during extraction of protein to eliminate the beany flavors, but this treatment reduces protein yield. Therefore lipoxygenase-null lines can be used without heat treatment during protein extraction to improve protein yield. Furthermore, large-seeded (about 20 g/100 seeds) soybean cultivars are favored for tofu-making and receive higher prices due to their higher protein yield. Seeds of vegetable soybean lines usually exceed 25 g/100 seeds.

In this study we compared five grain and three vegetable soybean lines for protein recovery of soymilk. Protein recoveries of 78-82% were measured for lines with seed sizes ranging from 13 to 35 g/100 seeds (Figure 13). NPT2 with 100-seed weight of 40 g had the highest protein recovery. This suggests that vegetable soybean lines may have potential for use as grain soybean in processing.

In conclusion, the lipoxygenase-null vegetable soybean lines produced less beany flavors but similar nutritional qualities and isoflavone contents compared to AGS292. The lowering of beany flavors can enhance the consumption of soybean and avoid heat-caused protein loss for soybean milk. Larger-sized seeds typical of vegetable soybean varieties also produce promising protein yield in making soymilk. Because soybean seeds at grain stage can provide more folic acid and isoflavone and import better oil stability, the AVRDC lipoxygenase-null lines could be useful at both vegetable and grain stages.

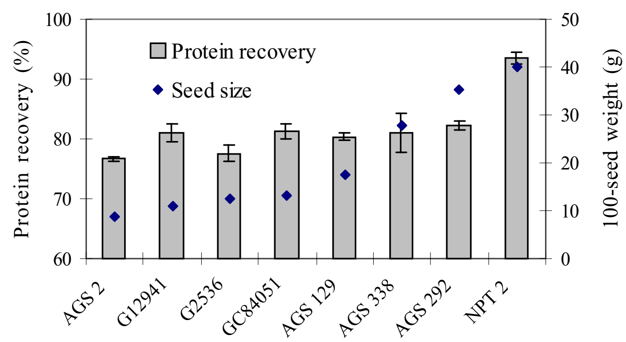

Figure 13. *Protein recovery of soymilk made with seeds of varied seed sizes.*

Table 69. *Isoflavone contents (µg/g dry wt) at vegetable and grain stages.*

	Vegetable			Fresh grain			Aged grain[1]		
	L123	L0	L3	L123	L0	L3	L123	L0	L3
Daidzin	121	116 ± 20	115 ± 22	254	265 ±1 2	251 ± 14	420	502 ± 45	481 ± 97
Genistin	73	58 ± 12	67 ± 27	207	187 ± 13	179 ± 27	289	306 ± 24	297 ± 64
Daidzein	22	21 ± 1	23 ± 6	20	22 ± 2	20 ± 5	35	29 ± 7	26 ± 4
Genistein	71	8 ± 4	11 ± 8	10	14 ± 7	12 ± 0	22	16 ± 3	17 ± 9

[1]Seeds were harvested in May 2000 and stored for one year under room temperature.

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 and nongovernmental organizations design year-round vegetable production systems.

Project Coordinator: M Koizumi

Tomato Information System

The major objectives of the Tomato Information System are to provide accurate summarization of data, efficient storage and retrieval of information, and meaningful linkages with other relevant sources of information. With the essential databases developed, a system was designed to provide for the retrieval and display of data from the tomato inbred line database based on specification of desired characteristics. This database includes variable fields for name of line, plant habit, fruit weight, fruit type, heat tolerance, time to maturity, target environments, levels of resistance to important tomato diseases, and other characteristics. Both single- and multi-parameter query systems for specific characteristics have been developed using an information retrieval module where the acceptable range of one or more criterion variables are specified to get the desired subset of lines. A summary report of all lines in this response subset which satisfy the specified criteria is then given for all or selected characteristics of the lines. Frequency count of inbred lines for each level of the different variables is also available in the query system.

The tomato diseases database is linked with the inbred line database whereby lines resistant to a particular disease and their characteristics are displayed through hyperlinked words. The tomato insect pest database is linked to an integrated pest management website (www.entomology.de/vegetable/) developed by Dr. Christian Ulrichs, while the tomato field management database is linked to relevant International Cooperators' Guides on crop management found on the AVRDC website (www.avrdc.org.tw/LC/tomato/publications.html). Technical terms are hyperlinked to photos to aid the user in understanding these terms.

The Tomato Information System was evaluated by scientists for accuracy and adequacy of information. Then it was tested and rated by potential users based on the following criteria: 1) adequacy of information (*does it have sufficient information to diagnose a disease*?); 2) user-friendliness (*is it easy to use even with minimal knowledge?*); 3) potential usefulness (*is it useful for quick and accurate diagnosis of disease?*); and 4) screen appearance (*does the screen design provide for easy reading and accessing of information?*). Using a scale of 1-5, where 1 = poor and 5 = excellent, the means scores for all criteria were 4 (very good). The Tomato Information System is currently in the final preparation stages and will be published on CD-ROM in 2003.

Program III

Collaboration in research and germplasm management

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

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

Collection of vegetable germplasm for food security and biodiversification

The Genetic Resources and Seed Unit (GRSU) of AVRDC in collaboration with national agricultural research and extension systems (NARES) and regional center/programs continued to assemble vegetable germplasm for utilization in crop improvement programs and address needs for biodiversification. For the period 2001, more focus was put on vegetable species indigenous to the South and Southeast Asian region and Taiwan. A total of 1,018 accessions were acquired in 2001 bringing the total number of accessions in the collection to 48,631 accessions (Table 70).

Collecting expedition in Thailand

This activity is part of the technical assistance project (RETA 5839) funded by the Asian Development Bank entitled "Collection, Conservation, and Utilization of Indigenous Vegetables." This project aims to improve the conservation and utilization of indigenous vegetables in South and Southeast Asia, ultimately contributing to the improvement of human nutrition and the reduction of poverty. The project has five participating countries, namely Bangladesh, Indonesia, Philippines, Thailand and Vietnam.

The germplasm collecting activity falls under the component on conservation and utilization of the genetic resources of indigenous vegetables. The aim of this project component is to collect about 500 accessions of indigenous vegetable germplasm per country, conserve the collected germplasm, and multiply them for exchange and utilization.

Table 70. *Accessions of vegetable germplasm conserved at AVRDC as of 31 Dec. 2001.*

Crop	No. of accessions
Principal crops:	
Glycine	14,195
Capsicum	7,509
Lycopersicon	7,217
Vigna radiata	5,646
Solanum	2,623
Brassica	1,688
Allium	1,078
Subtotal	39,956
Other crops:	
Vigna unguiculata	1,388
Luffa	631
Phaseolus	621
Vigna mungo	481
Cucumis	460
Amaranthus	439
Cucurbita	377
Vigna unguiculata ssp. *sesquipedalis*	352
Abelmoschus	338
Lablab	255
Pisum	216
Vigna unguiculata ssp. *unguiculata*	86
Others	3,031
Subtotal	8,675
Total	48,631
No. of genera	148
No. of species	334
No. of countries	151

The collecting team consisted of staff from the Tropical Vegetable Research and Development Center (TVRC), Kasetsart University, Kamphaengsaen, Thailand; and AVRDC. The trip was conducted in the provinces of Phrae, Lampang, Phayyao, Chiang Rai, Chiang Mai and Lamphun in the northern part of Thailand on 22 to 27 Jan. 2001. The itinerary was scheduled to target collecting of germplasm of indigenous vegetable species which are specifically grown in the region during the particular time of year, including the photoperiod-sensitive species. Highest priority was given to *Amaranthus, Solanum, Corchorus, Luffa, Alternanthera, Canavalia, Centella, Coccinia, Cucurbita, Cucumis, Lablab, Lagenaria, Momordica, Oenanthe, Portulaca, Psophocarpus, Talinum, Trichosanthes* and *Vigna*. Leafy vegetables, such as *Anethum, Apium, Brassica, Moringa* and *Ocimum* were given special attention.

Market visits were conducted in towns and cities to acquire an indication of the indigenous vegetables currently being grown in the area, as well as to delimit the most likely sites where indigenous vegetables were being grown. The sampling strategy and sampling sites discussed by Altoveros and Engle (2000) was followed throughout the expedition. Data on the collected material, the collecting sites, associated vegetation and indigenous knowledge were recorded on the standardized collecting sheets of AVRDC.

The collected materials were processed on site or at the base whenever possible. The collected germplasm were brought to AVRDC Asian Regional Center/TVRC where they were further cleaned, dried and processed prior to storage in cold stores.

A total of 258 accessions of at least 55 species of indigenous vegetables were collected during the expedition. Significant collections were made for several vegetables, including 33 accessions of eggplant (*Solanum* spp.), 21 of sacred basil (*Ocimum sanctum*), 17 each of winter squash (*Cucurbita moschata*) and pepper (*Capsicum* spp.), 12 each of wax gourd (*Benincasa hispida*) and sweet basil (*Ocimum basilicum*), 11 of ivy gourd (*Coccinia grandis*), and 10 of Ceylon spinach (*Basella alba*). The most number of materials were collected from the province of Chiang Mai (90 accessions), followed by Chiang Rai (70), Phrae (38), Lamphun (27), Lampang (17), Phayyao (15), and Bangkok (1).

For the most part, collecting was successful for the photoperiod-sensitive legumes such as butterfly pea (*Clitoria ternatea*), lablab bean (*Lablab purpureus*), sword fruit tree (*Oroxylum indicum*), lima bean (*Phaseolus lunatus*), agati (*Sesbania grandiflora*), and winged bean (*Psophocarpus tetragonolobus*). However, many lablab bean genotypes were just beginning to bear pods, indicating that the optimum time for collecting is from late February. Also, only one accession of yam bean (*Pachyrhizus erosus*) was encountered, although it was observed that the tubers were being sold along the roadside, indicating that a more thorough collecting may turn up more materials.

The team encountered a wild population of wax gourd (*B. hispida*) with small round fruits in Muang Mae Lai in the province of Phrae. Future collecting expeditions could be conducted in the area to assemble a more thorough sampling of the many populations of wild wax gourd in the area. The more common larger- and elongated-fruited forms were also collected from several provinces.

Three distinct genotypes, possibly species, of unidentified *Ocimum* were collected from Mae-rim in Chiang Mai, and Muang and Lee in Lamphun. The genotypes have leaf and floral morphologies distinct from *O. basilicum, O. gratissimum* and *O. sanctum*. In all of the home gardens visited, sweet basil and holy basil were almost always encountered.

Wild type bitter gourd (*Momordica charantia*) with very small fruits were ubiquitous in disturbed areas near roadsides in all the provinces visited. Small-fruited tomatoes with fruits reminiscent of *Lycopersicon esculentum* ssp. *cerasiforme* were collected.

Significant variation was collected for the species of amaranth, especially *Amaranthus tricolor* and *A. gracilis*, as well as eggplant and its relatives (*Solanum melongena, S. xanthocarpum, S. nigrum, S. torvum* and *S. sanitwongsei*). Interesting variation was also noted for fruit shape and size of *Cucurbita moschata*.

As per agreement, one half of each sample collected was brought to the AVRDC genebank for conservation. The other half was left with TVRC for regeneration and characterization.

Collecting expedition in Taiwan

Collecting expeditions were conducted in collaboration with farmers' associations in the counties of Hualien (77 accessions), Ilan (20), Penghu Islands (43), and Taitung (75), including Green Island (19 of 75). A total of 215 samples were collected. Significant collections were made for several vegetables, including 15 accessions of yardlong bean (*Vigna unguiculata* ssp. *sesquipedalis),* 12 of smooth luffa (*Luffa aegyptiaca*), 11 each of bottle gourd (*Lagenaria siceraria*) and bitter gourd (*Momordica charantia*), 8 of pepper (*Capsicum annuum*), 7 of lettuce (*Latuca sativa*), and 6 each of garland chrysanthemum (*Chrysanthemum coronarium)*, winter squash (*Cucurbita moschata*), cowpea (*Vigna unguiculata* ssp. *unguiculata*), and corn (*Zea mays*).

Hualien, Ilan and Taitung are in the eastern side of Taiwan, where agriculture is less developed. There are still farmers in these areas that plant old traditional varieties. They understood the need for conserving these varieties and gladly donated seeds. They appreciated the fact that something is being done to conserve these varieties. At present there are still one or two farmers in each village that produce vegetable seeds for their own use as well as to supply the other farmers in the village.

In each village the collecting team encountered many traditional vegetable varieties not found in the other villages. When the team interviewed the farmers about these varieties, they were usually given a history of the variety. In some case, a particular variety may be a hundred years in cultivation in the village. However, farmers growing these varieties are mostly 60–65 years old. According to them, the young generation are not interested in growing these traditional varieties. In some villages where these traditional varieties used to be grown, the collecting team could not find them anymore. The last old farmer that grew them had already passed away and the varieties he or she grew were lost at the same time.

Farmers demonstrated how some indigenous vegetables were cooked and invited the collecting team to taste them. *Momordica chochinchinensis* were sliced and sauteed with slices of red hot pepper for seasoning. Young shoots of *Miscanthus floridulus* were also sauteed with slices of red hot pepper. *P. tetragonolobus* was boiled and seasoned with soybean sauce and red hot chili pepper.

In Peng-hu Islands, it is very windy and the soil is saline. The farmers plant their vegetables behind stone walls. They usually plant peanut and angled luffa. They plant cabbage in winter. Most of the farmers were women because the men go out to fish. In Green Island, there are many wild species of vegetables, e.g., wild eggplant and wild cucurbits.

There were many tribal people in Hualien. Many indigenous vegetables were seen sold in the traditional market, e.g. *M. cochinchinensis*, winged bean, bird's nest fern and glossy nightshade. The following vegetables were sold at the night market: yardlong bean, roots of the East Indian lotus, mustard, Obalonus mushroom, bird's nest fern and small-fruited bitter gourd. Mature fruits of different types of gourds (bottle gourd and luffa) were hung on walls or eaves over stoves.

In Ilan, it often rains so the humidity is high. Farmers find it difficult to store the seeds. Bird's nest fern was cultivated under net in Peifu village in Guang-fu, Hualien. *M.cochinchinensis* was cultivated and grown on trellis. *Atylosia* was used as green manure and also planted in pastures. The roots are used for toothache and throat problems and the leaves are said to be good for the stomach and kidney.

The expeditions showed that although Taiwan agriculture is well developed, there are still quite a number of indigenous vegetables being grown. However, these varieties are in danger of getting lost together with the demise of the farmers that grow them. Indigenous knowledge on their utilization may also be forgotten with the disappearance of the varieties.

Regeneration of vegetable accessions conserved at GRSU for preservation and exchange

The Genetic Resources and Seed Unit (GRSU) regularly regenerates germplasm accessions for preservation and exchange. Table 71 shows the number of accessions regenerated and characterized from fall of 2000 to 2001. A total of 2312 accessions including at least 48 species were regenerated. Seeds were stored under long-term storage condition (-20 ºC) as part of the base collection and under medium-term storage condition (5 ºC) as part of the active collection. Accessions of *Allium sativum* and *Allium cepa* ssp. *aggregatum* were maintained in a field genebank.

Table 71. *Germplasm accessions regenerated in 2000-2001 at AVRDC headquarters.*

Scientific name	No. of accessions
Allium cepa	25
A. cepa ssp. *aggregatum*	20
A. sativum	257
Amaranthus atropurpureus	1
A. dubius	10
A. hypochondriacus	12
A. palmeri	1
A. retroflexus	4
A. tricolor	93
A. viridis	1
Basella alba	41
Brassica juncea	10
B. oleracea cvg. Chinese kale	2
B. rapa	28
Capsicum annuum	277
C. baccatum	2
C. chinense	4
C. frutescens	1
C. sp.	2
Celosia argentea	1
Chrysanthemum coronarium	16
Corchorus capsularis	6
C. olitorius	4
Glycine max	906
Gynandropsis gynandra	21
Ipomoea aquatica	22
Lablab purpureus	6
Luffa acutangula	12
L. aegyptiaca	7
Lycopersicon cheesmanii	1
L. chilense	*4*
L. esculentum	1
L. pennellii	1
L. pimpinellifolium	1
Phaseolus lunatus	9
Solanum aethiopicum	21
S. americanum	11
S. incanum	9
S. indicum	7
S. melongena	5
S. macrocarpon	5
S. scabrum	4
S. torvum	10
S. villosum	3
S. xanthocarpum	7
Talinum paniculatum	1
T. triangulare	3
Vigna mungo	11
V. radiata	400
V. umbellata	6
Total	2312

Enhancing vegetable germplasm utilization through distribution

A total of 9529 samples, including breeding lines, were sent out from AVRDC in 2001 (Table 72). About 98% went to 73 countries, and the other 2% went to AVRDC regional centers. A total of 2830 samples (30% of the samples sent out) came from the AVRDC genebank (Table 73). An additional 932 samples from the genebank were given to other AVRDC units at headquarters for research. Although there has been a decreasing trend in the distribution of germplasm, the use of germplasm accessions by Center scientists has been increasing over the last three years.

Table 72. *Recipients of germplasm from AVRDC in 2001.*

Recipient	Samples	Total
Outside Headquarters		9,529
Korea	2,081	
India	1,516	
Bangladesh	582	
Vietnam	554	
Philippines	536	
Taiwan	503	
USA	488	
Thailand	385	
China	279	
Ghana	161	
Others (63 countries)[1]	2,282	
Regional Centers		
ARC	130	
RCA	32	
Headquarters Units		932
Allium	33	
Soybean	147	
Tomato	296	
Olericulture	24	
Crop & Soil Management	1	
Entomology	24	
Nutrition & Analytical Laboratory	1	
Bacteriology	3	
Mycology	17	
Virology	168	
Physiology	156	
Technology Promotion and Services Unit	55	
Farm Operations	7	
Total		10,461

[1]Argentina, Australia, Barbados, Belgium, Belize, Bhutan, Botswana, Brazil, Cambodia, Canada, Congo, Dominican Republic, Egypt, El Salvador, Ethiopia, Fiji, France, Germany, Greece, Guyana, Hong Kong, Hungary, Iran, Israel, Italy, Ivory Coast, Japan, Jordan, Kenya, Laos, Malaysia, Mauritius, Myanmar, Namibia, Nepal, Netherlands, New Caledonia, Nicaragua, Nigeria, Pakistan, Panama, Papua New Guinea, Paraguay, South Africa, Reunion Is., Saudi Arabia, Seychelles, Sierra Leone, Singapore, Spain, Sri Lanka, Sudan, Swaziland, Sweden, Tanzania, Tonga, Trinidad & Tobago, Turkey, Uganda, Ukraine, United Kingdom, Venezuela, and Zaire.

Table 73. *Recipients of germplasm accessions from the AVRDC Genetic Resources and Seed Unit in 2001.*

Classification	No.	Samples	Purpose
Government organizations	26	1,809	Screening for disease resistance and insect resistance, performance evaluation, nitrogen uptake, breeding, research
Genebanks	3	504	Safety duplication, genetic research, screening for disease resistance
Universities	19	228	Research on disease resistance, thesis, teaching, other researches
Private companies	6	115	Research, cultivation, evaluation, disease differential
Private individuals	5	99	Evaluation, home garden, private collection, research
Seed companies	8	49	Breeding, evaluation, disease screening, research
Non-government organizations	2	25	Evaluation, disease screening, cultivation
International projects	1	1	Disease tolerance
Total		2,830	

Leaf infiltration method for detecting living *Xanthomonas campestris* pv. *vesicatoria* from pepper seeds

Bacterial spot caused by *Xanthomonas campestris* pv. *vesicatoria* (XCV) is one of the most important diseases of pepper in the humid tropics. The pathogen can be transmitted through seeds. Declaration that pepper seeds are free from XCV or produced in a XCV-free area is required for importing pepper seeds into several countries. Consequently, an efficient seed detection method for XCV is imperative for both disease management and seed certification purposes. Several detection methods, such as direct plating on semi-selective media, enzyme-linked immunosorbent assay (ELISA) with monoclonal antibodies, and polymerase chain reaction (PCR) with specific primers have been reported. However, these methods are either strain-specific or cannot differentiate dead from living XCV cells.

Using a host plant as a selective medium has been successfully used in detecting bacterial pathogens from rice seeds; rice seed-wash was infiltrated into rice leaves for detecting *Xanthomonas oryzae* pv. *oryzicola*. For pepper, the variety Early Calwonder (ECW) has been well characterized and is known to be susceptible to all XCV races. It is easy to infiltrate bacterial suspension into fully expanded leaves of ECW, and only living XCV cells can multiply in ECW. Therefore, the objective of this study is to use ECW as a natural selective medium for detection of living XCV from pepper seeds.

To understand the potential sensitivity of the infiltration method, pure XCV cultures with different bacterial cells (presented as initial XCV cells in Tables 74 and 75) were used to infiltrate ECW. The strains used in the study were XVT28, 48, and 12, which belong to races P1, P2, and P3, respectively. Seedlings of ECW were raised to the stage where they had five fully expanded leaves. The three youngest true leaves were used. A volume of 0.1 ml of bacterial suspension was infiltrated into each leaf and the infiltrated area was marked. Inoculated plants were kept at 28 ºC with frequent water sprinkling (30 seconds/2 hours). About 14 days after inoculation, symptoms including lesion numbers were recorded. The infiltrated area was excised and macerated with 1-ml sterile water for detecting initial and final XCV population (presented as colony formed unit or cfu) by direct plating on nutrient agar (NA) plates. Thus, a positive detection by this method would mean appearance of typical symptoms of bacterial spot or positive detection of final NA plating.

To determine whether other bacteria associated on pepper seeds may affect the detection results, nine seed samples of randomly-selected pepper accessions were used (Table 74). A non-destructive seed extraction method was applied to prepare seed-wash samples. Pepper seeds (250 seeds in 10 ml peptone buffer) were first extracted by sonication at room temperature for one hour. The extract was concentrated by high-speed centrifugation (12,000 g for 10 minutes) and suspended in 1-ml peptone buffer as a seed-wash. The amount of total bacteria present in the seed-wash was determined by dilution plating on NA plates. About 1000 XCV cells were added into each seed-wash and infiltrated into ECW as described above. Symptoms and final internal XCV populations were recorded as described above.

The sensitivity of the infiltration method could be 3.5 to 5.8 cells present in the 0.1-ml suspension as

Table 74. *Effect of other bacteria present in pepper seed-wash on the multiplication of* Xanthomonas campestris *pv.* vesicatoria *(XCV) in pepper leaves of variety Early Calwonder and induced symptoms (lesion numbers).*

Accession	Total bacteria[1] (cfu)	Initial[2] XCV (cfu)	Final[2] XCV (cfu)	Lesion number
PBC491	–[3]	–[3]	2.3×10^7 b[4]	7.5
PBC577	1288.2	102.3 b	7.6×10^7 ab	26.0
PBC529	707.9	34.7 cd	4.6×10^7 ab	8.0
PBC843	446.7	27.5 d	1.5×10^7 b	2.5
PBC848	229.0	85.1 b	10.5×10^7 ab	13.0
PBC844	89.1	91.2 b	14.1×10^7 ab	20.0
PBC110	39.8	81.3 b	16.2×10^7 ab	29.0
PBC1022	10.0	40.7 c	7.1×10^7 ab	13.0
PBC1210	0.0	49.0 c	4.2×10^7 ab	8.0
XVT-28 (control)[5]	NA[6]	186.2 a	57.5×10^7 a	116.0

[1]Amount of bacteria present in seed-wash prepared from 250 seeds of each seed lot determined by plating on nutrient agar.
[2]Amount of XCV (original concentration = 1862.1 cfu/ml after mixing with each seed-wash before infiltration [initial] and internal XCV population in the infiltrated area 14 days after infiltrating in pepper leaves [final]).
[3]The amount of bacteria was too large to be estimated.
[4]Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.
[5]Bacterial suspension of XVT28 with concentration of 1.8×10^3 cfu/ml was used as a control.
[6]NA = not applicable.

determined by three XCV pure cultures (Table 75). The three tested strains showed similar multiplication trends in ECW. The severity of disease symptoms correlated well with the initial and final amount of XCV cells. No XCV colonies were found in the seed-washes, but many kinds of other bacteria were found. This indicated that the tested seedlots were possibly free from XCV.

The infiltration method is highly specific, as other bacteria associated with seeds did not affect the detection result (Table 74). Although the initial XCV amounts in all seed-wash samples were significantly lower than the control, the final XCV amounts were similar with the control except for seed-wash samples from PBC491 and 843. Nevertheless, the final amount was still high enough to be easily detected by NA plating. The reduction of initial XCV amount could be due to certain antagonistic bacteria present in the seed-wash. However, being saprophytes, their growth was suppressed inside the pepper leaf.

To compare the efficiencies of the detection methods, 11 pepper seed lots collected from fruits showing XCV symptoms were used as testing samples. The seed-washes were prepared as described before and directly used to detect XCV by infiltration, plating with a semi-selective medium (Tween-B), and a PCR method with specific primers (RST9/10). Among the 11 contaminated seed samples, the positive detection numbers were 11, 4 and 4 by infiltration, plating and PCR, respectively.

From these studies, we conclude that the infiltration method has good specificity and sensitivity, and can be widely adopted by many laboratories, as no special equipment is required.

Table 75. *Relationships among initial and final internal populations of* Xanthomonas campestris *pv.* vesicatoria *in leaves of pepper variety Early Calwonder, and induced symptoms at 14 days after infiltration.*

Race/Strain	Initial[1]	Final[1]	Induced symptoms
T1P1/XVT28	490.0	2.8×10^9	yellowing
	10.0	3.2×10^6	13 lesions
	4.4	5.6×10^3	3 lesions
T1P2/XVT48	426.6	7.8×10^9	yellowing
	12.9	6.2×10^7	11 lesions
	3.5	2.0×10^5	1 lesions
T1P3/XVT12	363.0	3.1×10^{11}	101 lesions
	13.5	3.0×10^8	14 lesions
	5.8	1.8×10^7	6 lesions

[1]Data presented are average XCV colony formed unit (cfu) over 3 replicates.

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, and functional properties such as antioxidant activity were gathered.

Yield evaluation of indigenous leafy vegetables

High yield is one of the most important factors for vegetable production. However, yields of vegetable crops grown in the tropics and subtropics are unstable. Plants may encounter biotic problems such as diseases and insects, as well as abiotic problems such as high temperature, high moisture and waterlogging.

Yield evaluations were carried out in spring and summer in Taiwan. A total of 101 accessions of *Amaranthus* spp., 21 of *Basella alba*, 37 of *Corchorus* spp., and 24 of *Ipomoea aquatica* were grown in spring 2001 in the field of AVRDC; and 153 accessions of *Amaranthus* spp., 43 of *B. alba*, and 35 of *I. aquatica* were grown in summer 2001. All plant materials were sown in the greenhouse and transplanted in the field. Twenty plants (10 plants and two replications in randomized block design) were evaluated for yield. Harvesting was done weekly, weather permitting.

***Amaranthus* spp.**

Amaranthus is a C4 plant and can be expected to grow well even in the hot-wet environment of tropical and sub-tropical regions. In fact, *Amaranthus* can be seen almost anywhere in these regions and are sometimes considered weeds. However, comparison of spring and summer plantings in Taiwan show that yields during the hot-wet summer are much lower compared to the yields in spring.

Table 76 shows the 10 highest yielding *Amaranthus* accessions in the Spring and Summer 2001. In spring, total yield for all accessions ranged from 70 to 7,630 g over a period of six weekly harvests. Average weekly harvest ranged from 4 to 382 g. The total yield of the popular light green-leaf type varieties from Taiwan and Japan ranged from 3,560 to 4,450 g. Six of the top yielders were from Bangladesh, and one each from Ghana, Senegal, Tanzania and Vietnam. Nine were leaf and/or stem type. Leaves were green or dark green. The accession from Senegal is a weed species and is not suitable for use as vegetable. Plant height at the first harvesting for the top yielders ranged from 22 to 45 cm. Plant height of the popular light green-leaf type varieties ranged from 22 to 27 cm. None of the three check varieties were among the top 10 in yield.

In summer, only two harvests could be carried out due to flooding and early flowering. Total yield ranged from 50 to 810 g. Average weekly harvest ranged from 25 to 405 g. Three of the top yielders had purple leaves. One of the check varieties (Tot4868) was among the top 10 in yield.

Accessions introduced from African countries were high yielding but had big and hard leaves. Accessions with purple and dark purple leaves mainly came from Bangladesh.

Three accessions among the top yielders belong to *A. dubius* (Tot2261, Tot4096 and Tot4141) and the rest except for one belong to *A. tricolor*. The exception is a weedy type from Senegal received as *A. palmeri*.

Four accessions were among the highest yielders for both spring and summer, suggesting that some varieties have wide adaptability.

The seedlings were transplanted in beds covered with silver-colored plastic mulch. However, in Summer 2001, precipitation was high and water often filled the space between beds. Bed height was not adequate enough to avoid flooding the plants. This flooding contributed to lower yields in summer. However total yields were different among accessions, and accessions that are good candidates for planting during the hot-wet summer months can be identified.

Basella alba

Table 77 shows the top 10 yielders in *Basella alba* in Spring and Summer 2001. *Basella* accessions can be divided into two major groups, those having either green or purple stems. These major groups can further be classified into some minor groups, e.g., a group with big stem and big leaf, or a group with slender stem and small leaf. Usually an accession with small leaves and slender stems produces more lateral shoots than one with big leaves and big stems. This small-leaf group has more shoots that can be harvested, but total yield is not always higher than the harvest from the big-leaf group.

Less than 20 plants were available for yield evaluation for some accessions. Therefore, yield comparison was done using yield per plant. In spring, the average yield per plant for accessions ranged from 341 to 1,682 g, with the average being 881 g. In summer,

Table 76. *The highest yielding* Amaranthus *spp. accessions, along with check varieties, AVRDC, Spring and Summer 2001.*[1]

Accession	Origin	Leaf color[4]	Spring[2] Total yield (g)	Spring[2] Avg yield/ week (g)	Spring[2] Avg yield/ plant (g)	Summer[3] Total yield (g)	Summer[3] Avg yield/ week (g)	Summer[3] Avg yield/ plant (g)
Tot4344	Bangladesh	G	7,630	1,272	382	(700)	(350)	(35)
Tot4303	Bangladesh	DG	7,410	1,235	371	830	415	42
Tot4510	Bangladesh	G	6,950	1,158	348	900	450	45
Tot4438	Bangladesh	G	6,250	1,042	313	(600)	(300)	(30)
Tot4685A	Bangladesh	G	5,800	967	290	830	415	42
Tot4096	Tanzania	DG	5,650	942	283	(670)	(335)	(34)
Tot2362	Senegal	G	5,330	888	267	(50)	(25)	(3)
Tot4141	Vietnam	DG	5,120	853	256	(400)	(200)	(20)
Tot2261	Ghana	DG	4,880	813	244	(480)	(240)	(24)
Tot4559	Bangladesh	G	4,880	813	244	1,100	550	55
Tot4658	Bangladesh	P	(3,270)	(545)	(164)	1,100	550	55
Tot4570	Bangladesh	DP	(2,660)	(443)	(133)	900	450	45
Tot4317	Bangladesh	DP	(2,790)	(465)	(140)	890	445	45
Tot4661	Bangladesh	G	(3,210)	(535)	(161)	880	440	44
Tot4282	Bangladesh	LG	(4,200)	(700)	(210)	820	410	41
Tot4868	Japan (ck)	LG	(4,450)	(742)	(223)	990	495	50
Tot5472	Taiwan (ck)	LG	(3,560)	(593)	(178)	(700)	(350)	(35)
Tot5473	Taiwan (ck)	LG	(3,840)	(640)	(192)	(810)	(405)	(41)
Average for all entries			2,689	448	134	523	261	26

[1]Data in parentheses were not among the ten highest yields for that season.
[2]In spring, weekly harvests were carried out six times from 15 May to 27 July 2001 using 20 plants (10 plants/plot, 2 plots).
[3]In summer, weekly harvests were carried out two times from 25 July to 1 Aug. 2001 using 20 plants (10 plants/plot, 2 plots).
[4]DG = dark green, G = green, LG = light green, P = purple, DP = dark purple.

average yield per plant among accessions ranged from 0 to 1,680 g, with an average of 737 g. In summer, 8 of the 10 top yielders came from Bangladesh. It is possible that the accessions from Bangladesh were tolerant to flooding.

The top yielders included both green stem and purple stem types. As was the case with *Amaranthus*, some accessions were high yielding in both spring and summer. Accessions Tot4263, 4241 and 3974 were especially impressive during the hot-wet season.

Corchorus spp.

Table 78 shows the yield evaluation for *Corchorus* accessions in Spring and Summer 2001. *Corchorus* accessions in this trial included two species, *C. capsularis* with globose fruit pods and *C. olitorius* with long fruit pods. Usually *C. olitorius* has big, wide leaves while *C. capsularis* has narrow and small leaves. Total yields of *C. olitorius* accessions were usually higher than those of *C. capsularis.* All the 10 top yielding accessions and/or check varieties were *C. olitorius*. They all have green stems except for the checks which had green with pale purple stems. The check varieties were among the top 10 accessions for yield.

Corchorus is one of the most nutritious and functional vegetables during the hot-wet summer season. However during the cool-dry season in Taiwan, plants grew very slowly and flowered early, resulting in low total yield.

Ipomoea aquatica

Table 79 shows the top yielding *Ipomoea aquatica* accessions in spring and summer 2001. Segregation for stem color (green and pale purple) was observed in some accessions. Some accessions with pale purple stems had pale purple young leaves. However, almost all of the accessions had green leaves.

Variants in the same accession were harvested separately resulting in yield based on less than 20 plants.

Table 77. *The highest yielding* Basella alba *accessions, along with check varieties, AVRDC, Spring and Summer 2001.*[1]

Accession	Origin	Stem color[4]	Spring[2] Total yield (g)	Spring[2] Avg yield/ week (g)	Spring[2] Avg yield/ plant (g)	Summer[3] Total yield (g)	Summer[3] Avg yield/ week (g)	Summer[3] Avg yield/ plant (g)
Tot4308	Bangladesh	G	33,640	3,738	1,682	7,360[5]	920[5]	1,227
Tot4283	Bangladesh	G	18,590[5]	2,066[5]	1,239	16,160	2,020	(808)
Tot1716	Philippines	G+PP	(1,180[5])	(131[5])	1,180	–	–	–
Tot4263	Bangladesh	G	23,470	2,608	1,174	20,110	2,514	1,006
Tot4129	Vietnam	G	(10,450[5])	(1,161[5])	1,045	13,030	1,629	(652)
Tot4269	Bangladesh	G	18,910	2,101	946	(5,040[5])	(630[5])	1,680
Tot4241	Bangladesh	P	18,430	2,048	922	17,790	2,224	890
Tot4091	Vietnam	G	17,650	1,961	883	(3,440)	(430)	(430)
Tot1525	Philippines	G+R[6]	17,240	1,916	862	–	–	–
Tot4376A	Bangladesh	G	–[7]	–	–	(2,460[5])	(308[5])	1,230
Tot1543	Philippines	PP	15,730	1,748	(787)	5,830[5]	729[5]	1,166
Tot3974	Bangladesh	G	–	–	–	21,560	2,695	1,078
Tot0071	Malaysia	P	–	–	–	6,730[5]	841[5]	961
Tot4255	Bangladesh	G	15,180	1,687	(759)	18,320	2,290	916
Tot4243	Bangladesh	G	14,160	1,573	(708)	17,860	2,233	893
Tot5900A	Japan (ck)	G	(8,790[5])	(977[5])	1,256	–	–	–
Tot5900B	Japan (ck)	P	(10,750)	(1,194)	(717)	–	–	–
Average for all entries			14,783	1,643	881	11,562	1,445	737

[1]Data in parentheses were not among the ten highest yields for that season.
[2]In spring, weekly harvests were carried out nine times from 31 May to 17 Aug. 2001 using 20 plants (10 plants/plot, 2 plots).
[3]In summer, weekly harvests were carried out eight times from 8 Aug. to 18 Oct. 2001 using 20 plants (10 plants/plot, 2 plots).
[4]G = green, G+PP = green with pale purple stem, P= purple, PP = pale purple.
[5]Less than 20 plants harvested.
[6]Segregated into green and red stemmed plants.
[7]Not tested.

For comparison, average yield per plant was used. In both spring and summer plantings, the top yielders included accessions with green and pale purple stems. Some accessions gave high yields in both spring and summer. In spring, the check varieties were among the top 10 in yield. However, in summer the yields of the checks were relatively lower than the top 10 accessions in yield.

Table 78. *The highest yielding Corchorus accessions, along with check varieties grown at AVRDC, Spring 2001.*[1]

Accession	Origin	Total yield (g)	Avg yield/ week (g)	Avg yield/ plant (g)
Tot4885	Japan	6,860	762	343
Tot4128	Taiwan	6,720	747	336
Tot4712	Bangladesh	6,570	730	329
Tot4669	Bangladesh	6,390	710	320
Tot4721	Bangladesh	5,920	658	296
Tot4316	Bangladesh	5,800	644	290
Tot4879	USA	5,730	637	287
Tot4312	Bangladesh	5,250	583	263
Tot4541	Bangladesh	4,870	541	244
Tot4624	Bangladesh	4,810	534	241
Tot5876	Japan[2](ck)	6,980	776	349
Tot5877	Japan[2] (ck)	6,710	746	349
Average for all entries		3,949	439	195

[1]Weekly harvests were carried out nine times from 15 May to 17 Aug. 2001 using 20 plants (10 plants/plot, 2 plots).
[2]Green with pale purple stem; all other accessions shown have green stems.

Table 79. *The highest yielding* Ipomoea aquatica *accessions, along with check varieties grown at AVRDC in Spring and Summer 2001.*[1]

Accession	Origin	Stem color[4]	Spring[2] Total yield (g)	Spring[2] Avg yield/ week (g)	Spring[2] Avg yield/ plant (g)	Summer[3] Total yield (g)	Summer[3] Avg yield/ week (g)	Summer[3] Avg yield/ plant (g)
Tot1920B	Indonesia	PP	(16,940[5])	(2,118[5])	2,823	11,480[5]	1,435[5]	1,276
Tot1920A	Indonesia	G	24,290[5]	3,061[5]	1,884	(6,070[5])	(759[5])	3,035
Tot1918A	Indonesia	G	18,430[5]	2,304[5]	1,843	12,650	1,581	(847)
Tot1927A	Indonesia	G	(12,650[5])	(1,581[5])	1,807	(8,710)	(1,089[5])	1,089
Tot1919A	Indonesia	G	23,120[5]	2,890[5]	1,778	17,140	2,143	(857)
Tot1918B	Indonesia	PP	25,100[5]	3,138[5]	1,673	14,860	1,858	(826)
Tot1923A	Indonesia	G	30,940	3,868	1,547	15,860	1,983	(793)
Tot1917A	Indonesia	G	29,670	3,709	1,484	12,470[5]	1,559[5]	1,386
Tot1923B	Indonesia	PP	(11,560[5])	(1,445[5])	(1,284)	(9,050)	(1,131)	1,131
Tot1927B	Indonesia	PP	24,990	3,124	(1,250)	10,400[5]	1,300[5]	(1,040)
Tot1926	Indonesia	G	–[6]	–	–	(8,850[5])	(1,106[5])	2,950
Tot1925B	Indonesia	PP	–	–	–	(3,730[5])	(4665)	1,864
Tot1928B	Indonesia	PP	–	–	–	10,730[5]	1,341[5]	1,533
Tot1921A	Indonesia	G	–	–	–	(9,070[5])	(1,134[5])	1,512
Tot1917B	Indonesia	G	–	–	–	10,290[5]	1,286[5]	1,143
Tot5981	Taiwan (ck)	G	28,600	3,575	1,430	(9,670)	(1,209)	(744)
Tot5875	Taiwan (ck)	G	27,350	3,419	(1,368)	–	–	–
Tot5874	Japan (ck)	G	27,930	3,491	1,397	16,810	2,101	(841)
Average for all entries			22,840	2,855	1,451	11,680	1,460	969

[1]Data in parentheses were not among the ten highest yields for that season.
[2]In spring, weekly harvests were carried out eight times from 25 May to 16 Aug. 2001.
[3]In summer, weekly harvests were carried out eight times from 26 July to 4 Oct. 2001.
[4]G= green, PP = pale purple.
[5] Less than 20 plants harvested.
[6]Not tested.

Evaluation of antioxidant compounds in indigenous leafy vegetables

A diversified diet that includes many vegetables enhances nutritional well-being and is essential for good health. It is recognized that these vegetable-rich diets have protective potential against various diseases like cancer and coronary heart disease. Increased intake of vegetables is recommended because they are excellent sources of protective antioxidants such as vitamin E (tocopherol), vitamin A (carotenoids), vitamin C (ascorbic acid), and phenolic compounds. Indigenous vegetables can play a major role in the diversification of diets. In this study, antioxidant activity and also quantitative analysis of ascorbic acid and total phenols were carried out using four indigenous vegetables.

Amaranthus spp. (75 accessions), *Basella alba* (43 accessions), *Corchorus* spp. (34 accessions) and *Ipomoea aquatica* (41 accessions) maintained at the Center were used as plant materials. Seeds of *Basella* and *Ipomoea* accessions were sown in the greenhouse on 15 June 2001 and transplanted 10 July 2001. Seeds of *Amaranthus* accessions were sown directly in the field on 9 July 2001. Seeds of *Corchorus* accessions were sown in the greenhouse on 12 Apr. 2001 and transplanted on 3 May 2001. Plant materials were harvested in Aug. 2001 from 10 plants of each accession. Several Taiwanese and Japanese commercial cultivars were used as controls.

Antioxidant activity was assayed by 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 three minutes. Fifty ml of sample solution (10 mg/50 ml) was used for the analysis. T-Butyl-4-hydroxyanisole (BHA) was used as positive antioxidant control.

Ascorbic acid content was determined by RQflex plus with the analytical test strip (MERCK) using metaphosphoric acid extracts (final concentration of metaphosphoric acid was 5%). Ascorbic acid was used as standard solution.

Total phenolic compounds were assayed by Folin-Denis method (AOAC1984) 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.

Corchorus showed the highest antioxidant activity among four indigenous leafy vegetables analyzed in this experiment (78%), followed by *Ipomoea* (73%), *Amaranthus* (51%) and *Basella* (42%). Variation within species was also observed, although very little in the case of *Corchorus*. Its antioxidant activity ranged from 76-80%, compared to *Ipomoea* at 59-86%, *Amaranthus* at 26-69%, and *Basella* at 29-64% Antioxidant activity of *Corchorus* was higher than that of 10 mM BHA positive antioxidant control. The top 10 accessions of each vegetable in terms of antioxidant activity are shown in Tables 80–83.

The ascorbic acid content of the indigenous leafy vegetables are shown in Tables 80–83. *Corchorus* (153 mg/100 g fresh weight [FW]) showed the highest ascorbic acid content, followed by *Basella* (95 mg), *Amaranthus* (59 mg) and *Ipomoea* (45 mg). The standard deviation (SD) for *Corchorus* was highest, followed by the SD for *Basella*, *Amaranthus, Ipomoea*.

Total phenol contents of indigenous leafy vegetables are shown in Tables 80–83. *Ipomoea* (726 mg chlorogenic acid equivalent /100 g FW) had the highest total phenol content followed by *Corchorus* (503 mg), *Basella* (315 mg) and *Amaranthus* (247 mg). *Ipomoea* showed the biggest SD value for total phenol content. Its highest value observed was 1,324 mg chlorogenic acid equivalent/100 g FW and the lowest was 478 mg.

Table 80. *The highest rated* Amaranthus *spp. accessions for antioxidant activity, ascorbic acid and total phenol contents.*[1] *Data for check varieties are included. AVRDC, sown 9 July 2001.*

Accession	Origin	Species	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
Tot4141[5]	Vietnam	*dubius*	69	91	405
Tot2261[5]	Ghana	*dubius*	68	88	(263)
Tot1823	Indonesia	*tricolor*	68	68	(246)
Tot4143	Vietnam	*hypoch.*[6]	65	(55)	398
Tot4096[5]	Tanzania	*dubius*	64	85	(267)
Tot1818	Indonesia	*tricolor*	63	68	305
Tot4582	Bangladesh	*tricolor*	59	110	(233)
Tot2262	Ghana	*hypoch.*	58	(50)	382
Tot4152	Vietnam	*hypoch.*	58	55	373
Tot2255	Ethiopia	*cruentus*	58	(51)	302
Tot2328	Nigeria	*dubius*	(57)	100	284
Tot4745	Vietnam	*retroflexus*	(57)	67	315
Tot4510[5]	Bangladesh	*tricolor*	(56)	92	361
Tot3919	Vietnam	*hypoch.*	(56)	(40)	375
Tot4868[5]	Japan (ck)	*tricolor*	(28)	57	(129)
Tot5472	Taiwan (ck)	*tricolor*	(27)	(46)	(204)
Average for all entries			51	59	247
SD			9.5	18.4	70.8

[1]Data in parentheses were not among the ten highest rated accessions for a given trait.
[2]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 70%.
[3]Mg/100 fresh weight.
[4]Mg chlorogenic acid equivalent/100 g fresh weight.
[5]One of the 10 highest yielding lines.
[6]*hypoch. = hypochodriacus.*

Conclusion

Based on yield, antioxidant activity, ascorbic acid and total phenol content, several accessions are

Table 81. *The highest rated* Basella alba *accessions for antioxidant activity, ascorbic acid and total phenol contents. AVRDC, transplanted 10 July 2001.*

Accession	Origin	Stem color[1]	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
Tot4387	Bangladesh	G	64	140	254
Tot3578	Vietnam	G	57	107	354
Tot4169	Vietnam	G	57	72	355
Tot4639	Bangladesh	G	56	93	322
Tot3577	Vietnam	G	55	143	372
Tot3576	Vietnam	G	55	111	366
Tot3581	Vietnam	P	52	125	330
Tot4354	Bangladesh	G	51	131	399
Tot1285	Thailand	G	51	113	327
Tot4591	Bangladesh	G	49	106	388
Average for all entries			42	95	315
SD			9.5	19.8	24.2

[1]G = green, P = purple.
[2]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 69%.
[3]Mg/100 fresh weight.
[4]Mg chlorogenic acid equivalent/100 g fresh weight.

recommended for further evaluation. These include *Amaranthus* spp. accessions Tot4141, Tot2261, Tot4096, Tot4510, and Tot4868; *Basella alba* accessions Tot4387, Tot3577, Tot3576 and Tot4354; *Corchorus* spp. accessions Tot4316, Tot4541, Tot4721, Tot4878, and Tot4885; and *Ipomoea aquatica* accessions Tot1923A, 1928B, 1920A, 1925B, 1918B, and 1919A.

When comparing these accessions with the commercial check varieties, none of the *Amaranthus* checks were relatively high in antioxidant activity, ascorbic acid or total phenol contents (Table 80). Checks were not included in the *Basella* trials. For *Corchorus*, the check varieties were relatively high yielding, and high in antioxidant activity, ascorbic acid and total phenol contents (Table 82). For *Ipomoea*, the check varieties were high yielding but relatively low in antioxidant activity, ascorbic acid and total phenol contents with one exception (Table 83).

Table 82. *The highest rated* Corchorus *spp. accessions for antioxidant activity, ascorbic acid and total phenol contents.*[1] *Data for check varieties are included. AVRDC, transplanted 3 May 2001.*

Accession	Origin	Species	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
Tot4067	Vietnam	*capsularis*	80	210	552
Tot4708	Bangladesh	*capsularis*	80	200	(503)
Tot4316[5]	Bangladesh	*olitorius*	79	216	598
Tot4541[5]	Bangladesh	*olitorius*	79	(135)	607
Tot4670	Bangladesh	*capsularis*	79	191	(505)
Tot4683	Bangladesh	*capsularis*	79	169	556
Tot4713	Bangladesh	*capsularis*	79	158	535
Tot3499	Vietnam	*capsularis*	79	185	(531)
Tot4721[5]	Bangladesh	*olitorius*	(77)	199	616
Tot4879[5]	USA	*olitorius*	(78)	146	639
Tot4885[5]	Japan (ck)	*olitorius*	(78)	(134)	556
Tot5876	Japan (ck)	*olitorius*	79	(123)	666
Tot5877	Japan (ck)	*olitorius*	80	152	546
Average for all entries			78	153	503
SD			1.1	31	81.9

[1]Data in parentheses were not among the ten highest rated accessions for a given trait.
[2] Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 73%.
[3]Mg/100 fresh weight.
[4]Mg chlorogenic acid equivalent/100 g fresh weight.
[5]One of the 10 highest yielding lines.

Table 83. *The highest rated* Ipomoea aquatica *accessions for antioxidant activity, ascorbic acid and total phenol contents.*[1] *Data for check varieties are included. AVRDC, transplanted 10 July 2001.*

Accession	Origin	Antioxid. activity[2]	Ascorbic acid[3]	Total phenol[4]
Tot1928A	Indonesia	83	(38)	1213
Tot1923A[5]	Indonesia	79	48	849
Tot1928B[5]	Indonesia	79	45	901
Tot3976	Taiwan	78	55	(575)
Tot0511	Bangladesh	78	44	785
Tot1920A[5]	Indonesia	77	68	865
Tot1924A	Indonesia	77	44	1324
Tot1924B[5]	Indonesia	77	43	1124
Tot1918B[5]	Indonesia	77	51	737
Tot1929	Indoensia	76	39	803
Tot1919A[5]	Indonesia	(74)	52	915
Tot5981	Taiwan (ck)	76	(41)	(725)
Tot5874	Japan (ck)	76	(36)	(653)
Average for all entries		73	45	762
SD		6.5	7.4	180.4

[1]Data in parentheses were not among the ten highest rated accessions for a given trait.
[2]Measured as 100 minus peroxidation percentage. Ten mM BHA (positive control) is 74%.
[3]Mg/100 fresh weight.
[4]Mg chlorogenic acid equivalent/100 g fresh weight.
[5]One of the 10 highest yielding lines.

Genetic diversity analysis of AVRDC's *Momordica* accessions

The genus *Momordica* is native to the Asia and is comprised of 45 to 60 species. *M. charantia* (bitter gourd) is the most important cultivated *Momordica* species. It was likely first domesticated in eastern India and southern China, and is now grown throughout the tropics. *M. charantia* is grown for its fruits, young shoots, and edible flowers. Its notable bitterness is attributed to the non-toxic alkaloid momordicine, which has been used for centuries in traditional medicine; other *Momordica* species are grown for local markets.

The objectives of this study are to establish molecular phylogenetic relationships and genetic diversity data among *Momordica* accessions collected by AVRDC, eliminate duplicate collections, and find species-specific DNA markers for taxonomy purposes.

Eighty-three accessions, consisting of four species collected from 11 countries were used for this study (Table 84). The CTAB (hexadecyltrimethyl ammonium bromide) method was followed to extract genomic DNA from young leaves of *Momordica* plants grown in greenhouse. A total of 332 10-mer random primers including 240 UBC (Univ. of British Columbia) and 92 Operon (Operon Technologies, Alameda, Cal.) primers were prescreened 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; 50 mM KCl), 3 mM MgCl2, 100 µM dNTPs, 0.2 µM primer, 1 unit *Taq* DNA polymerase and 25 ng plant genomic DNA. Amplifications were performed in an Eppendorf Thermocycler. 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 to 2.5 hours, then stained with ethidium bromide. The images were then recorded by the AlphaImager 2000 (Alpha 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.

After primer prescreening, 51 primers producing polymorphic and scorable bands were chosen for further amplification of DNA from all accessions. Table 85 shows the list of scorable RAPD bands generated by each primer.

A total of 359 RAPD bands were scored. The scorable band size ranged from 400 to 2800 bp. Among the 359 bands, 73 bands (20.3%) were unique to *M. cochinchinensis* (sweet gourd) and/or *M. dioica* (spine gourd). After the 73 unique bands were eliminated, 286 bands showed the diversity of *M. charantia* and *M. balsamina*. Among the 286 bands, 238 bands (83.2%) were polymorphic. This suggests that *M. charantia* has a wide genetic background. Furthermore, only two bands were common in all 83 accessions.

Similarity levels between the *M. charantia* and *M. balsamina* (Tot5932) accessions ranged from 0.51 to 0.98 (Figure 14). Low similarity was found within *M. cochinchinensis* (Tot4034) and *M. dioica* (Tot5658)

Table 84. *Accession information of* Momordica *collection in AVRDC's Genetic Resources and Seed Unit (GRSU).*

Origin[1]	Species	No.	Accessions (GRSU code)
Thailand (TH)	*M. charantia*	20	Tot899, Tot468, Tot5796, Tot5848, Tot5849, Tot950, Tot1008, Tot1398, Tot4206,Tot4208, Tot4209, Tot4213, Tot5135, Tot5467, Tot5704, Tot5749, Tot5768, Tot5793, Tot5128, Tot5197.
	M. dioica	1	Tot5658.
	M. sp.[2]	2	Tot1095, Tot1140.
Philippines (PH)	*M. charantia*	8	Tot1504, Tot1505, Tot1513, Tot1567, Tot1615, Tot1616, Tot1568, Tot1747.
Vietnam (VN)	*M. charantia*	2	Tot4131, Tot4204.
	M. cochinchinensis	1	Tot4034.
Taiwan (TW)	*M. charantia*	2	Tot5111, Tot4358.
	M. balsamina	1	Tot5932.
India (IN)	*M. charantia*	4	Tot1756, Tot2533, Tot5851, Tot5852.
	M. sp.[2]	1	Tot2407.
Pakistan (PK)	*M. charantia*	1	Tot2377.
Sri Lanka (LK)	*M. charantia*	2	Tot5847, Tot5869.
Lao PDR (LA)	*M. charantia*	1	Tot4009.
Indonesia (ID)	*M. charantia*	5	Tot1849, Tot1854, Tot1856, Tot1843, Tot1850.
Bangladesh (BD)	*M. charantia*	30	Tot4234, Tot4244, Tot4256, Tot4257, Tot4275, Tot4296, Tot4297, Tot4333, Tot4362, Tot4383, Tot4409, Tot4491, Tot4507, Tot4513, Tot4531, Tot4533, Tot4548, Tot4549, Tot4574, Tot4614, Tot4622, Tot4645, Tot4671, Tot4679, Tot4705, Tot4717, Tot4722, Tot5850, Tot4370, Tot5521.
	M. dioica	1	Tot4392.
Belize (BZ)	*M. charantia*	1	Tot3991.

[1]Parentheses show the designated abbreviation of countries used by GRSU.
[2]The scientific name of an ambiguous sample is shown as *Momordica* spp.

Table 85. *List of scorable random amplified polymorphic DNA (RAPD) bands generated by each primer.*

Primer	Sequence (5'→3')	Mono-[1]	Poly-[2]	Unique-[3]	Primer	Sequence (5'→3')	Mono-[1]	Poly-[2]	Unique-[3]
UBC165	GAAGGCACTG	3	3	1	UBC494	TGATGCTGTC	0	5	2
UBC202	GAGCACTTAC	2	1	1	UBC498	GACAGTCCTG	3	0	4
UBC204	TTCGGGCCGT	0	6	1	UBC504	ACCGTGCGTC	0	4	0
UBC205	CGGTTTGGAA	0	5	1	UBC588	CAGAGGTTGG	1	3	0
UBC209	TGCACTGGGG	1	4	2	UBC605	CCGATCATTC	0	1	1
UBC211	GAAGCGCGAT	0	7	2	UBC608	GAGCCCGAAA	0	5	0
UBC218	CTCAGCCCAG	2	3	7	UBC614	GTAGTCTCGC	0	6	0
UBC219	GTGACCTCAG	0	4	2	UBC626	CCAAGCCCGG	2	7	4
UBC250	CGACAGTCCC	2	4	3	UBC634	CCGTACACGC	0	3	1
UBC262	CGCCCCCAGT	0	7	1	UBC646	GTCCACTTCC	1	5	0
UBC268	AGGCCGCTTA	0	3	0	UBC650	AGTATGCAGC	1	2	2
UBC300	GGCTAGGGCG	0	5	1	UBC654	CCCTGGTCTG	1	1	3
UBC303	GCGGGAGACC	1	7	0	UBC688	GCAGGAGCGT	0	7	0
UBC305	GCTGGTACCC	2	7	1	UBC691	AAACCAGGCG	0	3	2
UBC312	ACGGCGTCAC	0	9	0	UBC693	GACGAGACGG	3	6	3
UBC313	ACGGCAGTGG	4	6	3	OPI2	GGAGGAGAGG	0	7	0
UBC327	ATACGGCGTC	0	3	2	OPI4	CCGCCTAGTC	0	7	1
UBC388	CGGTCGCGTC	0	6	2	OPI6	AAGGCGGCAG	2	1	2
UBC391	GCGAACCTCG	2	4	0	OPI7	CAGCGACAAG	3	1	1
UBC396	GAATGCGAGG	0	3	0	OPI8	TTTGCCCGGT	1	3	1
UBC416	GTGTTTCCGG	1	4	4	OPAE12	CCGAGCAATC	1	4	1
UBC421	ACGGCCCACC	1	2	0	OPAX5	AGTGCACACC	1	5	1
UBC431	CTGCGGGTCA	0	6	1	OPAX7	ACGCGACAGA	0	8	0
UBC478	CGAGCTGGTC	0	10	0	OPAN11	GTCCATGCAG	2	4	4
UBC485	AGAATAGGGC	1	6	3	OPAN16	GTGTCGAGTC	3	9	1
UBC487	GTGGCTAGGT	1	6	0					
Sub-total		23	131	39	Sub-total		25	107	34

[1]Number of monomorphic bands/per primer within *M. charantia* and *M. balsamina.*
[2]Number of polymorphic bands/per primer within *M. charantia* and *M. balsamina.*
[3]Number of unique bands/per primer within *M. cochinchinensis* and/or *M. dioica.*

with Jaccard's similarity coefficients of 0.18 and 0.19, respectively. Based on morphological description, *M. cochinchinensis* is different from *M. charantia. M. cochinchinensis* is dioecious and perennial, while *M. charantia* is monoecious and annual. These results indicate that the genus *Momordica* has high genetic diversity and confirm that *M. charantia* is more closely related to *M. balsamina* than other *Momordica* spp.

All accessions could be separated into nine clusters (Figure 14). The dendrogram shows that the genetic diversity of *M. charantia* has high correlation with geographical origin. Accessions collected from Philippines, Vietnam, Indonesia and Taiwan are grouped in cluster III. Accessions collected from Sri Lanka and Pakistan are grouped with India and Bangladesh in cluster II. In accordance with this dendrogram, it confirms that India is an important center of genetic diversity for *M. charantia* since accessions from India are distributed in clusters II, III and IV. Accessions from Bangladesh were divided into two subgroups in clusters II and IV. Furthermore, Thailand should be considered as another center of *M. charantia* diversity since accessions were distributed in cluster I, II, III, IV, V and VI.

According to the RAPD data, a few accessions should be re-defined. For example, accession Tot5658 (*M. dioica* from Thailand) is in cluster IV and shows higher correlation with *M. charantia* than Tot4392 (*M. dioica* from Bangladesh), which is in cluster VIII. Thus, Tot5658 might be classified into *M. charantia*. Some other ambiguous samples such as Tot2407 (India), Tot1095 (Thailand) and Tot1140 (Thailand) should also be classified into *M. charantia*. Except for DNA molecular data, these identifications are also supported

Figure 14. *Cluster analysis of 83* Momordica *accessions. The scale on the bottom of the dendrogram is the Jaccard's similarity coefficient based on 359 random amplified polymorphic DNA (RAPD) bands, Roman numerals on the right indicate* Momordica *clusters.*

by morphological characteristics (data not shown). Tot5111 and Tot4358, which were all originally classified as *M. charantia*, were both collected from Shanhua, Taiwan. In this study, Tot5111 was clustered with *M. charantia* in cluster III, but Tot4358 was grouped with Tot5932 (*M. balsamina* from Taiwan) in cluster VII with a high similarity level (0.95). The morphological characteristics investigated by AVRDC-GRSU also show similarity between these two accessions. This result implies that Tot4358 should be classified as *M. balsamina*.

These results show that RAPD analysis is a useful tool for *Momordica* germplasm diversity analysis and genotypic identification, and can provide baseline information on genetic relationships among these *Momordica* accessions. Genetic diversity information is essential for rational germplasm conservation and utilization, as well as for genetic improvement. Based on DNA molecular data, the most important cultivated *Momordica* species, *M. charantia*, shows high genetic diversity and the genetic diversity of accessions from Indonesia and Philippines are relatively location-specific. However, to identify the species-specific DNA markers, it is necessary to increase the accession number of other *Momordica* spp. such as *M. balsamina*, *M. cochinchinensis*, and *M. dioica* so that the entries have sufficient representation.

Project 9. Collaborative research and networks for vegetable production

The objective of Project 9 is 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 NARS partners and advanced laboratories.

Project Coordinator: G Kuo

AVRDC-ROC cooperative program

Effect of defoliants and flooding on mechanical harvesting of mungbean

Manual harvesting of mungbean is labor-intensive and mechanical harvesting is an option to reduce production costs. However, one obstacle to mechanical harvesting is that mungbean foliage does not dry or abscise when pods are mature. Plants must be defoliated to facilitate mechanical harvesting. The objective of this experiment was to determine the best defoliating treatment for mechanical harvesting. Two AVRDC inbred lines, VC3890A and VC6040A, were evaluated. Three defoliants were used: 1) urea (46N–0P–0K), 10 times dilution; 2) ethrel (39.5% a.i.), 500 times dilution; and 3) sodium chlorate (99% pure), 400 times dilution. A check plot with no defoliants was also included. The experiment was conducted using a split plot design with three replications. The main plot was flooding. The sub-plots were two cultivar x four defoliant treatments. The plot size (and the harvest plot size) was 5 m x 2 m. Seeds were sown on 12 Sept. 2001. The plant population density was 400,000 plants/ha. Defoliants were applied once when 80% of the pods reached the mature pod color (black), which occurred on 12 Dec. 2001.

Observations were made on days to flower. Ten randomly selected plants from each treatment were tagged at the flowering stage and the total number of leaves per plant was recorded. The number of green and dried leaves remaining on the plant was recorded at 7 days after defoliant application (DADA). At 8 DADA, the number of plants harvested, pod number for five plants, seed number per 10 pods, 100-seed weight, and seed yield were recorded. After harvest, germination and hard seed percentage were determined by germinating 100 randomly selected seeds from each replication for each treatment combination using a petri dish and Whatman filter paper. To avoid damage by birds, the trial area was covered by nylon net at maturity stage.

Results showed that the differences in percentage dried leaves and percentage defoliation between flooding treatment and check were insignificant. However, highly significant differences between defoliants were observed for both traits. Differences between inbred lines were insignificant (Table 86).

Among the three defoliants, ethrel was most effective with nearly 90% defoliation followed by sodium chlorate and then urea (Table 87). Treatment with defoliants did not affect the germination percentage of seeds. However, the percentage of hard seeds was significantly higher in plots treated with sodium chlorate compared to ethrel. Hard seed is undesirable since it can lead to poor germination and weak sprout growth. Therefore, it is recommended that ethrel can be effectively used to defoliate mungbean to facilitate mechanical harvesting.

Table 86. *Analysis of variance for percentages of dried leaves and defoliation at 7 days after application of defoliants on mungbean, sown 12 Sept. 2001.*

		Mean square ($x10^{-4}$)	
Source	df	Dried leaves	Defoliation
Block (B)	2	239	115
Flood (F)	1	0.7	0.6
Error (A)	2	48	23
Lines (L)	1	12	1.3
Defoliants (D)	3	1549***	1231***
L x D	3	167	109*
L x F	1	26	10
D x F	3	41	95
L x D x F	3	190*	140*
Error (b)		59	37

*, **, *** Differences significant at $P \leq 0.05$, 0.01, and 0.001, respectively.

Table 87. *Effects of defoliants on percentages of germination rate, hard seed, dried leaves and defoliation, sown 12 Sept. 2001.*

Defoliants	Germination (%)	Hard seed (%)	Dried leaves (%)	Defoliation (%)
Urea	89.5 a[1]	9.8 ab	81 b	74 c
Ethrel	91.9 a	7.3 b	92 a	90 a
Sodium chlorate	89.1 a	11.0 a	95 a	81 b
Check	92.0 a	7.3 b	70 c	66 d

[1]Data followed by the same letter within each column indicate that the difference was not significant by least square difference ($P \leq 0.05$).

Regional yield trials

Vegetable soybean

Nine lines, including three AVRDC lines, three Tainan DAIS lines and three Kaohsiung District Agricultural Improvement Station (DAIS) lines, were evaluated in eight trials against three check varieties, KS1, KS2 and KS5. The experimental design was randomized complete block design with four replications, conducted in four locations in southern Taiwan: Shanhua, Kaohsiung, Poh-Tzy and Shy- Hwu.

The lines showed significant differences in graded pod yields. AVRDC line GC93032-2-1-1-1 gave the highest yield of 9.5 t/ha over four locations in spring (Feb.–May 2001) (Table 88). Another AVRDC line, GC93010-1-1-2-2-6, produced the highest yield (8.0 t/ha) across four locations in fall (Sept.–Nov. 2001), whereas KS#5 (check variety) produced only 5.6 t/ha (Table 88).

KS#5 had the highest 100-fresh bean weight in both spring and fall trials across two and four locations, respectively (Table 89). A Kaohsiung DAIS-developed line, KVS1027, had the highest protein content at 47.8% (Table 89). None of the new lines could match the sugar content of check variety KS#1.

Mungbean

Regional yield trials were conducted in Spring (Feb.–May 2001) and Summer (July–Oct. 2001) 2001 by AVRDC and the Tainan DAIS. The latter conducted trials at their research station and at Yen-Suei. Each trial used randomized complete block design with four replications at each location. The top performers were NS85-20, followed by NS85-29, VC6040A and NS85-18, with yields in the range of 1.12–1.39 t/ha (Table 90). These lines have large, dull seeds and uniform maturity that are preferred by local consumers and growers. NS85-20 was especially impressive and the highest yielder in both spring and summer trials. Yields at AVRDC were relatively low in the spring trial due to cold injury in the beginning and rains during harvest.

Table 88. *Graded pod yield (t/ha) of vegetable soybean lines tested in regional yield trials for southern Taiwan, Spring (Feb.–May) and Fall (Sept.–Nov.) 2001.*

	Spring					Fall				
Line	AVRDC	Kaohsiung	Poh-Tzy	Shy-Hwu	Mean	AVRDC	Kaohsiung	Poh-Tzy	Shy-Hwu	Mean
KVS968	5.9	6.7	8.4	6.2	6.8	5.0	6.3	6.1	5.1	5.6
KVS1027	5.4	9.5	8.8	6.1	7.5	4.9	8.3	8.1	6.6	7.0
KVS1159	6.0	6.3	5.2	5.3	5.7	4.1	7.0	6.6	6.0	5.9
TS85-06V	5.4	8.0	8.6	6.6	7.2	3.0	6.2	5.3	6.1	5.2
TS87-S4	6.5	7.8	7.0	6.1	6.9	2.8	6.9	5.9	6.2	5.5
TS87-12V	8.0	8.8	9.5	9.4	8.9	5.2	7.4	9.6	8.1	7.6
GC92001-P-25-1	7.9	9.5	7.1	7.0	7.9	5.0	8.5	7.3	5.0	6.5
GC93010-1-1-2-2-6	4.6	7.8	7.4	8.4	7.1	7.2	7.9	8.0	8.7	8.0
GC93032-2-1-1-1	9.4	8.4	11.7	8.3	9.5	4.2	6.2	7.9	9.5	7.0
KS#1(ck)	6.7	8.2	8.4	7.1	7.6	3.3	8.9	5.7	6.6	6.1
KS#2(ck)	7.8	8.8	6.8	8.8	8.1	5.8	6.7	7.1	6.3	6.5
KS#5(ck)	5.9	6.9	7.9	8.0	7.2	3.1	8.4	5.8	5.1	5.6
Mean	6.6	8.1	8.1	7.3	7.5	4.5	7.4	7.0	6.6	6.4
LSD (0.05)	1.2	2.4	3.3	1.0		0.9	–[1]	1.5	1.4	

[1]Not determined.

Table 89. *Quality analysis of vegetable soybean lines tested in regional yield trials for southern Taiwan, Spring (Feb.–May) and Fall (Sept.–Nov.) 2001.*

	Spring			Fall					Spring		
	100-fresh seed weight (g)								Protein (%)	Sugar(%)	Color[1]
Lines	AVRDC	Kaohsiung	Mean	AVRDC	Kaohsiung	Poh-Tzy	Shy-Hwu	Mean	AVRDC	AVRDC	AVRDC
KVS968	71	87	79.0	70	93	69	68	75.0	47.3	13.8	3.5
KVS1027	61	80	70.5	61	105	67	64	74.3	47.8	12.0	4.0
KVS1159	47	82	64.5	56	88	65	64	68.3	43.1	12.9	4.0
TS85-06V	73	92	82.5	68	89	72	78	76.8	47.3	14.4	3.8
TS87-S4	67	87	77.0	61	81	68	70	70.0	45.1	13.1	3.7
TS87-12V	67	87	77.0	65	97	78	76	79.0	46.3	13.1	3.6
GC92001-P-25-1	74	80	77.0	69	85	73	69	74.0	46.7	12.9	4.0
GC93010-1-1-2-2-6	73	87	80.0	74	96	76	75	80.3	46.3	12.5	3.7
GC93032-2-1-1-1	68	85	76.5	60	70	68	73	67.8	46.7	13.0	3.8
KS1(ck)	68	80	74.0	58	89	69	70	71.5	43.1	15.0	3.5
KS2(ck)	61	85	73.0	56	76	63	67	65.5	45.1	12.0	3.7
KS5(ck)	81	93	87.0	67	108	70	79	81.0	46.8	12.7	3.6
Mean	67.6	85.4	76.5	63.8	89.8	69.8	71.1	73.6	46.0	13.1	3.7
LSD (0.05)	64.6		12.0						1.1	0.7	0.2

[1]Pod color rated on 1–6 scale with 1 = very dark green-yellow, and 6 = pale green-yellow.

Table 90. *Yield (t/ha) of mungbean lines in regional yield trials conducted at AVRDC, Tainan District Agricultural Improvement Station (DAIS), and Yen-Suei during Spring (Feb.–May) and Summer (July–Oct.) 2001.*

	Spring				Summer			
Entry	AVRDC	Tainan DAIS	Yen-Suei	Mean	AVRDC	Tainan DAIS	Yen-Suei	Mean
NS85-02	0.69	0.87	1.43	1.00	1.30	0.96	1.00	1.09
NS85-18	0.86	1.07	1.42	1.12	1.56	1.01	0.74	1.10
NS85-20	0.76	1.68	1.73	1.39	1.76	1.02	0.98	1.25
NS85-23	0.58	0.90	1.36	0.95	1.47	0.78	1.20	1.15
NS85-26	0.66	1.33	1.13	1.04	1.71	0.98	0.67	1.12
NS85-29	0.84	1.20	1.40	1.15	1.56	1.01	0.76	1.11
NS85-32	0.65	1.13	1.34	1.04	1.75	0.82	0.77	1.11
VC6040A	0.80	1.22	1.35	1.12	1.54	1.01	0.81	1.12
TN-5(ck)	0.75	1.29	1.17	1.07	1.44	1.02	0.79	1.08
Mean	0.73	1.19	1.37	1.10	1.57	0.96	0.86	1.13
LSD (0.05)	0.12	0.48	0.39		0.22	0.14	0.43	

Fresh market tomato

This experiment was conducted to identify fresh market hybrids for summer production. Five AVRDC hybrids were evaluated along with commercial variety, Farmers 301, during Aug.–Dec. 2001 at AVRDC. The experimental design was randomized complete block design with four replications. Plants were set in twin rows on raised beds with plants spaced 50 cm apart. FMTT556 and FMTT593, large-fruited lines with dark green shoulders, gave highest yields at 58.4 t/ha and 58.1 t/ha, respectively. FMTT552 produced 46.6 t/ha, followed by FMTT553, FMTT591, and Farmers 301 at 44.8, 38.2 and 30.4 t/ha, respectively (Table 91). FMTT593 had the lowest acidity and highest color value among the FMTT lines. This line was named as Taichung ASVEG No. 10 and released to Taichung DAIS and farmers on 27 July 2001.

Table 91. *Regional yield trial of fresh market tomato hybrids, AVRDC, transplanted Aug. 2001.*

Lines	Days to maturity	Fruit set (%)	Fruit weight (g)	Marketable yield (t/ha)	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)
FMTT552	112.1	81.0	109.2	46.6	4.83	0.32	1.81
FMTT553	111.8	81.8	96.2	44.8	4.95	0.30	1.82
FMTT556	112.6	81.6	137.9	58.4	4.38	0.29	1.89
FMTT591	110.0	80.7	107.3	38.2	4.40	0.28	1.73
FMTT593	113.8	82.8	165.8	58.1	4.75	0.27	1.90
Farmers 301	114.2	79.9	79.5	30.4	5.08	0.31	1.94
Mean	112.4	81.3	116.0	46.1	4.73	0.30	1.85
LSD (0.05)	10.4	5.0	39.7	9.9	0.43	0.05	0.21

[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.

Red cherry tomato

Three red cherry tomato hybrids (CHT1126, CHT1127 and CHT1130) were tested at AVRDC along with check variety Tainan ASVEG #6. Trials were conducted in Spring (Feb.–June 2001) and Fall (July–Nov.) 2001. These AVRDC hybrids were selected because they set fruit under high temperatures, resist cracking, and are flavorful. The experimental design was randomized complete block design with four replications, two rows per plot and 50 cm between plants. The AVRDC lines had comparable or larger fruit size, similar yields in the spring and significantly higher yields in the fall compared to the check variety (Table 92). As for fruit quality, CHT1126 was slightly but consistently more acidic (Table 93). All AVRDC lines had higher color values in the fall compared to the check. Among the AVRDC lines, CHT1127 was the leader in yield and soluble solids in the spring trial, but lowest for these traits in the fall.

Table 92. *Fruit quality analysis of red cherry tomato hybrids grown at AVRDC, transplanted in Feb. and July 2001.*

	Spring			Fall		
Lines	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	Solids (°Brix)	Acid (%)	Color (a/b)
CHT1126	6.73	0.40	1.25	5.85	0.33	1.83
CHT1127	6.83	0.39	1.35	5.25	0.30	1.75
CHT1130	6.48	0.34	1.24	5.38	0.30	1.79
Tainan ASVEG No. 6	6.68	0.36	1.26	5.60	0.32	1.48
LSD (0.05)	0.39	0.04	0.18	0.23	0.03	0.12

[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.

Table 93. *Yield analysis of red cherry tomato hybrids grown at AVRDC,transplanted in Feb. and July 2001.*

	Spring				Fall			
Lines	Days to maturity	Fruit set (%)	Fruit weight (g)	Marketable yield (t/ha)	Days to maturity	Fruit set (%)	Fruit weight (g)	Marketable yield (t/ha)
CHT1126	84.3	72.0	7.3	44.2	113.9	74.9	4.6	21.0
CHT1127	82.9	77.0	8.0	45.8	113.1	72.6	6.9	17.7
CHT1130	83.2	73.0	8.1	44.8	116.6	73.8	7.1	21.4
Tainan ASVEG No. 6	84.0	78.3	8.1	42.1	112.2	73.9	5.2	6.2
LSD (0.05)	1.5	4.9	1.3	3.5	10.3	6.0	2.4	13.9

High beta-carotene cherry tomato

An experiment was conducted to evaluate three cherry tomato hybrids with high beta-carotene contents (CHT1190, CHT1200 and CHT1201). Trials were conducted at AVRDC during spring (Feb.–April 2001) and fall (Oct. 2001–Apr. 2002). Compared to the check variety Tainan ASVEG No. 6, the AVRDC lines matured slightly later, produced similar or larger-sized fruit, and had comparable yields (Table 94). The most notable differences were with regard to fruit quality (Table 95). The AVRDC lines, all with golden fruit color, were significantly less acidic, contained more than twice as much beta-carotene, and had significantly less lycopene than the standard red-fruited Tainan ASVEG No. 6. Soluble solids among the lines were not significantly different.

Lettuce

Four accessions, LT40, LT45, LT86, and TOT423, were evaluated in three seasonal trials with two check varieties, French Salad and Min Fun No. 3. LT45, sold as the variety Sierra, gave the highest average yield, 34.9 t/ha in three seasons, and outyielded the two checks by 85-88% (Table 96). LT45 is a Batavia type, which is a new form of leaf lettuce for Taiwan production. Outer leaves are brownish-red and inner leaves are shiny green. Plants are upright, medium-sized, very heavy with crispy leaf texture. It is heat tolerant, resistant to bolting, and tolerant to lettuce mosaic virus.

Table 96. *Yield (t/ha) of lettuce in regional yield trials across three seasons at AVRDC, 2001.*

Line	Yield (t/ha) Mar.–May	June–Sept.	Sept.–Dec.	Mean
LT40	29.5	8.6	44.0	27.4
LT45	22.1	10.2	72.3	34.9
LT86	18.8	7.2	56.8	27.6
Tot423	33.0	6.0	49.1	29.4
French Salad	13.6	3.3	39.6	18.8
Min Fun No. 3	19.5	2.7	33.4	18.5
Mean	22.8	6.3	49.2	26.1
LSD (0.05)	3.0	2.9	6.3	

Table 94. *Yield analysis of high beta-carotene cherry tomato hybrids grown at AVRDC,transplanted in Feb. and Oct. 2001.*

	Spring				Fall			
Lines	Days to maturity	Fruit set (%)	Fruit weight (g)	Marketable yield (t/ha)	Days to maturity	Fruit set (%)	Fruit weight (g)	Marketable yield (t/ha)
CHT1190	85.3	79.5	0.8	37.1	132.0	93.0	11.8	82.8
CHT1200	85.2	83.7	0.8	38.2	135.6	92.8	11.9	83.1
CHT1201	85.6	80.7	0.8	35.1	131.6	92.3	12.3	84.9
Tainan ASVEG No. 6	83.1	78.7	0.8	38.4	127.2	89.8	8.4	82.7
LSD (0.05)	0.8	3.9	0.1	4.3	3.1	2.8	0.8	9.9

Table 95. *Fruit quality analysis of high beta-carotene cherry tomato hybrids grown at AVRDC, transplanted in Feb. and Oct. 2001.*

	Spring					Fall				
Lines	Solids (°Brix)	Acid[1] (%)	Color[2] (a/b)	Beta-carotene (mg/100g)	Lycopene (mg/100g)	Solids (°Brix)	Acid (%)	Color (a/b)	Beta-carotene (mg/100g)	Lycopene (mg/100g)
CHT1190	6.15	0.31	0.13	1.89	0.11	6.50	0.45	0.63	2.86	0.54
CHT1200	6.25	0.32	0.15	1.94	0.16	6.18	0.46	0.55	2.81	0.40
CHT1201	6.50	0.32	0.16	2.06	0.18	6.38	0.44	0.67	2.88	0.47
Tainan ASVEG No. 6	6.55	0.36	1.11	0.81	2.29	6.25	0.50	1.40	0.81	1.99
LSD (0.05)	0.58	0.03	0.15	0.17	0.31	0.39	0.03	0.09	0.52	0.61

[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.

Introduction of indigenous vegetables to Taiwan

The ROC Council of Agriculture supported a project to introduce diverse indigenous vegetables from the tropics to Taiwan. The project entails: collection of relevant information; molecular depiction of confused species; field testing to observe for botanical and horticultural traits; adaptability and production potential; observation of potential diseases and insect pests; analyses of nutrient contents and health-related factors; and evaluation of consumer acceptance.

Observational trials of indigenous vegetables

Pigeon pea (Cajanus cajan)

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, has developed pigeon pea lines for use as a vegetable. The objective of this trial was to evaluate promising selections from AVRDC and ICRISAT for quality and yield traits.

Thirty-four elite selections from AVRDC germplasm were sown on 21 Sept. 2001. Plot size was 2 m x 1.5 m. Plantings were thinned to five plants per plot. Fresh green pods were harvested and yield data were collected from all plants. The earliest maturing lines produced pods after 111 days; harvesting of all lines continued until 153 days after sowing. Yield data was obtained from the 20 earliest maturing lines (Table 97). Tot2125 produced the highest yield of 822 g.

Eighteen lines introduced from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India were sown on 18 Oct. 2001. Twenty-five plants of each line were planted in 5 m x 1 m plots. Plants were spaced 20 cm apart in rows spaced 1 m apart. Five plants were chosen at random for evaluating quality and yield characteristics. Green pods were harvested at one-week intervals up to 156 days after sowing. Results are shown in Table 98.

It was laborious to pick the pods and shell the peas (peas are the desired edible portion). The high yielding entries from AVRDC produced 100-seed weights of only 18-29 g/100 seeds. The lines from ICRISAT had larger seed weights and may have greater potential. However, harvesting and shelling machinery must be developed to make production more economical.

Table 97. *Elite selections of AVRDC pigeon pea germplasm, sown 21 Sept. 2001.*[1]

Accession	Days to flower	Fresh pod weight (g/5plants)	Fresh seed weight (g/5 plants)	100-seed weight (g)
Tot1718	84	1126	552	18.2
Tot1731	84	894	438	18.2
Tot2125	83	1400	822	22.0
Tot2487	66	916	375	24.8
Tot2489	61	457	219	27.4
Tot2493	74	1165	524	21.4
Tot3152	87	745	373	28.5
Overall mean[1]	88	481	229	20.7
Range[1]	61–105	120–1400	49–822	13.9–28.5

[1]Yield data were taken from the 20 earliest maturing of 34 lines. Harvesting was done for 153 days after sowing.

Table 98. *Promising selections of pigeon pea from International Crops Research Institute for the Semi-Arid Tropics grown in an observational trial at AVRDC, sown 18 Oct. 2001.*[1]

Line	Days to flower	Fresh pod weight (g/5 plants)	Fresh seed weight (g/5 plants)	100-seed weight (g)
ICPL87091	82	266	140	28.8
ICPL94050	82	446	221	36.8
KAT60/8	94	427	246	35.6
ICPL99066	75	238	135	32.4
ICPL87051	112	663	296	38.2
ICP13092	124	253	133	35.2
ICP9145	112	323	203	28.5
Overall mean[1]	92	247	150	27.5
Range[1]	66–124	65–663	40–415	17.8–38.2

[1]Yield data from all 18 lines. Harvesting was done for 156 days after sowing.

Hyacinth bean (Dolicos lablab)

The objective of the study was to identify early maturing and high yielding selections of hyacinth bean. Fifty-two lines were collected from Bangladesh, India, Indonesia, Taiwan, Thailand and Vietnam. Seeds were sown on 21 Sept. 2001 in plots 2 m x 1.5 m in size. Plants were thinned in each plot to stand 50-cm apart in rows; rows were spaced 1.5-m apart. Fresh pod weights for the inner three plants were collected at fresh green-pod maturity stage for up to 150 days after sowing (yields of early-maturing lines decline after 150 days).

Yield characteristics of productive selections are shown in Table 99. Yields among the lines ranged from 315 to 5333 g/3 plants; the mean yield of all entries was 2205 g/3 plants. Among lines that matured early, CO 13 from India produced the highest yield followed by Tot2029 and Tot2449 from Thailand. Tot2456 from Thailand is also high yielding but its maturity is relatively late. Among all 52 lines tested, the 13 lines shown in Table 99 appear to be promising. They will be further evaluated for pod characteristics and consumer preference in selected countries.

Table 99. *High yielding selections of hyacinth bean from observational trial conducted at AVRDC, sown 21 Sept. 2001.*

Line	Origin	Days to first harvest	Yield (g/3 plants)[1]
CO 13	India	80	5333
Tot1153	Thailand	88	3747
Tot2029	Indonesia	80	4414
Tot2449	Thailand	83	4040
Tot2456	Thailand	125	5035
Tot4004	Laos	125	3085
Tot4268	Bangladesh	80	3890
Tot4300	Bangladesh	80	3330
Tot4356	Bangladesh	125	3060
Tot4552	Bangladesh	80	3231
Tot4772	Vietnam	80	3350
Tot4881	Vietnam	80	3276
Tot5471	Taiwan	97	3364
Mean of 52 lines		95	2205

[1]Beans were harvested for up to 150 days after sowing.

Cowpea (Vigna unguiculata)

The objective of this observational trial was to study the potential of cowpeas as a vegetable crop. Seven early maturing cowpea lines introduced from the International Institute of Tropical Agriculture (IITA) were sown on 15 Oct. 2001. Four, 4-m-long rows per plot were sown for each line. Spacing between rows was 75 cm; spacing between plants within rows was 20 cm. Yield data were collected from the two middle rows for each plot. Since plants were grown during the cool off-season, they matured in 75-86 days and yields were low. All lines were infected by powdery mildew. Results of this trial indicate that cowpeas are unsuitable as a cool season crop (Table 100). The trial will be repeated during the hot summer season.

Table 100. *Performance of International Institute of Tropical Agriculture cowpea lines at AVRDC, sown 15 Oct. 2001.*

Line	Days to first flower	Fresh pod wt. (kg/ha)	Powdery mildew[1]
IT93K-915	72	13.3 b[2]	MS
IT92KD-263-4-1	58	508.9 a	HS
IT97K-147-3	67	128.9 b	MR
IT92KD-267-2	62	113.3 b	HS
IT86F-2014-1	53	474.4 a	MR
IT83S-899	63	101.1 b	MS
IT81D-1228-14	70	36.7 b	MS
Means		196.7	
CV		64.8	

[1]HS = highly susceptible, MS = moderately susceptible, MR = moderately resistant.
[2]Means within columns separated using Duncan's multiple range test, $P \leq 0.05$.

Nutritional potential of indigenous vegetables

Indigenous vegetables are domesticated or partially domesticated crops that are grown in particular regions but underutilized. Recently they have gained more attention for reasons of genetic conservation and their potential for crop diversification. Vegetables, in general, are an important source of micronutrients in diets. In addition to preventing nutrient disorders, higher vegetable consumption is recommended because of its associations with lower risks of chronic diseases and cancers. However, vegetables species vary in their contents of nutrients. The objectives of this study were to measure the nutrient contents of indigenous vegetables collected from local sources and to investigate their potential nutritional contribution.

Forty samples of 36 species of indigenous vegetables were collected in 2001 from AVRDC plots, local markets, and home gardens in the southern Taiwan. Edible portions from 1-2 kg of raw materials were prepared for nutrient analyses by washing and cutting them into pieces, thoroughly mixing, following by oven-drying at 45 °C or freezing at –20 °C. Samples were analyzed for dry matter, crude fiber, sugar, vitamins A and C, calcium (Ca), and iron (Fe). Analytical methods of the Association of Official Analytical Chemists (AOAC) were used with some modifications. Nutrient values were compared among three categories of vegetables: 1) the tested indigenous vegetables; 2) the top 30 most popular vegetables in Taiwan (consumption survey conducted by AVRDC

Socio-economic Unit, 1999); and 3) about 100 kinds of vegetables listed in a food composition table published in Taiwan. Data of nutrient intake in Taiwan was referred to the Food Balance Sheet, Taiwan, 2000.

Nutrient values of the tested indigenous vegetables are listed in Table 101. The ranges of the values were wide due to various types of vegetables tested, including leaves of perennial trees, leaves of herbaceous plants, herbaceous stems, flowers and fruits. Chinese cedar contained the highest amount of protein, in part due to its high dry matter. Chinese boxthorn leaves, garden pea sprouts, and vegetable sponge flower buds had the highest protein density based on dry weight (data not shown). Vitamin C contents of the tested vegetables were mostly below 100 mg/100 g edible portion, with the exceptions of Chinese cedar and coffee senna, two vegetables reported to contain high vitamin C. The vitamin C contents of these two vegetables were outstanding in comparison to other vegetables and similar to that of chili pepper and moringa leaf. For beta-carotene, coffee senna had the highest value and equivalent to that of moringa leaflet. Ambrette, basil, Chinese boxthorn, and perilla were relatively high in beta-carotene, with their values exceeding that of carrot, a popular vegetable known to have high beta-carotene. Chinese knotweed showed the highest values of calcium and iron. Chinese boxthorn, peppermint, and saururus were also high in iron content. When average nutrient densities were compared in Figure 15, the sample set collected in this study was superior to a set of approximately 100 kinds of vegetables commonly consumed in Taiwan for beta-carotene and iron.

Generally, low nutrient contribution from vegetables in diets could be due to either low vegetable consumption or low nutrient density of consumed vegetables. For countries where micronutrient deficiency is a concern, the increased use of extremely high nutrient dense crops in diets is an effective way to improve micronutrient intakes. For example, biofortification with vegetables such as 10 g of dried Chinese knotweed and 27 g of cooked fresh coffee senna leaf could achieve 100% recommended daily allowance (RDA) for iron (15 mg/day) and vitamin A (1000 IU/day), respectively. In addition to their high nutrient densities, some indigenous vegetables can be easily adapted in stressful environments, grown using low amounts of inputs, grown less intensively, fit easily into farmers' production customs in certain areas, and benefit low income and/or malnourished groups. Before these indigenous vegetables are extended for wider use, however, their anti-nutrient factors and toxicity properties need to be examined.

The nutritional effect of increasing the number of vegetables in Taiwanese diets was also evaluated. The per capita vegetable supply in Taiwan is about 316 g/day and consists of over 100 vegetables. The three most popular vegetables are cabbage, bamboo shoot and sponge gourd. Then there is a group of eight slightly less popular vegetables: radish, leaf lettuce, kang kong, sweet potato leaves, pak-choi, spinach, Chinese cabbage and carrot (listed in order of consumption rate). These 11 vegetables contribute 50% of the vegetable supply in Taiwanese diets.

The nutritional effect of diversifying vegetables in the diet is shown in Figure 16. Vitamin A and iron contents were rather low if only the three most popular vegetables were consumed. The weighted average contents of these two nutrients increased significantly if the 11 most popular vegetables were consumed. But

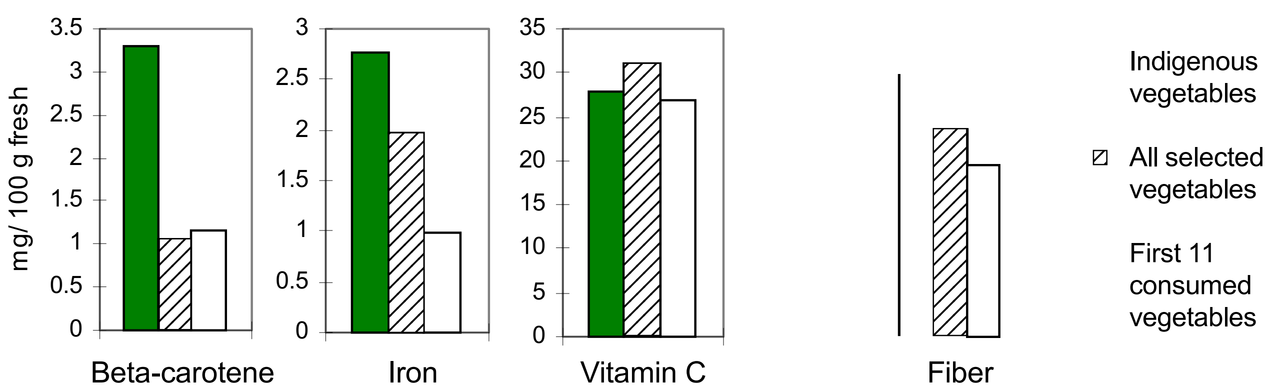

Figure 15. *Comparison of the average nutrient contents of indigenous vegetables, a group of approximately 100 vegetables consumed in Taiwan, and the 11 most consumed vegetables in Taiwan.*

Table 101. *Nutrient values[1] of indigenous vegetables collected in 2001.*

No.	English name	Dry matter (g)	Fiber (g)	Protein (mg)	Sugar (g)	Vitamin C (mg)	Beta-carotene (mg)	Ca (mg)	Fe (mg)
1	Ambrette	12.7	2.5	3.0	0.46	69	6.89	309	1.74
2	Basil	7.7	1.0	2.4	0.26	20	5.34	118	2.47
3	Betel-nut palm	10.6	1.2	2.3	2.83	17	0.02	26	0.75
4	Betel-nut palm flower	18.2	5.9	2.1	1.94	26	0.05	40	2.04
5	Chayote	4.5	0.4	0.5	2.65	5	<0.01	14	0.28
6	Chinese boxthorn	15.0	1.2	6.4	1.12	23	9.54	177	9.48
7	Chinese cedar	36.5	2.7	8.5	3.94	248	5.80	330	4.54
8	Chinese honeysuckle	31.6	15.4	2.1	1.43	13	0.52	196	10.71
9	Chinese knotweed	17.4	3.8	2.5	1.62	16	5.04	557	25.56
10	Chinese yam, purple	27.1	0.3	2.8	0.82	7	0.01	7	3.86
11	Chinese yam, white	20.7	0.3	3.0	0.66	4	0.01	2	1.51
12	Coffee senna	12.7	1.2	5.3	0.76	131	21.93	130	2.38
14	Common basella, green	6.2	0.6	1.7	0.53	49	4.33	90	1.47
15	Common basella, red	7.4	0.7	1.9	0.74	78	4.00	128	1.50
13	Common dayflower	7.7	1.4	1.8	0.50	19	2.79	113	3.44
16	Dasheen stalk	4.5	0.7	0.8	1.31	3	0.37	15	0.39
17	Duck's tongue grass	4.5	0.6	1.6	0.09	8	1.85	27	2.18
18	Feather celosia	6.3	0.8	2.1	0.36	2	2.50	62	1.47
19	Fennel	6.1	0.7	2.1	0.31	26	5.64	68	1.25
20	Fireweed	7.5	0.9	2.4	0.38	12	4.32	67	2.43
21	Garden pea sprout	4.9	0.6	2.7	0.82	13	0.86	3	0.63
22	Gynura, red	8.7	0.8	1.7	0.95	19	3.88	122	1.68
23	Gynura, white	5.8	0.7	1.3	0.26	11	1.33	85	0.82
24	Hyacinth bean, purple	13.0	1.7	2.7	3.78	13	0.15	30	1.37
25	Lotus stem	5.0	0.7	0.7	1.29	3	1.47	16	0.86
26	Madeira vine	5.3	0.4	1.4	0.29	10	4.33	136	1.30
27	Muskmelon	9.5	0.2	1.3	7.42	18	0.05	6	0.87
28	Ngai camphor plant	17.6	2.1	2.6	0.49	17	5.55	167	4.44
29	Oriental pickling melon	3.0	0.2	0.2	2.17	10	0.02	10	0.35
30	Peppermint	8.4	0.9	2.6	0.50	22	7.26	64	6.37
31	Perilla	11.1	1.3	3.5	0.64	34	10.06	123	2.53
32	Potherb fame flower	6.2	0.7	2.0	0.19	3	3.29	43	1.05
33	Purslane, red flower	4.0	0.5	1.3	0.14	5	2.95	47	1.07
34	Purslane, white flower	4.1	0.4	1.2	0.14	9	2.96	36	0.53
35	Purslane, yellow flower	4.9	0.7	1.4	0.26	13	1.16	35	1.66
36	Saururus	10.3	1.9	1.9	0.54	22	1.69	66	6.05
37	Serpent gourd	4.3	0.6	0.5	1.81	4	0.04	23	0.42
38	Sweet potato vine	9.0	1.3	2.5	0.57	19	3.13	55	1.14
39	Vegetable sponge flower bud	11.5	1.2	4.4	0.93	20	1.10	56	1.12
40	Wild balsam pear	5.7	1.0	0.7	0.44	75	0.33	11	0.43
	Range	3–37	0.2–15.4	0.2–8.5	0.1–7.4	2–248	0–22	3–630	0.1–2.3
	Mean	10.4	1.5	2.3	1.16	28	3.31	90	2.85
	SD	7.6	2.5	1.6	1.39	44	4.04	107	4.36

[1]Units based on a 100-g edible portion.

further diversifying the vegetable pattern did not significantly increase the average contents. In general, a large diversification of vegetables in diets did not affect the average nutrient density. This result implies that the nutritional function of broadly diversifying vegetables in Taiwanese diets is mainly for higher consumption rates, with only minor effect on nutrient density.

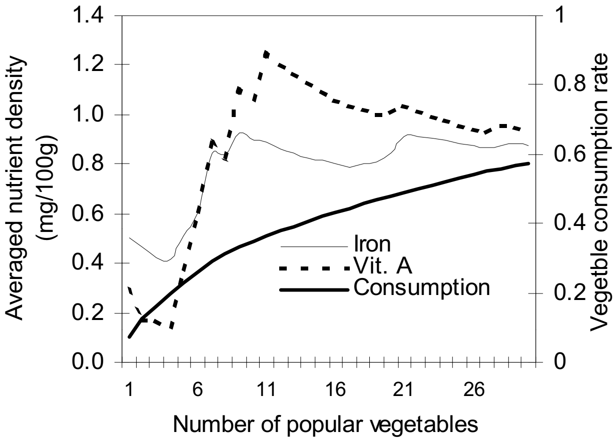

Figure 16. *Trends of the averaged nutrient contents and total consumption rate of 30 most popular vegetables in Taiwan.*

Daily nutrient supplies from current diets in Taiwan meet the recommended dietary allowances (RDA), except for iron. According to the Food Balance Sheet of Taiwan, major nutrients supplied from vegetables were vitamin A and C, which nearly reach 100% of RDA. However, vitamin intake higher than the RDA is recommended nowadays for health maintenance. The most consumed vegetables in Taiwan are low in vitamin A and iron content, whereas, the tested indigenous vegetables had the highest vitamin A, iron, and fiber contents on average (Figure 15). Therefore, increasing indigenous vegetable consumption would help enhance dietary nutrient intake, especially for iron. However, poor eating quality of indigenous vegetables due to high fiber content on average is a concern. Selection of indigenous vegetables with moderate fiber contents below 1.0 g/100 g would improve eating quality.

In this report, we first conclude that the most outstanding vegetables in nutrient contents are Chinese boxthorn for protein, Chinese cedar for vitamin C, Chinese knotweed for iron and coffee senna for beta-carotene. Secondly, consuming a selected group of nutrient-dense vegetables is an effective way to increase nutrient intakes in countries suffering micronutrient deficiencies. And thirdly, higher vegetable consumption and diversification will enhance phytochemical diversifications for health promotion. In this regard, incorporating indigenous vegetables into current diets is recommended to achieve both higher nutrient and phytochemical intakes.

Nutrient value, iron bioavailability and antioxidant activity of *Moringa* leaflets

Moringa oleifera is a perennial tree and widely grown in the tropics. Its foliage is consumed as a vegetable and various parts of the tree can be used for industrial oil, medicinal preparations, and water purification. Because of its multiple uses, the tree has tremendous economic potential.

This work was conducted in collaboration with the Olericulture Unit to evaluate the *Moringa* germplasm collected by the Genetic Resources and Seed Unit (GRSU) for nutrition values and antioxidant activity. The effect of cooking on in vitro iron bioavailability was also studied.

Seeds of eight *Moringa* accessions (seven of *M. oleifera* and one of *M. stenopetala*) were sown in Nov. 2000 and transplanted to the field in Apr. 2001. In addition to these eight accessions, a three-month old *Moringa* tree of African origin obtained from a local nursery was transplanted in the AVRDC field in June and a ten-year-old tree growing on the AVRDC campus were included in this study. One to two kg of leaflets from each tree were sampled in August and dried in an oven at 45 °C or frozen at -20 °C. Leaflets within samples were sorted as being either light green or dark green. Light green leaflets were still developing whereas dark green leaflets were fully developed yet not senescing. No senescing leaflets were included in the study. Dried leaflet samples were analyzed for moisture, protein, sugar and fiber, calcium and iron contents. Frozen leaflets were used for vitamin A and C analyses.

Extracts of fresh leaflets with water and methanol were stored at -80 °C for antioxidant analyses presented as anti-radical power (ARP, $1/IC_{50}$). IC_{50} represents the concentration of sample extract inhibiting a respective reaction by 50%. Materials for the iron bioavailability study were collected in April from the tree on the AVRDC campus. After harvest, leaflets were immediately stored at 4 °C and used within two days.

Ranges and means of nutrient contents of the seven *M. oleifera* accessions and the African and AVRDC *Moringa* trees are given in Table 102. *Moringa* leaflets were rich in protein, beta-carotene, vitamin C, calcium, and iron in comparison to nutrient dense vegetables such as peas (12 g protein), carrot (60 mg beta-carotene), chili pepper (150 mg vitamin C), and amaranth (330 mg calcium and 2-8 mg iron) on a 100-g edible portion

Table 102. Nutrient contents[1] of *Moringa* leaflets sampled at AVRDC, 2001.

Sample	Leaflet type	Dry matter (g)	Protein (g)	Fiber (g)	Sugar (g)	Vitamin C (mg)	Beta-carotene (mg)	Calcium (mg)	Iron (mg)
Accessions[2]	Mix of light and dark green	21.7±1.3 (20–23.8)	–[3]	1.94±0.30 (1.65–2.49)	2.30±0.27 (1.93–2.85)	166± 22 (145–202)	28.7±4.0 (24.8–34.3)	699± 70 (584–786)	3.44±0.8 (1.65–4.23)
African tree	Light green	22.6	–	1.83	2.68	275	20.4	282	2.66
	Dark green	21.0	–	1.95	1.93	187	25.0	688	4.23
AVRDC tree	Light green	24.3	9.2	1.38	4.64	363	12.6	124	4.87
	Dark green	24.3	8.0	1.30	3.11	348	18.2	730	8.76

[1]Based on 100-g fresh weight of edible portion.
[2]Accessions Mo01-04, Mo06-07, Mo17. The mean of the seven accessions with standard errors are presented in the upper line. The range of means for these accessions is presented in parentheses in the lower line.
[3]Not tested.

basis. Variations among the seven accessions in mentioned nutrients were limited except for iron as evidenced by the low ratios of maximum to minimum contents among the seven accessions, which were 1.35, 1.38, 1.39 and 2.56 for calcium, beta-carotene, vitamin C and iron, respectively. Although these accessions originated from diverse regions, a sample size of seven accessions is insufficient to make conclusions on genetic diversity of nutrients in *M. oleifera*.

Dark green, developed leaflets accumulated more beta-carotene, calcium and iron, whereas light green, developing leaflets contained more sugars. Iron contents of the older tree grown on the AVRDC campus was about two times higher than the other younger trees.

Mungbean, a staple food in South Asia, provides energy but its protein quality is rather poor due to the low contents of lysine, methionine and cystine. *Moringa* provides both high protein content and protein quality, and meets the estimated amino acid requirement pattern of protein for children of age 2 to 5. Previous studies have shown that compared to mungbean alone, a 4:1 mungbean:*Moringa* leaflet ratio doubles the amino acid score. A combination of mungbean and *Moringa* leaflets can improve protein quality. Mixing mungbean and *Moringa* in meal preparation is a traditional practice in places such as India, where *Moringa* is native. The knowledge of its benefits to nutrition should receive more scientific inquiry in the future.

Higher iron bioavailability for certain vegetables can be achieved through cooking. In this case, boiling raw and dried *Moringa* leaflets in water increased the in vitro iron bioavailability by 3.5 and 3 times, respectively (Figure 17).

Anti-radical power of *Moringa* leaflets was evaluated with three types of free radicals: O_2^- (superoxide), DPPH (1,1-diphenyl-2-picrylhydrazl), and ABTS (2,2'-azinobis 3-ethylbenzothia). Compared to 110 kinds of vegetables reported in previous reports, the ARP of *M. oleifera* of African origin and *M. stenopetala* (Accession Mo28) ranked in the top five vegetables. The averaged ARP of all the *Moringa* accessions for the three radicals ranked within the top ten vegetables. The water extractable portion of *Moringa* leaflets exhibited higher ARP than methanol portions (data not shown). Younger, light green leaflets showed higher ARP for ABTS and DPPH radicals (Figure 18) whereas mature, dark green leaflets exerted higher superoxide scavenging (SOS) activity.

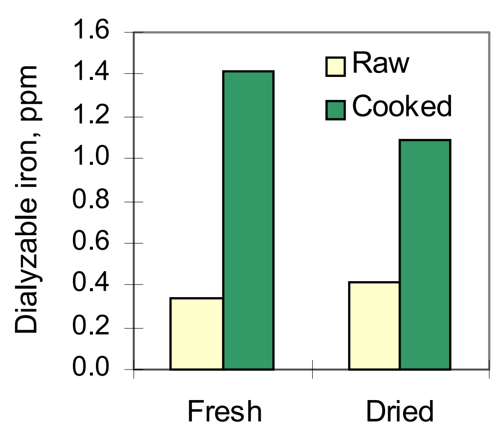

Figure 17. *In vitro iron bioavailability of raw and cooked* Moringa *leaflets.*

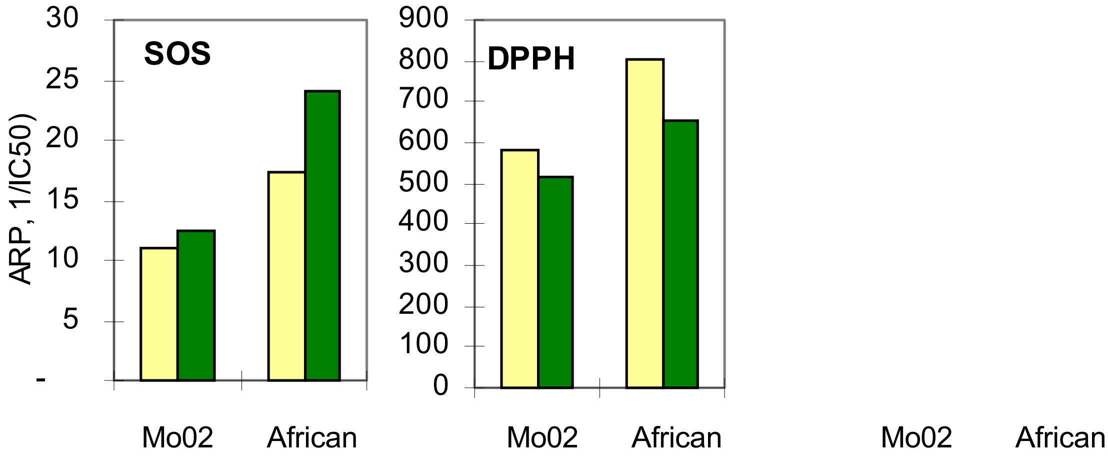

Figure 18. *Comparison of anti-radical power (ARP) of light green, developing leaflets versus dark green, fully developed leaflets of* Moringa *accessions. SOS = superoxide scavenging, DPPH = (1,1-diphenyl-2-picrylhydrazl), and ABTS = (2,2'-azinobis 3-ethylbenzothia).*

In conclusion, we report that: 1) genetic differences for nutrient contents of the accessions in the study were not significant; 2) fully developed leaflets were more nutritious, however, developing leaflets exerted higher antioxidant activity; 3) leaflets from the older tree were richer in iron; 4) higher iron bioavailability of raw and dried leaflets can be achieved through cooking; and (5) protein quality of mungbean meals can be improved by adding *Moringa* leaflets.

Seedling establishment and growth potential of young Moringa *spp. plants*

Groups of *Moringa* spp. seeds were sown to develop seedling establishment methods and to evaluate growth potential of different accessions. Group 1 consisted of 26 *M. oleifera* accessions (23 from Thailand, and one each from Luzon Island of the Philippines, Virgin Islands of the USA, and AVRDC). Seeds were sown on 12 Apr. 2001 using a standard seed germination procedure (seeds placed between rolled paper towels which are stood upright in a water-fed tank). Seeds rotted and germination was poor using this technique.

Group 2 consisted of three accessions from the Virgin Islands. Seeds were sown on 22 June in pots containing a standard medium for seedlings. Germination was excellent, up to 95%. A large-leaved *M. stenopetala* produced 13 seedlings out of 17 seeds, whereas the other four seedlings were albino and died by the 5-true-leaf stage. This seedling establishment method was judged to be reasonable, but only cost-effective for high quality seeds.

Group 3 consisted of four accessions. Seeds were first sorted by their health and sown on 13 Sept. 2001. Healthy seeds were directly sown in pots. Weak seeds were sown in peat moss trays and those seedlings that germinated were transplanted to pots before developing true leaves. Among the accessions, one purchased in an Indian market failed to germinate. A large-seeded *M. peregrina* provided by the World Church Service produced 10 seedlings out of 11 seeds. The seedlings of this *M. peregrina*, however, grew slowly and their stems were easily broken.

Group 4 consisted of three accessions and a duplicated accession from another group. Seeds were sown on 21 Nov. 2001. Even though they were nursed under greenhouse conditions, all accessions were slow to germinate due to low temperature.

Moringa was found to grow fast, especially under warm conditions. Grown in pots in a tunnel plastic nethouse, Group 1 seedlings grew an average of 50 cm in one month, 100 cm in two months, and 200 cm in three months. Accession Mo02, introduced from the Virgin Islands, was most vigorous. It grew 245 cm by 9 July (88 days after sowing), and 305 cm 10 days later. On average, seedlings of Group 2 also grew nearly 50 cm within one month, nearly 100 cm in two months, but then reached only 150 cm within three months due to the continuous rainy days and declining temperatures (Table 103). Accession Mo2 was the most vigorous plant among this group, too.

M. oleifera seedlings of Group 3 grew only 30 cm after one month and 60 cm after two months, due to declining temperatures. *M. peregrina* grew only 10 cm after one month and less than 15 cm after two months, thereafter stunting.

A total of 147 selected *Moringa* seedlings grown in pots in the greenhouse were cut to 50 cm one week prior to transplanting to the field for seed multiplication. Each plant yielded 3–20 g of young tips, 15–95 g of young leaves, and 7–55 g of matured leaves. The large variation depended on accession and growth status.

According to pot cultivation in tunnel plastic nethouse, results from preliminary observation and harvest data showed seven *M. oleifera* accessions, namely Mo01, Mo02, Mo07, Mo08, Mo09, Mo16, and Mo17, growing up to 200 cm height within 100 days after sowing. They have potential for use as a leafy vegetable. Accessions Mo03 and Mo07 blossomed early (77 days and 83 days after sowing, respectively) and they have potential for young pod production.

Survey of viral diseases on indigenous vegetables at AVRDC

This year in conjunction with the Indigenous Vegetable Project, experimental plots of indigenous vegetables grown at AVRDC were monitored for the presence of viruses.

Five indigenous vegetable genera, namely *Amaranthus* (76 lines), *Corchorus* (36 lines), *Ipomoea* (24 lines), *Basella* (40 lines) and *Abelmoschus esculentus* (2 lines) were surveyed. Virus-like symptoms were only observed in *Basella* and *Amaranthus*. Symptomatic plants were collected and inoculated to two common virus indicator plants, i.e., *Nicotiana benthamiana* and *Chenopodium* sp. They were then tested by electron microscopy for presence of virus particles and later by serology using double antibody sandwich enzyme-linked immunosorbent assay (DAS ELISA) and immunoelectron microscopy (IEM). For ELISA, a potyvirus specific– monoclonal antibody and antisera against the following common viruses were used: cucumber mosaic virus (CMV), chili veinal mottle virus (ChiVMV), turnip mosaic virus (TuMV), tomato mosaic virus (ToMV), soybean mosaic virus (SMV) and broadbean wilt virus (BBWV). For IEM, an additional 13 antisera were used, i.e., bean common mosaic virus (BCMV), watermelon mosaic virus-2 (WMMV-2), zucchini yellow mosaic virus (ZYMV), bean yellow mosaic virus (BYMV), tobacco etch virus (TEV) potato virus Y (PVY), celery mosaic virus, lettuce mosaic virus, clover yellow vein virus, peanut mottle virus, cowpea aphid borne mosaic virus, tobacco vein banding mosaic virus, and sweet potato latent virus.

Two distinct viruses, i.e., BBWV-2 (a newly recorded finding for Taiwan) and an unknown potyvirus (detected by ELISA with the potyvirus specific monoclonal antibody) were found to infect *Basella*. BBWV-2 was detected on 10% of the surveyed *Basella* and on 30% of the surveyed *Amaranthus* plants in the AVRDC fields. In IEM this potyvirus produced a medium-strong decoration with yam mosaic virus and a weak decoration with soybean mosaic virus. No decoration was obtained with the other 12 potyvirus antisera listed above.

The literature was reviewed for viruses occurring on 30 families of common indigenous vegetables. The review included the main Taiwan, Korean and Japanese Plant Disease records as well as the Virus Identification Data Exchange (VIDE) database. A total

Table 103. *Leaf number and plant height[1] of* Moringa *spp. sown 22 June 2001, potted 19 July and grown under greenhouse conditions.*

			Days after sowing								
Acc.	Species	Character	10	20	30	40	50	60	70	80	90
Mo2	*M. oleifera*	Leaf number	4	7	9	12	15	18	20	22	25
		Plant height (cm)	12	34	60	76	86	112	130	154	166
Mo27	*M. oleifera*	Leaf number	3	6	8	11	15	20	23	26	29
		Plant height (cm)	8	23	39	51	64	92	116	140	154
Mo28	*M. stenopetala*	Leaf number	5	9	12	16	18	22	25	28	31
		Plant height (cm)	15	31	44	54	59	71	83	100	108

[1]Mean of 10 sample plants.

of 267 virus citations were found. Thirty-eight percent of these consisted of the following six viruses: CMV, TuMV, cucumber green mottle mosaic virus (CGMMV), WMMV, WMMV-1 and ZYMV.

Post-entry inspection for diseases and insect pests

Viral diseases

Legumes are known to be infected with a number of seed-transmitted viruses. Forty lines of three legume species, *Phaseolus lunatus*, *Cajanus cajan* and *Lablab* sp., were monitored visually for the presence of seed-transmitted viruses. Three plants, two *Lablab* sp. and one *Phaseolus lunatus*, among 960 plants showed virus-like symptoms and were discarded.

Five indigenous vegetable species were grown in the field. For *Basella* spp., virus symptoms were observed in nine of 64 lines and 28 of 2560 plants overall. For *Ipomoea* spp., symptoms were observed on only one of 44 lines (1760 plants overall). For *Amaranthus* spp., symptoms were found on five of 76 lines and six of 3040 plants overall. No virus symptoms were found on *Corchorus olitorius* or *Abelmoschus esculentus*. Further examination by electronmicroscopy and immuno electronmicroscopy (ELISA) indicated the presence of two viruses affecting the *Bas*ella spp., namely broad bean wilt virus and a potyvirus. We are now attempting to bring the two viruses in pure culture in a suitable plant host.

Fungal diseases

The following fungal diseases were identified on indigenous vegetables: on malabar spinach, cercospora leaf spot caused by *Cercospora beticola*; on okra, powdery mildew caused by *Sphaerotheca fusca*; on rice bean, southern blight caused by *Sclerotium rolfsii*; on pet-sai, damping-off caused by *Rhizoctonia solani* and alternaria leaf spot caused by *Alternaria brassicae*; on kangkong, cercospora leaf spot caused by *Pseudocercosporella ipomoeae* and white rust caused by *Albugo ipomoeae-pandura*; and on amaranth, white rust caused by *Albugo bliti*. The incidence of cercospora leaf spot of Malabar spinach and powdery mildew of okra was especially high.

Bacterial diseases

Bacterial diseases reported in Taiwan were checked for 123 species of indigenous vegetables. Among them, records of reported bacterial diseases were found for 23 species. The common pathogens include *Xanthomonas campestris* pv.*campestris* (black rot), *Erwinia carotovora* subsp. *carotovora* and *Erwinia chrysanthemi* (both cause soft rot), and *Pseudomonas (Ralstonia) solanacearum* (bacterial wilt). An inspection procedure has been designed. A total of 195 accessions (32 species) was inspected at their seedling stage among the 58 species, which will be regenerated in Autumn 2001. No bacterial diseases were found.

Insect pests

The following pests were observed on indigenous vegetables: armyworm (*Spodoptera litura*), spinach moth (*Hymenia recurvalis*), and numerous species of spider mites, leaf miners, and aphids.

Indigenous vegetable database

A database system on indigenous vegetables was developed. The purpose of the system is to link all information on indigenous vegetables collected or generated by AVRDC. The target users are researchers and extension workers. The information in the database includes vegetable name and description, origin, geographic distribution, uses, nutritional properties, recipes, references, and evaluation results. The database also includes agronomic information such as cropping patterns, seed production, propagation, favorable soil, optimum temperature, major diseases, and crop photos. The system links with the AVRDC Genetic Resources and Seed Unit's genebank information and the AVRDC Library's literature on indigenous vegetables.

Increasing public awareness

AVRDC received 1051 visitors, consisting of 646 from Taiwan, 237 from China, and 168 from other nations. AVRDC also helped arrange side-trips to introduce international visitors to small-scale farming and intensive crop production systems in Taiwan.

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 2001 was the *AVRDC Report 2000*, which reported the research and development activities of the Center for that year. The report also featured a comprehensive summary of AVRDC activities in Bangladesh for several years. Another major publication was the *Report of the Sixth External Program and Management Review of the Asian Vegetable Research and Development Center.* The booklet, *Toward a Healthy Future: AVRDC in the New Decade*, 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 strategic program direction of AVRDC.

Two technical bulletins were published: 1) *Vegetables in Bangladesh: Economic and Nutritional Impact of New Varieties and Technologies;* and 2) *Urban and Peri-Urban Agriculture in Metro Manila: Resources and Opportunities for Food Production.*

Numerous scientific findings were published in refereed scientific journals. Topics of these reports included gene action and heritability of high temperature fruit-set in tomato, the presence of chili veinal mottle virus in *Solanum aethiopicum* in Tanzania; molecular characterization of tomato leaf curl virus and ageratum yellow vein begomovirus; and storage variability among short-day onion cultivars under hot, humid conditions.

The following International Cooperators' Guides were published: *Summer Tomato Production Using Fruit-Setting Hormones*, *Hybrid Seed Production in Tomato*, and *Seed Production of Open-Pollinated Tomato Lines*. Numerous publications were written in 2001 for future publication. These include *Suggested Cultural Practices for Kangkong; Suggested Cultural Practices for Basella; Suggested Cultural Practices for Vegetable Amaranth; Suggested Cultural Practices for Eggplant; Suggested Cultural Practices for Onion;* and C*ontrolling Eggplant Fruit and Shoot Borer: A Simple, Safe and Economical Approach; Rain Shelters for Tomato Production in the Hot-Wet Season;* and *Grafting Tomatoes for Production in the Hot-Wet Season*.

In support of the peri-urban project in Manila, *Supporting Farmers towards Safe Year-round Vegetable in Manila* was written and published in an international urban agriculture magazine. A poster on controlling major pests of pak-choi was published.

Other publications included the proceedings of the final workshop of the South Asia Vegetable Research Network Phase II and a policy paper on productivity resource degradation in Pakistan's Punjab. All AVRDC publications in 2001 are listed at the end of this Annual Report.

The AVRDC international newsletter *Centerpoin*t was published four times. An evaluation of *Centerpoint* was also conducted. Users enjoyed the format of the document, requested for more research information, and especially enjoyed learning of germplasm releases, new publications, and regional activities. Nearly all *Centerpoint* readers had access to the internet and e-mail.

The Office of Publications and Communications mailed 17,502 publications in 2001. The Center's mailing list now contains 1,655 entries, including 606 libraries in 169 countries. The office printed more than a quarter of a million pages and handled more than 200 art requests from Center scientists. About 10,000 photos were shot and processed.

AVRDC web site

More than 35,000 domain addresses (organizations or persons) from 123 countries accessed the AVRDC web site, <www.avrdc.org.tw>. This represents a 72% increase in the number of users of the site. The numbers of users from developing countries increased approximately 100% from the previous year, a reflection of the greater access that persons in developing countries have to the internet.

Users were most interested in accessing educational and other resources from the web site. Users downloaded over 13,000 educational documents; these persons received these educational documents instantly and without need of paying postage. Numerous new educational documents on vegetable production were placed into the AVRDC on-line Learning Center.

Centerpoint was placed on-line in 2001, increasing readership of *Centerpoint* by over 300%.

Collecting and sharing tropical vegetable information

This subproject is handled by the Center's library. In 2001, the library acquired over 500 new books and over 340 serial publications. Subscriptions to 99 journals were renewed.

The library updated the Center's bibliographic databases to facilitate information storage and retrieval. A total of 87 books, 481 crop documents, and 29 new serial titles were indexed and added to the library database; this database now hold 38,235 bibliographic records and 3,840 journal records. A total of 219 journal issues were bound; this hard-copy collection of journals now totals 15,165 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 2001. Nine issues of SDI bulletins and two issues of recent AVRDC Library acquisitions were established on the library web site in 2001. A total of 487 users from 31 countries accessed the SDI services via the internet.

Library staff conducted 16 literature searches of CD-ROM databases and Tropical Vegetable Information Services databases for internal and external users. A total of 975 documents were photocopied and delivered to 74 users in 68 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 2001, 89 scholars from 20 countries received training in vegetable research and development at AVRDC headquarters in Taiwan. A complete list of trainees can be found in the back.

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 97% 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 3.51, the quality of their instruction from trainers at 3.92, and the assistance from the Communications and Training Office at 4.05.

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 2001. The following information is provided, in detail, to highlight the immediate impact of AVRDC training programs:

Nguyen Kim Chien, scientist from the Research Institute of Fruit and Vegetables in Hanoi, received training on the biological control of insect pests. His research focused on studying factors that attract eggplant fruit and shoot borer (EFSB) to eggplant crops. EFSB is the most serious pest on eggplant in the region and many farmers spray their crops 50 or more times during the season to control the pest. Mr. Nguyen's research activities assisted in the development of techniques that will safely control EFSB with minimal pesticide use. His research contributed to two publications in scientific journals, a new AVRDC International Cooperators' Guide on safely controlling EFSB, and a published brochure for farmers. He is currently a key resource person in a project entitled 'Sustainable Development of Peri-urban Agriculture in Southeast Asia—Cambodia, Lao, Vietnam' (SUSPER). This project is a collaborative project of AVRDC and several agencies and is sponsored by the French Ministry of Agriculture.

Vu Thanh Hai, faculty member of Hanoi Agricultural University, received training on vegetable production technologies for the hot-wet season. Tomato and pepper crops can be severely damaged from soil diseases and flooding during the off-season. The grafting of tomato and pepper seedlings onto disease-resistant rootstocks or flood-tolerant eggplant rootstocks can lead to significantly higher yields. Mr. Vu's research has contributed to the development of new training materials and an AVRDC International Cooperators' Guide on grafting to be published in the future. Mr. Vu has already conducted training in these technologies to faculty and students of Hanoi Agriculture University and to other scientists, farmers, and nurseries in the Hanoi region.

Nguyen Ngoc Tri, faculty member of University of Agriculture and Forestry in Ho Chi Minh City, received training in biotechnology. His training focused on the molecular characterization and genetic diversity of *Vigna* species using random amplified polymorphic (RAPD) DNA. RAPD analysis is the simplest and fastest of DNA-based techniques to study genetic diversity and compatibility among plant species. Among the direct applications of Mr. Nguyen's training is the development of molecular tools that can rapidly evaluate breeding lines for mungbean yellow mosaic virus, which is a devastating disease throughout Asia. Mr. Nguyen is currently assisting his university in establishing a biotechnology center for utilizing polymerase chain reaction, plant transformation, molecular markers, and other applied biotechnology tools.

An Vannak, researcher from Kbal Koh Vegetable Research Station in Cambodia, received intensive training on identifying vegetable diseases and evaluating genetic lines for disease resistance. He studied screening techniques for all major fungal, bacterial and viral diseases of vegetables in the region. Furthermore, Mr. Vannak was trained in the propagation and long-term storage of fungi for future pathological studies, as well as the evaluation of seed treatment technologies for pepper. Upon returning to Cambodia, one of his first projects was evaluating the stability of eggplant lines for bacterial wilt resistance.

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 4.50. Similarly, the quality of their training from their instructors was rated at 4.00; the assistance from the Communications and Training Office was rated at 4.50; and the research facilities were rated at 4.25. All four students stated that they would recommend this training program to their colleagues and all students stated that they would like to continue their training at AVRDC if given the opportunity in the future.

Four new scholars, two from Vietnam and one each from Cambodia and Laos, were awarded scholarships for training at AVRDC headquarters during 2001 for 2002. One trainee each from Laos and Myanmar were awarded similar scholarships for training at AVRDC-Asian Regional Center.

Research internships and visiting scientists

Twenty-one additional researchers from 6 countries completed research internships. 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.

Dr. Manuel Palada, a visiting scientist from the Virgin Islands, USA, completed a sabbatical on off-season vegetable production. He supervised research activities related to off-season tomato production and the evaluation of leafy vegetable lines. He wrote publications and developed training materials on off-season tomato production, and suggested cultural practices for kangkong, vegetable amaranth and *Basella*.

A research scholar from Japan undertook extensive training on vegetable breeding and seed production for developing countries. Visiting scientists from Denmark learned of marketing systems in Taiwan, a scientist from Hungary studied pepper breeding practices, and a group of scientists from the Cambodian Agricultural Research and Development Institute learned of activities at AVRDC.

Graduate degree-oriented training

AVRDC collaborated with National Pingtung University of Science and Technology (NPUST), University of Hannover, University of Bonn, Technical University of Munich (TUM), and Kasetsart University in Thailand to make its facilities and expertise available to graduate students conducting thesis research on tropical vegetables.

In 2001, nine graduate students studied at AVRDC under this program. Among the NPUST scholars, students from Macedonia, Senegal, Solomon Islands, and Swaziland studied integrated pest management topics, and a student from Dominica received training in socio-economic impact analysis. A graduate student from the University of Hannover also received training in socio-economics during 2001.

A Vietnamese scholar from the University of Bonn received training related to the control of *Pythium* during off-season tomato production. A German graduate student from TUM received training in biological control of tropical crucifer insects. A Thai graduate student from Katsetsart University studied the control of bruchids in the storage of legume seeds.

Summer program for undergraduates

For the 27th consecutive year, AVRDC hosted undergraduate students from universities in Taiwan. Thirty-eight students from 11 universities were trained in 2001. This is the highest number in the history of the Center. 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. All students received training in the English language. This training provided a valuable experience to students who are deciding their futures in agricultural science.

Five students from the University of the Philippines at Los Baños came to AVRDC for training in statistical design and analysis. Undergraduate students from France and Japan conducted research studies on indigenous vegetables.

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 18 publications on crop and seed production, 51 fact sheets on managing vegetable disorders, and 45 fact sheets on managing vegetable pests. Twelve computer-based tutorials were developed on major vegetable production topics. Responses from users have been very positive. The site is located at <www. avrdc.org.tw/LC/home.html>.

English language training

Twenty-five international trainees, 20 AVRDC staff, and 47 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 13,000 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 twenty slide sets, 10 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 eight public institutions in 2001. 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 (PT4723 and PT4727), 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), vegetable soybean line (Kaohsiung Selection No. 1), and mungbean line (Tainan No. 5). In total, 1812 kg of seeds were produced and distributed.

Contract research projects

In 2001, AVRDC was granted with 23 contract research projects from the Council of Agriculture, and three from the National Science Council of the host country in a total of US$1.57 million. In addition, AVRDC tomato and pepper units implemented two research contracts with Kagome Co. 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.

Project Coordinator: G Kuo

Manila peri-urban agriculture project

Asian cities, such as Manila, face an enormous challenge to remedy micronutrient deficiencies in diets of the poor, to recycle solid wastes, and reverse environmental degradation. The AVRDC peri-urban vegetable project in the Philippines, sponsored by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), is designed to: stabilize the supply of safe and nutritious vegetables to metropolitan areas; and to develop an approach for information acquisition, testing and dissemination suitable to peri-urban areas in Asia.

Project Coordinator: JR Burleigh

Socio-economic studies

Consumer preference of pak-choi cultivars

When selecting a variety, farmers prefer to grow one for which consumers will pay higher prices. High yielding accessions of pak-choi have been identified after four years of trials at Central Luzon State University (CLSU). Two of these accessions were rated by seven qualified panelists from CLSU on color and shape of leaves; color, size and number of stalks; and general acceptability to determine which of these features are discernable by consumers. Results showed that leaf color, stalk color and leaf shape were the most visually discernable features. Three potentially high-yielding accessions were subsequently evaluated by 50 consumers in Los Baños, Laguna to determine preference based on these features. The native cultivar, Black Behi, was the most preferred followed by Bp21, Bp03, and Bp29 (Table 104). Bp21 was judged as being "liked very much" and therefore may be acceptable in the market.

Table 104. *Consumer ratings[1] of selected characteristics of pak-choi accessions in Laguna, Philippines.*

	Accessions[2]			
Characteristics	Black Behi	Bp 21	Bp 03	Bp 29
Leaf color	1.90	2.66	3.02	3.58
Leaf shape	2.08	2.72	3.16	3.54
Stalk color	2.08	2.72	2.94	3.70
General acceptability	2.08	2.72	3.10	3.35

[1]Ratings: like extremely = 1.00-1.88; like very much = 1.89-2.77; like moderately = 2.78-3.66; like slightly = 3.67-4.55.

[2]Chi-square values are highly significant.

Technology adoption after training in Farmer Field Schools

Interviews were conducted with 30 persons who attended Farmer Field Schools (FFS) on pak-choi production. Trainees were from *Barangay* (community) Mallorca which is located in the Municipality of San Leonardo, Nueva Ecija Province; Barangays Hornalan and Bunggo in the Municipality of Calamba, Laguna Province; and Barangay Cale in the City of Tanauan, Batangas Province. They received training in monitoring for pests systematically from crop emergence to harvest, fertilizing with organic materials, using raised beds, excluding insects through the use of net tunnels, and sowing in lines. Trainees listed those practices that they used before and after training, and reasons for use and non-use.

Depending on practice, there was a 23 to 47% increase in number of farmers using a practice after receiving training in the FFS (Table 105). Dramatic increases were noted in the use of raised beds, use of net tunnels for insect control, and sowing in lines. These practices were rarely, if ever used before the FFS. Organic fertilizer was used by 15 (50%) participants before FFS, but an additional seven farmers adopted the practice after. Even pest monitoring showed an increase in adoption as farmers noted that monitoring reduced labor and pesticide expenses.

Table 105. *Number of farmers using improved practices for pak-choi production before and after training in Farmer Field Schools (FFS).*

		No. farmers using practice		
Practice	No. farmers in FFS	Before FFS	After FFS	Percent increase
Pest monitoring	30	8	20	40
Organic fertilizer	30	15	22	23
Raised beds	30	1	15	47
Net tunnels	30	0	12	40
Sowing in lines	30	1	12	37

Farmers noted that good quality pak-choi was produced under net tunnels, which had been provided to farmers at no charge for testing. Farmers who grew crops under nets used less pesticide and pak-choi leaves were relatively free of surface debris. The 13 farmers who did not adopt net tunnels expressed interest if credit were provided to purchase netting.

The labor needed to raise beds was considered excessive by 33% of the participants, but 67% adopted the practice because they noted an improvement in drainage. Almost 75% of farmers used organic fertilizer. They understood that organic matter supplies plant nutrients, improves soil structure, and reduces inorganic fertilizer costs.

Socio-economic survey of farmers from new provinces

From the expansion provinces, Quezon, Laguna, and Batangas, the project randomly selected 160 farmers to serve as respondents to questions on age, household size, education, years in farming, land tenure status, production practices, labor utilization, and gender roles. These factors were used to construct regression models with yield and income as dependent variables.

Farmer income and employment from pak-choi. The project calculated net income and labor for: 1) farmers who cultivated five consecutive crops of pak-choi followed by two crops of rice, and 2) those that cultivated two crops of rice with each crop followed by a fallow period. Farmers in Group 1 had a mean net income of 220,136 PHP/ha, whereas those in Group 2 earned 40,219 PHP/ha. That is, a pak-choi/rice farmer had a net income fivefold greater than a farmer who grew rice only.

Although the difference in net income is dramatic, the sustainability of the pak-choi-based system is questionable. The rice-only farmer includes two periods of fallow in his rotation, whereas the pak-choi/rice farmer does not. Furthermore, the net income for the pak-choi/rice system is based on five consecutive crops of pak-choi and given the uncertainty of rainfall, and damage from pests and diseases, the probability of five successful crops may be low and the income calculation somewhat inflated.

Gender roles in pak-choi/rice and rice-only farming systems. In both the pak-choi/rice and rice-only systems, males prepared the land, seeded the crop, applied fertilizer, sprayed pesticides, irrigated, harvested, and threshed rice. In contrast, women did most of the transplanting of rice and pak-choi. And women did most of the weeding in pak-choi. That is, when equipment was used, men were the operators, but when hand labor was employed, it was the women and sometimes children who were drafted into the labor force.

Factors affecting yield and income/ha from pak-choi. A linear regression analysis showed that farming experience, amount of nitrogen fertilizer used, and time spent in transplanting significantly influenced yield and explained 72% of the variation in yield of pak-choi. With regard to variation in income, the cost of chemicals used in production; cost of labor for fertilizer application, spraying, weeding and watering; and cost for fuel, irrigation fees, plastic bags, and transportation explained 67% of the variation in income (Table 106).

Table 106. *Significant variables associated with yield of pak-choi and farm income.*

Dependent variable	Regression coefficients	t-value	Probability	R^2
Yield	$0.22X_1$ [1]	4	0.001	
	$0.17X_2$	3	0.012	
	$0.20X_3$	2	0.035	0.72
Income	$0.30X_1$ [2]	4	0.002	
	$0.79X_2$	4	0.003	
	$-0.28X_3$	2	0.032	0.67

[1] X_1 is years in vegetable farming; X_2 is amount (kg/ha) of nitrogen fertilizer; X_3 is hours for transplanting.
[2] X_1 is cost of chemicals; X_2 is cost of labor for fertilizer application, spraying, weeding, and watering; X_3 is cost for fuel for irrigation pumps, as well as irrigation fees, plastic bags, and transportation.

Regression implies cause and effect. A positive yield response from farming experience, N fertilizer, and time spent transplanting is reasonable. However, the positive signs for cost of chemicals and cost of labor probably reflect an indirect effect of those variables on income; that is, cost reflects quantity used and quantity used affects production and therefore, income. A similar argument can be used to explain the positive sign for the variable, labor cost, which reflects time spent to apply fertilizer, spray, weed and irrigate.

Income and job creation generated by post-harvest vegetable activities

Vegetable production generates business in the input and output markets. Vegetable production requires more inputs (labor, fertilizer, chemicals, funds) than rice, and increases agribusiness activities of suppliers and creditors. On the other hand, the bulkiness and perishability of vegetables require that market traders use appropriate postharvest facilities and practices in handling the commodities until they reach the consumer. It is well understood, therefore, that an increase in vegetable production will impact businesses beyond the production sites.

Data presented below show current income and employment among input suppliers (n = 28) and vegetable traders (n = 130), and projected values based on assumed increases in hectarage planted to pak-choi in three provinces of Southern Luzon: Quezon, Laguna, and Batangas. Using a questionnaire, the data gathered included the traders' socio-demographic and business profile, and trading operations. Marketing margin was likewise calculated. Changes in traders' incomes and labor hired by them as a result of extensive cultivation in the area were determined.

It is assumed that by increasing hectarage planted to pak-choi, inputs, income and employment will increase proportionately and that there would be sufficient market demand for the increased production (Table 107). Thus, input suppliers will increase the number of employees from 22 based on the current number of hectares devoted to vegetables to 26 and 44 with increases to 600 ha and 1000 ha, respectively.

Table 107. *Input volumes, income, and employment of distributors and dealers based on existing and projected operations for vegetable production, May–June 2001.*

Input suppliers	Current operations (500 ha)	Projected operations (600 ha)	(1000 ha)
Distributor			
Volume procured			
Seeds (kg)	968	1,162	1,936
Fertilizers (bags)	3,382	4,058	6,764
Chemicals (liters)	3,805	4,566	7,580
Chemicals (kg)	1,302	1,563	2,605
Income (PHP)[1]	38,590	42,618	59,094
Employment (persons)	17	20	34
Dealer			
Volume procured			
Seeds (kg)	1,452	1,742	2,904
Fertilizers (bags)	318	382	636
Chemicals (liters)	11	14	23
Chemicals (kg)	3	3	5
Income (PHP)[1]	12,709	14,788	23,443
Employment (persons)	5	6	10

[1]PHP = Philippine peso. 50 PHP = 1 US dollar.

Accordingly, income would increase from 51,299 PHP to 57,406 and 82,537 per production cycle for 600 and 1000 ha, respectively (50 PHP = 1 USD). These figures are projections but suggest that by increasing the area growing pak-choi, both income and employment among input suppliers will increase over that associated with rice cultivation.

Table 108 shows pak-choi volume handled and net income during one month (one crop cycle) among a sample of 130 vegetable traders in Southern Tagalog provinces and in Manila. These traders handled 1.22 Mil kg of pak-choi and earned a net income of 3.97 Mil PHP. Figures on total volume produced during this period were not available. These traders employed 559 persons to perform all postharvest activities associated with pak-choi and other vegetables. That is, an employee sorts and packages all vegetables procured, not just pak-choi. The division of labor of an employee among several vegetable species is not known.

Soil and crop nutrition

Composted household waste as fertilizer

Results from previous studies showed that pak-choi yields were unchanged when half the nitrogen requirement came from composted household organic waste, rather than from inorganic fertilizers. The present effort was designed to demonstrate to farmers the effectiveness of composted household waste as a supplement to their usual fertilizer practice of relying solely on inorganic fertilizers.

Replicated trials with two treatments were established on 14 farms in nine barangays in Central and Southern Luzon. Treatment one (T_1) was the farm fertilizer practice, and treatment two (T_2) was an introduced fertilizer practice based on available N, available P and exchangeable K (Table 109). Experimental plots were raised beds, 20 cm in height and 2 x 10 m in size. Both treatments were seeded in lines and beds were covered with screen netting to prevent ingress of insect pests. Nitrogen was applied to T_1 plots at the time of seeding according to the farm practice. Composted household waste and inorganic fertilizer (14N–6P–11.6K) were applied to T_2 plots during land preparation. In addition, urea (46N–0P–0K) was applied to T_2 plots 10 and 21 days after seeding.

Two crops of pak-choi were seeded on each farm. In Central Luzon, crop 1 was seeded on seven farms

Table 108. *One month volume and net income of 130 pak-choi traders in Southern Tagalog and Manila during May–June, 2001.*

Vegetable traders	Traders interviewed	Pak-choi handled (kg)		Net income (PHP[1] x 1000)	
		Average	Total	Average	Total
Assembler-Wholesaler	42	20, 552	863, 163	48.4	2,034
Wholesaler-Retailer	22	15,754	346,588	83.5	1,837
Retailer	66	171	11,286	1.5	100
Total	130		1,221,037		3,971

[1]PHP = Philippine peso. 50 PHP = 1 US dollar.

between June and Aug. 2001; crop 2 was seeded between Oct. and Nov. 2001. In Southern Luzon, crop 1 was seeded on seven farms between July and August 2001; crop 2 was seeded between Nov. 2001 and Jan. 2002. Yield data from each location/crop combination were subjected to analysis of variance (ANOVA) to determine treatment effects. Yield for Barangay Mallorca is an average of four farms and that for Barangay Castellano, of three farms. Farms within barangays used the same fertilizer practice (T_1) and received the same combination of inorganic and organic fertilizer in the introduced practice (T_2).

In Central Luzon, there was no treatment effect on marketable yield of pak-choi in either crop (season). During the hot-wet season in Southern Luzon, there was no treatment effect except at the Barangay Kiling location in which T1 yield was significantly greater than that from T2. During the hot-dry season in Southern Luzon, yields were significantly greater from T2 in Barangays St. Tomas and Balele, but there was no treatment effect in the other five barangays (Table 109). Mean yields were 11 t/ha in the hot-wet season crop and 24.6 t/ha during the hot dry. Overall there was a much greater yield difference between seasons (crops) than between treatments.

Data from this study support our previous findings and indicate that many farmers habitually overfertilize with nitrogen. Nearly all farmers applied more inorganic N than researchers to their plots. Yield responses to this additional N varied and were, with the exception of the Kiling farm, not significant. The one farmer (from Balele) who applied less inorganic N than researchers produced significantly lower yields. Finally, we cannot rule out factors other than fertilizer regime that affect pak-choi yield.

Table 109. *Location, farm fertilizer practice, introduced fertilizer practice, and marketable yield of pak-choi from 14 farms in Central and Southern Luzon, Philippines, hot-wet season 2001 and hot-dry season 2001–2002.*

Luzon	Barangay	No. farms	Farmer fertilization (kg/ha)	Introduced fertilization (kg/ha + t/ha)	Marketable yield (t/ha)			
					Crop 1(hot-wet)		Crop 2 (hot-dry)	
					T_1	T_2	T_1	T_2
Central	Mallorca	4	120N–0P–0K	45N–6.5P–12.5K + 4.0CHW[1]	5.7	7.8	20.0	21.3
Central	Castellano	3	75.8N–0P–0K	35N–4.3P– 8.3K + 3.1CHW	8.6	7.0	23.7	26.1
Southern	Bunggo	1	110N–0P–0K[2]	60N–6.5P–12.5K + 5.4CHW	22.5	17.5	29.9	23.4
Southern	St. Tomas	1	132N–0P–0K	60N–6.5P–12.5K + 5.4CHW	16.6	13.5	25.8*	42.5*
Southern	Santisimo	1	120N–0P–0K	60N–6.5P–12.5K + 5.4CHW	15.8	9.8	12.6	20.3
Southern	Balele	1	52.5N–0P–0K	60N–6.5P–12.5K + 5.4CHW	2.0	2.5	7.7*	22.0*
Southern	Lusacan	1	87N–0P–0K	60N–6.5P–12.5K + 5.4CHW	8.6	10.6	23.3	23.3
Southern	Kiling	1	250N–0P–0K	60N–6.5P–12.5K + 5.4CHW	15.5*	8.5*	24.6	26.2
Southern	Bantilan	1	250N–0P–0K	60N–6.5P–12.5K + 5.4CHW	15.1	10.5	31.0	41.3
Treatment means within crop					12.2	9.8	22.0	27.3
Mean crop yield over treatments					11.0		24.6	

[1]CHW = Composted household waste.
[2]Farmer included 7 t/ha chicken manure in fertilizer practice.
*Significant at $P \leq 0.05$.

Fertilizer regimes for grafted tomatoes

Tomatoes can be grown during the wet season in Luzon only by grafting tomato scions onto eggplant rootstock. Such grafted plants tolerate flooding and bacterial wilt, the main impediments to wet season production. Fertilizer regimes have only been developed for production in the dry season, not the wet. It is likely that the response of grafted tomato grown in the wet season will differ from the response of non-grafted tomato grown during the dry. This study was designed to determine the response of grafted tomato to different fertilizer regimes in two soils, an entisol on the CLSU campus in Muñoz and an alfisol in Los Baños, Laguna. The campus site was reported to be low in N with low to moderate P. The Los Baños site also was low in N, but with high P. Both sites had adequate K.

The tomato variety CL5915 was grafted onto the eggplant EG 203 rootstock and seedlings transplanted onto beds 30 cm high and 2.5 x 3 m in size. Transplants were spaced 1 m between rows and 0.5 m within rows and trellised individually. Transplanting was done June 25 at CLSU and July 25 at Los Baños. Rain shelters protected experimental plots and beds were covered with black plastic mulch.

Seven fertilizer treatments in kg/ha were applied randomly to beds in three blocks: T_1 = 0N–38.7P–124.5K, T_2 = 60N–38.7P–124.5K, T_3 = 90N–38.7P–124.5K, T_4= 150N–38.7P–124.5K, T_5= 180N–38.7P–124.5K, T_6 = 180N–77.4P–124.5K, and T_7 = 240N–38.7P–124.5K.

In the entisol (CLSU campus) only yield from T_7 with 240 kg/ha N was significantly different from T_1 and T_6 with 0 and 180 kg/ha N, respectively (Table 110). In contrast, in the alfisol (Los Baños) mean yield from T_2 with 60 kg/ha N was significantly different from T_1 and from other treatments except T_3 at 90 kg/ha N.

These results suggest that the recommended rate of 150N–38.7P–124.5K kg/ha can be reduced to 60N–38.7P–124.5K in an alfisol (total N 0.042%; available P 259 ppm). There was a response to 240 kg/ha N in an entisol that is considered to be low in N and P (total N 0.109%; available P 54.89 ppm).

Table 110. *Effect of fertilizer treatments on yield of grafted tomato in an entisol at Muñoz and in an alfisol at Los Baños, Philippines, hot-wet season 2001.*

Fertilizer treatment (kg/ha)		Entisol-Muñoz yield (t/ha)	Alfisol-Los Baños yield (t/ha)
T_1	0N–38.7P–124.5K	20.68 b[1]	14.40 d
T_2	60N–38.7P–124.5K	25.28 ab	19.77 a
T_3	90N–38.7P–124.5K	24.42 ab	18.06 ab
T_4	150N–38.7P–124.5K	22.59 ab	15.60 cd
T_5	180N–38.7P–124.5K	26.27 ab	15.59 cd
T_6	180N–77.4P–124.5K	21.93 b	16.70 bc
T_7	240N–38.7P–124.5K	28.30 a	15.93 cd

[1]Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

Effect of potting medium on growth of eggplant and tomato seedlings

Two non-replicated experiments were conducted to determine percent uniformity in stem diameter of eggplant and tomato seedlings grown in three potting media (factor A) treated with five fertilizers (factor B). The three potting media were carbonized rice hulls (CRH), decomposed rice hulls (DRH), and coconut coir (CC). The five fertilizer treatments were controlled released fertilizer (CRF), 14N–6P–11.6K, foliar soluble fertilizer containing 2% urea (Foliar), CRF + Foliar, and 14N–6P–11.6K + Foliar.

In experiment 1, each medium was characterized by water holding capacity, water retention and infiltration rate, then moistened to saturation and placed in plastic trays containing 50 holes, each 5 x 5 cm. There were 15 trays representing treatment combinations of potting media x fertilizer. Twenty-five holes were seeded with eggplant a week earlier than tomato. Each hole was seeded with two to three seeds. Controlled-release fertilizer at three granules per hole (equivalent to 45N–19.4P–37.4K kg/ha) was added to all holes just prior to seeding; 14N–6P–11.6K at the same dose was added one week after emergence. Application of foliar fertilizer prepared from urea commenced a week after emergence and was repeated weekly until grafting.

In experiment 2, the same methodology was followed except that the potting mixes were selected based on results from experiment 1. The fertilizer treatments were the same as in experiment 1. Two potting mix combinations were tested: equal portions of CC and composted household waste (CHW), and equal portions of CC and DRH.

Among the three media, CC has the highest water holding capacity (436%), highest water retention, and very rapid infiltration rate (>2 mm/min). CRH was second in water holding capacity (285%), but had very low water retention and medium infiltration rate. DRH was the lowest in water holding capacity (200%).

Because there was little difference among fertilizer treatments within media, mean values were pooled and are presented in Table 111. Percent germination of both eggplant and tomato seeds in all trays containing the three potting media was 100%. However, percent uniform seedlings varied. Eggplant seedlings performed poorly in CRH; the seedlings germinated, but there was a progressive desiccation of the leaves. The very low water retention of CRH and electrical conductivity of about 1.8-2 dS/cm are suspected to be the causes of poor seedling performance. Even if fertilizer is applied, the nutrients are lost in the leachate from rapid drainage.

These results indicate that CC + CHW is the best medium from among those tested for both eggplant and tomato. About 80% of the seedlings were suitable for grafting.

Table 111. *Mean percent seedlings of eggplant and tomato with stem diameter suitable for grafting in five potting media[1] over five fertilizer treatments.*

	% seedlings suitable for grafting	
Potting medium	Eggplant	Tomato
Experiment 1		
CRH	4.0	33.6
DRH	40.8	64.8
CC	43.4	77.2
Experiment 2		
CC + CHW	83.4	86.8
CC + DRH	62.4	74.8

[1]CRH = carbonized rice hulls, DRH = decomposed rice hulls, CC = coconut coir, and CHW = composted household waste

Yields of leafy vegetable accessions

Nineteen accessions of five leafy vegetables were planted in July, Aug., Oct., and Dec. 2001 at the Bureau of Plant Industry (BPI), Los Baños. Seeds were sown in rows 15 cm apart on raised beds 1 x 2 m in size. Plots were arranged by species, and there were 3–4 replications depending on the number of accessions per species. Before sowing, plots were treated with 1 kg/m^2 organic compost. Inorganic fertilizer at 90N–8.6P–16.6K kg/ha was applied as basal with a split sidedressing of 35.0N–0P–0K kg/ha at 10 and 20 days after sowing. Plots were protected from insects by screen tunnels of 32-mesh netting. Irrigation was done when necessary. Yields were subjected to ANOVA to test for differences within accessions and planting dates.

The pak-choi accessions Bp21 and Bp29 yielded significantly more than accessions Bp04 and Bp09 in July, but there were no differences in August, October, and December (data not shown). Mean yields across planting dates showed little difference among accessions. Mean yields of Bp21 were highest (16.6 t/ha), followed by Bp04 (16.2), Black Behi (15.6), Bp03 (14.2), Bp29 (13.5), and Bp09 (12.2).

Kangkong accession Ia02 yielded as much or more than Ia04 and Ia18 across planting dates. Mean yields of Ia02 were highest (14.2 t/ha), followed by Ia04 (13.2), and Ia18 (11.5). There were no yield differences among the accessions of choysum (Bc 12, 13, 17, and 36), and nonheading Chinese cabbage (Bcc 03, 04, and 23). The Indian mustard accession Bj11 yielded significantly more than Bj01 and Bj03 in August, but only more than Bj01 in July. Bj01 appears not to be adapted to the Los Baños area. Yields of trials at BPI, grouped by species within month planted, are shown in Table 112.

When pak-choi accessions were grown on six farms in Laguna and Quezon, using researcher practices, the pak-choi accession Bp21 yielded significantly more than other accessions only on one farm. On five farms there were no differences among accessions. The kangkong accession Ia02 was among the highest yielders on two farms, whereas on four farms there were no differences among accessions. These data indicate that yields from Bp21 and Ia02 were relatively stable in most locations and over time. Both accessions therefore, appear to be adapted to environments in Southern Luzon and may be recommended for cultivation. In fact, nearly all evaluated accessions were found to be similar in productivity and could be successfully grown in Southern Luzon.

Table 112. *Yields of leafy vegetables for four planting dates. BPI-Los Baños, Philippines, 2001.*

	Yield (t/ha)				
Vegetable	July	Aug.	Oct.	Dec.	Mean
Pak-choi	9.8	15.5	17.4	18.2	15.2
Indian mustard	8.3	7.5	–[1]	–	–
Nonheading Chinese cabbage	9.8	15.0	–	–	–
Choysum	11.3	15.5	–	–	–
Kangkong	17.3	10.8	15.9	8.0	13.0
Mean	11.3	12.8			

[1]Not tested.

Grafted tomato studies with rain shelters

Two experiments were conducted during the hot-wet season of 2001. The first experiment tested the performance of two scions, Apollo and CL 5915, each grafted onto eggplant rootstock EG203 and tomato rootstock H7996. All plants were grown under rainshelters. Experiment 2 evaluated the effect of rainshelter on the performance of two scions, Apollo and CHT 501, grafted onto eggplant rootstock EG203. In both experiments grafted seedlings were transplanted onto beds 2.5 x 5 m, raised 30 cm. There was 1 m between rows and 0.5 m between plants within rows. Both experiments were treated with a basal application of 10 t/ha of organic matter followed by 60N–25.8P–49.8K kg/ha. A sidedressing of 90 kg/ha N was done at flowering and after first harvest. Plots were arranged in a randomized complete block design with three replications.

Results confirm that grafting enhances yield as non-grafted plots were unproductive (Table 113). CL5915 yielded significantly more than Apollo when grafted onto tomato rootstock, but not when grafted onto eggplant or non-grafted.

Table 113. *Yield (t/ha) of grafted tomato scions grown under rainshelters. CLSU, Muñoz, Philippines, hot-wet season, 2001.*

	Rootstock		
Scion	EG203	H7996	Non-grafted
Apollo	11.2 b[1]	9.8 b	3.0 c
CL5915	8.9 b	15.7 a	4.1 c

[1]Mean separation in a row and/or column by Tukey's mean separation test at $P \leq 0.05$.

Grafted CHT501 significantly yielded more than grafted Apollo when grown under plastic shelter, but not in open field (Table 114). Grafting improved yield under shelter for both scions and both rootstocks. In open field, grafting improved yield of both scions grafted onto EG203, but when grafted onto H7996 only CHT501 yielded more than nongrafted.

Our results confirm the value of rain shelters and grafting in hot-wet season production and indicate that CL5915 and CHT501 are valuable as scions.

Grafted tomato and cucurbit studies

Four fresh market tomatoes, CL 5915, BPI-Tm9, Del Monte and Momotaro were grafted onto eggplant rootstocks (EG203) and transplanted 7 Aug. 2001 on raised beds in plots 2.5 m^2 in size with 16 plants/plot. Beds were covered with polyethylene mulch for weed control and an arched net structure for protection from rain. Cultivars were planted in a randomized complete block design with four replications. Plots were fertilized with organic fertilizer at the rate of 1 kg/m^2. Inorganic fertilizers were applied at the rate of 168N–70.5P–269.8K kg/ha, split among basal and sidedressings at 2 and 4 weeks after transplanting. Tomatotone was sprayed five times at 4 to 7 day intervals. Fruit were picked seven times from 10 plants/plot.

Yields for the cultivars CL5915, BPI-Tm9, and Del Monte were 13.7, 11.0, and 14.7 t/ha, respectively, and those yields were not significantly different. Only the cultivar Momotaro yielded significantly less (6.6 t/ha).

On 16 Nov. 2001, following tomato, we seeded the cucumber cultivars, BPI Cu #4, BPI Cu #22 and 6T #1, and the squash cultivars EG SQ #39, EG SQ #41 and Rizalina in the same holes. Each entry occupied 8 m^2 and was replicated four times. One-half kilo ordinary compost and 10 g of 14N–6P–11.6K were applied to each hill prior to seed sowing. The cucurbits were sidedressed at 20 and 30 days after sowing with 10 g of 14N–6P–11.6K and 5 g of urea (46N–0P–0K) per hole. Sevin and wood ash at 1:1 ratio were dusted on plants to control pests. Yield data for each

Table 114. *Yield (t/ha) of grafted tomato scions grown under rainshelter and in open field. CLSU, Muñoz, Philippines, hot-wet season, 2001.*

	Rain shelter			Open field		
Entry	EG 203 rootstock	H7996 rootstock	Non-grafted	EG203 rootstock	H7996 rootstock	Non-grafted
Apollo	11.9 c[1]	10.3 c	3.6 d	6.0 a	5.3 ab	0.9 b
CHT 501	21.5 a	17.0 b	3.6 d	8.4 a	7.6 a	1.1 b

[1]Mean separation in a row and/or column by Tukey's mean separation test at $P \leq 0.05$.

plot were taken from 40 hills for cucumber and 20 hills for squash.

There were no significant differences in yield among the cucumber cultivars (overall mean was 19.9 t/ha). Among squash cultivars, EG SQ #39 and Rizalina (20.6 and 22.9 t/ha, respectively) yielded significantly more than EG SQ #41 (15.1 t/ha).

Integrated pest management

Soil solarization to curb flea beetle infestation of pak-choi

Two replicated trials were conducted on the CLSU campus to determine the effectiveness of soil solarization to control flea beetle (*Phyllotreta striolata*) infestation of pak-choi. Raised beds were prepared and covered with black polyethylene plastic for 2 weeks. After solarization, beds were tilled and standard practices were used for sowing and fertilization. After sowing, all beds were covered with screen tunnels to prevent infestations from exogenous insect pests.

In trial 1, solarization significantly increased yield and significantly lowered the number of damaged plants. Mean yield from solarized plots was 1.9 kg/m^2, but only 0.8 kg/m^2 from nonsolarized. The number of plants damaged by flea beetles was 5/m^2 from solarized plots and 18/m^2 from nonsolarized. In trial 2, there were no treatment differences.

Soil solarization may be a useful technology and when coupled with the use of screen tunnels may offer farmers a non-chemical procedure to curb infestations from important insect pests of pak-choi. Further testing is required.

On-farm testing of ICM strategies for pak-choi

Integrated crop management (ICM) practices for pak-choi developed by this peri-urban vegetable project include: 1) seeding in lines on raised beds; 2) screen tunnels; 3) composted household waste as fertilizer; and 4) spraying practices based on insect pest and disease monitoring. In 2001-2002, this management regime was used on seven farms in Nueva Ecija and eight farms in Southern Tagalog and contrasted with the farmer standard practice over hot-wet and hot-dry seasons. Insect pest and disease ratings were rated on a 0 to 9 scale, where 0 = no leaf damage, 1 = ≤ 20%, 3 = 21-40%, 5 = 41-60%, 7 = 61-80%, and 9 = 81-100% leaf damage.

There was no substantial difference in insect damage and disease ratings among the 14-farm/season combinations in Nueva Ecija, but among the 16-farm/season combinations in Southern Tagalog, the ICM regime reduced the mean insect damage rating from 4.98 to 2.57 (Table 115). The ICM regime in Southern Tagalog, therefore, reduced leaf damage by about 50%.

Table 115. *Mean insect and disease damage ratings for farmer practice and integrated crop management (ICM) regime for pak-choi over hot-wet and hot-dry seasons on seven farms in Nueva Ecija and eight farms in Southern Tagalog, Philippines, 2001-2002.*

	Insect damage[1]		Disease damage[1]	
Province	Farmer practice	ICM regime	Farmer practice	ICM regime
Nueva Ecija	2.73	2.70	1.68	1.83
S. Tagalog	4.98	2.57	0.45	0.76

[1]Rated using a 0-9 scale, where 0 = no leaf damage, 1 = ≤ 20%, 3 = 21-40%, 5 = 41-60%, 7 = 61-80%, and 9 = 81-100% leaf damage.

Insect and disease damage of leafy vegetables grown in screenhouse and open field

Four accessions of pak-choi (*Brassica campestris* cv. *pakchoi*), three of Chinese kale (*Brassica oleracea* cvg. *alboglabra*), three of Indian mustard (*Brassica juncea*) two of choysum (*Brassica rapa* cvg. *caisin*), and two of kangkong (*Ipomoea aquatica*) were planted in replicated trials under screenhouses and in open field on the CLSU campus over the hot-wet (June/July) and hot-dry (September/October) seasons of 2001. Accessions were direct seeded in rows on raised beds 1 x 2 m with 20 cm between rows and 10 cm between plants using a randomized complete block design with three replications. Beds were fertilized with 10 t/ha organic fertilizer and 60N–12.9P–24.9K kg/ha just before seeding. Thirty kg/ha N was applied as a sidedressing two weeks after seeding.

All accessions were examined for damage caused by such insects as diamondback moth, armyworm, cabbage webworm; and diseases such as damping-off and web blight. Insect damage and severity of disease were rated using a 0-9 scale, where 0 = no leaf damage, 1 = 1-20%, 3 = 21-40%, 5 = 41-60%, 7 = 61-80%, and 9 = 81-100% leaf damage.

Insecticides and fungicides were applied as needed to control pests and diseases within species. Foliage biomass was weighed from 20 plants selected randomly from the two interior rows.

There was little difference in insect damage among accessions within species, but there were some notable differences in disease damage (Table 116). For example, the pak-choi cultivar Black Behi grown in the open field was given a disease rating of 1.3 in contrast to others rated 3.0 to 4.4.

Table 116. *Mean insect and disease damage ratings[1] for leafy vegetables grown in a screenhouse and in the open field, CLSU,Muñoz, Philippines, hot-wet and hot-dry seasons (combined), 2001.*

	Screenhouse		Open field	
Accessions	Insect	Disease	Insect	Disease
Pak-choi				
Bp21	3.3	3.5	3.5	4.4
Bp22	3.9	3.4	2.7	3.0
Bp23	5.1	1.1	2.6	3.4
Mean pak-choi[2]	4.1	2.6	2.9	3.6
Black Behi (ck)	–[3]	–	3.3	1.3
Indian mustard				
Bj03	2.0	2.9	3.0	2.2
Bj11	1.7	1.8	3.9	2.0
Bj14	1.9	2.2	3.9	2.7
Mean	1.8	2.3	3.6	2.3
Chinese kale				
Ba11	3.0	2.3	0.8	1.5
Ba17	1.8	3.3	0.4	1.8
Ba24	2.5	2.5	1.2	2.9
Mean	2.4	2.7	0.8	2.1
Choysum				
Bc02	2.9	1.3	2.7	2.0
Bc20	2.3	4.3	1.7	2.3
Mean	2.6	2.8	2.2	2.1
Kangkong				
Ia02	1.0	0.1	1.3	0.0
Ia07	1.0	0.0	0.8	0.0
Mean	1.0	0.0	1.0	0.0

[1]Insect damage and severity of disease were rated using a 0-9 scale, where 0 = no leaf damage, 1 = 1-20%, 3 = 21-40%, 5 = 41-60%, 7 = 61-80%, and 9 = 81-100% leaf damage.
[2]Excludes Black Behi.
[3]Not tested.

In the hot-wet season, Black Behi and Bp22 produced higher yields than Bp21 and Bp23 for both screenhouse and open field conditions (Table 117).

Kangkong, the only non-Brassica among the group, was less subject to insect and disease damage than pak-choi, Indian mustard, Chinese kale, and choysum. Yields for all species were higher in the screenhouse compared to the open field (Table 118).

Table 117. *Yield of pak-choi accessions over two trials under screenhouse and in open field, CLSU, Muñoz, Philippines, hot-wet and hot-dry seasons, 2001.*

	Screenhouse		Open field	
Accession	Hot-wet	Hot-dry	Hot-wet	Hot-dry
Bp21	12.9 b[1]	14.8	9.3 b	22.7
Bp22	33.6 a	29.7	18.3 a	16.3
Bp23	13.9 b	–[2]	10.5 b	–
Black Behi	29.6 a	22.1	22.4 a	22.1

[1]Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.
[2]Not tested.

Table 118. *Mean yields (t/ha) for accessions of pak-choi, Chinese kale, Indian mustard, choysum, and kangkong in a screenhouse and in open field, and percent yield increase, CLSU, Muñoz, Philippines, hot-wet and hot-dry seasons (combined), 2001.*

Crop	Screenhouse	Open field	% increase
Pak-choi	18.1	17.4	4.0
Chinese kale	12.6	8.8	43.2
Indian mustard	25.1	14.4	74.3
Choysum	39.6	19.8	100.0
Kangkong	94.6	55.0	72.0
Mean	38.0	23.1	64.5

Seasonal fluctuations in populations of insect pests of pak-choi

Consecutive plantings of pak-choi on four beds 15 x 0.8 m and on two beds 15 x 2 m were made monthly from August 2001 to February 2002 at CLSU to monitor the number of insect pests attacking pak-choi. Two plots, each one square meter, were randomly selected from the small beds and delineated with cord. Plant numbers, both damaged and undamaged, and pest numbers were noted in the plots. Then the number of *Hellula undalis*, *Phyllotreta striolata*, *Spodoptera litura*, *Plutella xylostella*, *Crocidolomia binotalis* were counted and recorded (Table 119), as well as the number of pests/plant on surrounding crops (data not shown). No insecticides were used.

H. undalis was found every month except September and we believe that was due to a poor stand of pak-choi caused by non-uniform emergence perhaps exacerbated by flooding from rain. Interestingly, we found few *P. xylostella* larvae and numbers are not included in the table. P. *striolata*, *S. litura* and *C. binotalis* were found on most plantings as well. These observations support the view that insect pests are a constant threat to pak-choi production.

Table 119. *Number of pak-choi plants and insect pests[1] observed per square meter on monthly plantings in a plot at CLSU, Muñoz, Philippines, 2001–2002.*

Month	Observ.	Plants	*H. undalis*	*P. striolata*	*S. litura*	*C. binotalis*
Aug.	2	66.5	20.5	0.0	0.0	0.0
Sep.	4	20.2	0.0	7.0	0.5	0.0
Oct.	5	38.2	6.4	1.0	0.0	0.2
Nov.	15	46.0	20.4	6.1	13.1	8.4
Dec.	34	67.5	9.9	14.6	10.9	7.0
Jan.	19	55.6	10.9	11.0	6.5	3.5
Feb.	16	55.8	9.8	14.3	5.3	1.6

[1]*Hellua undalis, Phyllotreta striolata, Spodoptera litura, Crocidolomia binotalis.*

Insecticides for IPM of pak-choi

As in previous years, the project tested various insecticides for efficacy against insect pests of pak-choi. In 2001-2002 the project tested chlorpyrifos (Brodan), spinosad (Success), profenofos (Selecron) and phenthoate (local brand Pennant, not to be confused with Pennant herbicide) in a replicated trial. Insect damage was rated using a 0-9 scale, where 0 = no leaf damage, 1 = ≤ 20%, 3 = 21-40%, 5 = 41-60%, 7 = 61-80%, and 9 = 81-100% leaf damage. The mean values were: control 5.5, profenofos 2.0, chlorpyrifos 1.25, phenthoate 0.5, and spinosad 0.25. All insecticides significantly reduced damage rating, and phenthoate and spinosad were superior to the others.

Synthetic pheromone to monitor populations of Hellula undalis

In cooperation with the Pherobank®, Dr. Frans Griepink of the University of Wageningen provided 20 rubber septae each of six different dosages (10, 20, 50, 100, 200, 500 µg) of a pheromone designed to attract male moths of *H. undalis*. Two trials were conducted: trial one in San Leonardo, and trial two in Matinkis in Muñoz (2 cropping seasons), and Palestina in San Jose. Trials were not replicated within sites.

In trial one, all six dosages were randomly placed in a radish field (50 x 100 m) with a minimum distance of 20 m between traps and a trap height of 0.5 m. The traps were set to face the prevailing wind direction. During week one, the number of male moths was recorded early in the morning and lures were kept in a cool box until being reset in the field during the late afternoon. After week one, traps were left in the field and examined three more times.

In trial two, traps were left in the field from the outset. The number of males caught was recorded daily for two weeks.

Male *H. undalis* were trapped at all locations and the 10-µg dosage appears adequate to attract adult males (Table 120); it is also the most cost-effective. The cost of the pheromone is 750 Euro for the first gram and 450 Euro for each additional gram. Future studies, therefore, will be conducted with only 10-µg dosages.

Table 120. *Daily mean number of male* Hellula undalis *moths trapped at four locations by six dosages of a synthetic pheromone, Philippines, 2001–2002.*

Dosage	San Leonardo	Palestina	Matinkis crop 1	Matinkis crop 2
10 µg	20.1	1.4	0.8	12.9
20 µg	18.7	0.8	1.3	3.5
50 µg	15.1	0.2	0.8	3.7
100 µg	12.0	0.6	1.0	3.2
200 µg	14.0	0.8	1.0	3.2
500 µg	12.1	1.0	2.6	3.4

Efficacy of artificial diet to rear Hellula undalis

A preliminary trial was conducted to test the efficacy of an artificial diet for rearing *H. undalis*. The diet was prepared using nine parts of Bioserv, an artificial diet which is commonly used to rear beet armyworm, to one part of pak-choi leaves that were boiled in distilled water. From 619 eggs placed in 46 containers with artificial diet, 103 adults emerged with a sex ratio of 38 males to 44 females. The mortality rate of 83.4% was unacceptably high and further studies are required.

Technology transfer

Participatory rural appraisal

Based on the results of a participatory rural appraisal, no farmer organization operates in Laguna, Batangas, Quezon Province, Nueva Ecija, Tarlac, Pampanga, Bulacan and Pangasinan. To date, no attempt has been made to create an organization for them. Thus, existing structures in the barangays were utilized to mobilize farmers for the purpose of training in ICM of pak-choi and in grafted tomato production.

The appraisal conducted in the provinces of Batangas, Quezon, Laguna, and Nueva Ecija indicated an unstable trend in the supply of leafy vegetables to Manila markets. This was due to production constraints caused by insect pests, diseases, and flooding damage during the wet season. These findings served as an entry point for on-farm trials and succeeding technology promotion activities.

Declarations of cooperation

Memorandums of Agreement (MOA) between the project and local government units were signed in which duties and responsibilities of each party were stipulated. In 2001, ten MOAs were maintained/renewed and four new MOAs were signed with local chief executives.

Capacity building

Technologies, particularly on ICM of pak-choi and production of grafted tomato, were packaged and presented for evaluation to selected local government unit (LGU) extension workers and farmers during trainings.

A training of trainers (TOT) was conducted to equip future trainers with technical knowledge and skills needed to conduct Farmer Field Schools (FFS) in their respective municipalities. Fourteen LGU agricultural technicians and 6 researchers were trained.

Farmer Field Schools were subsequently implemented to facilitate learning and cooperation among pak-choi farmers. The FFS provided farmers with hands-on experiences in using raised beds to reduce flooding damage, applying urea in rates that maximize production and profits, sowing in rows instead of broadcasting for superior plant growth, and using mesh netting for shelters to improve quality and reduce pesticide use. In all, 263 farmers participated in the nine FFS. Funds for this training were primarily provided by the LGUs, with limited support from the project and the participants themselves.

Similarly, TOT on grafted tomato production was conducted. The number of participants totaled 33, consisting of 9 representatives from state colleges and universities (SCUs), 17 LGU agricultural technicians, and 7 officers from NGOs.

Technology promotion

The project's technologies were showcased in technology fairs conducted by LGUs, state colleges and universities (SCUs), and other scientific organizations. Research reports were presented in 13 local and national forums; four papers were judged as best of their forum. The project was showcased and featured in newspapers, radio and TV broadcasts.

The Land Bank of the Philippines (LBP) through its Technology Promotion Center (TPC) has earmarked a modest amount of funds to validate the cost and return from grafted tomato seedlings production, grafted tomato production, and physical net barriers for pak choi production. If found feasible and economically viable, TPC will provide credit to farmers for the purchase of these technologies.

On-farm trials were done in 19 sites to enhance farmers' awareness and verify the applicability of developed technologies.

Hanoi-CLV peri-urban agriculture project

The objective of the project entitled 'Sustainable Development of Peri-urban Agriculture in Southeast Asia—*Cambodia, Lao, Vietnam*' (SUSPER) 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 in the Ministry of Agriculture and Forestry. Representing Vietnam are the Research Institute of Fruit and Vegetable (RIFAV), Vietnam Agricultural Sciences Institute in Hanoi, and the University of Agriculture and Forestry in Ho Chi Minh City.

Project Coordinator: H de Bon

Initial planning activities

In October 2001, the initial meeting of the project's steering committee, which included representatives of all partner organizations, was held in Hanoi. The committee made plans to assess existing peri-urban agriculture production and marketing systems. This included a study of vegetable production practices with emphases on the hot-wet season and safe vegetable production practices.

Activities started in January 2002 in the four major cities with technical workshops, in-country trainings, training at AVRDC, and experimental testing. Demographic data on the peri-urban sites of the project are presented in Table 121.

Table 121. *Demographic data of major cities in Cambodia, Laos and Vietnam, 2000.*

City	Area (km^2)	Agric. land (km^2)	Pop'n density (persons /km^2)	Total pop'n (1000s)	Agric. pop'n (1000s)
Phnom Penh	375	89	2,568	963	80
Vientiane	3,920	833	145	569	178
Hanoi	919	435	2,952	2,712	829
Ho Chi Minh City	2,094	980	2,434	5,097	448

Safe vegetable production

Activities began with a one-year start-up project funded by the Consultative Group on International Agricultural Research (CGIAR)-sponsored 'Strategic Initiative for Urban and Peri-urban Agriculture' (SUIPA) led by the International Potato Center (CIP). From May 2001 to May 2002, AVRDC collaborated with CIRAD and RIFAV to conduct studies related to quality assurance of agricultural products in peri-urban Hanoi. The work focused on evaluation of a rapid approach to analyze the safety and quality of perishable products. The project provided for training at AVRDC and at the Taiwan Agriculture Research Institute (TARI) on the use of a quick bioassay test to assess postharvest pesticide residues on vegetables. Supporting activities in Hanoi included a survey to identify pests and pesticide treatments used by farmers on choysum (*Brassica campestris* ssp. *parachinensis*) and a survey of vegetable farmers to characterize their pesticide use patterns.

Choysum pests and efficacy of pesticide treatments

The main insects observed on choysum grown in the Hanoi area were diamondback moth (*Plutella xylostella*), imported cabbage worm (*Pieris rapae*), striped flea beetle (*Phyllotreta striolata*), armyworms (*Spodoptera* spp.) and aphids. In order to verify the efficacy of the pesticides used by vegetable farmers, different pesticide programs were compared over the hot-wet season (July to October) and cool season (November to March), in three locations around Hanoi, namely Co Bi, Hoi Xa, and Trau Quy (RIFAV). At each location, four adjacent 90 m² non-replicated plots were used to evaluate four pesticide treatments. Similar agronomic practices were employed at the three locations. The pesticide treatments over the crop period at each site were: 1) farmers' practice (FP) consisting of five chemical pesticide applications; 2) IPM-1 consisting of two to four applications chosen from flufenoxuron, spinosad, fenvalerate and cypermethrin, depending on season; 3) IPM-2 consisting of two to four applications of relatively low mammalian toxic insecticides chosen from imidaclorpid, abamectin, and *Bacillus thuringiensis*, depending on season; and 4) no pesticide application. Pest populations were assessed by making insect counts on 100 plants per plot every week. Natural enemies were collected from 100 plants per plot two days before harvest.

Marketable yields among different pesticide treatments were similar during the hot-wet season (Table 122). But during the cool season, the pesticide-treated plots had larger yields compared to the non-treated plot. Differences in yields among field locations were quite large, but the effect may have been due to planting date because the different locations were planted one month apart.

During the hot-wet season, striped flea beetles, armyworms, aphids and some grasshoppers were observed in low populations, i.e., between zero and one insect per plant. In the cool season, pest populations were higher, three to nine insects per plant, mainly due to increases in the striped flea beetle population.

An indicator of sustainable integrated pest management is the development of populations of natural enemies. The main beneficial insects and spiders identified were species of *Lycosa*, *Menocenlus*, *Micraspis*, *Ichiodon*, *Sparetus*, *Tetragnatha*, *Coccinella*, *Oxyopes*, *Lempia*, *Ophionea*, *Microlistis* and *Paederus*. The total number of natural enemies was influenced by the pesticide treatments (Table 123). Populations of natural enemies in the FP-treated plot were much lower than in the IPM and non-treated plots. The numbers of natural enemies collected from the two IPM treatments were in general intermediate to the FP and the no pesticide treatments.

Table 123. *Numbers of natural enemies collected from 100 choysum plants two days before harvest at three locations in Hanoi, hot-wet season 2001 and cool season 2001-2002.*

Location	FP[1]	IPM1[2]	IPM2[3]	No pesticide
		Hot-wet season		
Co Bi	1	7	7	9
Hoi Xa	2	15	20	25
Trau Quy	3	16	11	26
		Cool season		
Co Bi	1	8	6	6
Hoi Xa	4	9	10	12
Trau Quy	4	9	10	12

[1]Farmers practice of five applications of chemical pesticides.
[2]Two to four applications of flufenoxuron, spinosad, fenvalerate and cypermethrin, depending on season.
[3]Two to four applications of relatively low mammalian toxic insecticides imidaclorpid, abamectin, and *Bacillus thuringiensis*, depending on season.

Table 122. *Effect of pesticide treatments on marketable yields of choysum planted in non-replicated demonstation plots in Hanoi, hot-wet season 2001 and cool season 2001-2002.*

Location	Sowing date	Harvest date	Crop duration	Marketable yield (t/ha) FP[1]	IPM1[2]	IPM2[3]	No pesticide	Mean
			Hot-wet season					
Co Bi	July 6	Aug. 17	42	17.5	17.1	17.3	16.4	17.1
Hoi Xa	Sep. 19	Oct. 25	36	25.0	23.6	23.3	18.7	22.7
Trau Quy	Aug. 8	Sep. 18	41	16.3	15.9	16.4	16.0	16.2
			Cool season					
Co Bi	Nov. 4	Dec. 15	40	16.5	15.2	15.3	12.8	15.0
Hoi Xa	Feb. 15	Mar. 26	40	15.7	13.3	15.2	0	11.0
Trau Quy	Dec. 26	Feb. 17	51	16.6	14.1	14.8	0.4	11.5

[1]Farmers practice of five applications of chemical pesticides.
[2]Two to four applications of flufenoxuron, spinosad, fenvalerate and cypermethrin, depending on season.
[3]Two to four applications of relatively low mammalian toxic insecticides imidaclorpid, abamectin, and *Bacillus thuringiensis*, depending on season.

Survey of pesticide use on leafy vegetables

A survey of 100 leafy vegetable farmers in Hanoi indicated that they use fewer fungicides but more insecticides in the hot-wet season compared to the cool season (Table 124). Farmers stated that they have more insect problems during the hot-wet season. Application intervals were consistent from season to season.

Conclusions

An analysis of the demonstration plots and farmer survey suggests that pest problems are different from one season to the other. Also, the observations in the demonstration fields don't support the farmers' practices. More insect pests were found in the cool season, when farmers sprayed less insecticide. The hot-wet season favors the development of many crucifer diseases including soft rot (*Erwinia carotovora*), black rot (*Xanthomonas campestris* pv. *campestris*), and alternaria leaf spot (*Alternaria brassicae*), but farmers use less fungicide during this season. This initial study further showed that farmers would benefit from improving their skills in diagnosing disorders and selecting proper pesticides for controlling pests and diseases. Improved methods of information dissemination, involving the full participation of researchers, farmers, marketers and extensionists, will lead to improved use of pesticides.

Table 124. *Comparison of use of pesticides on choysum* (Brassica campestris cvg. parachinensis) *and Indian mustard* (Brassica juncea) *during two seasons, Hanoi, 2001.*

Season	Crop	Fungicides (a.i. kg/ha)	Insecticides (a.i. kg/ha)	Total (kg a.i./ha)	Mean number applications	Mean application interval (days)
Hot-wet	Indian mustard	0.3	4.3	4.5	3.5	7.5
Cool	Indian mustard	0.6	1.7	2.3	3.5	7.5
Hot-wet	Choysum	0.5	3.6	4.1	3.0	7.5
Cool	Choysum	0.8	2.2	3.0	4.0	7.5

AVRDC Asian Regional Center

The Asian Regional Center (AVRDC-ARC) is located at Kasetsart University, Kamphaengsaen, Nakhon Pathom, Thailand. It serves as an important link of AVRDC to its national partners in Asia. The regional center was established in 1992 as an expansion of the outreach program which started in 1982. Its objective is to determine the needs and capabilities of the region in terms of research and development in vegetables. For the last 20 years, AVRDC-ARC has been a partner of the national agricultural research and extension systems (NARES) of the different countries in Asia.

AVRDC-ARC conducts applied and adaptive research on AVRDC priority vegetable crops as well as other vegetables important in the region, conducts training and information dissemination, and coordinates subregional networks and collaborative research and development programs.

While AVRDC-ARC's activities remain focused on AVRDC's major crops and important regional crops, studies on other vegetables with economic importance in the region are handled in the regional training course. In selected countries, on-farm trials of promising AVRDC lines, together with those from private seed companies are being conducted.

Director: M Koizumi

Research at AVRDC-ARC

Screening for resistance to tomato leaf curl virus

This experiment was conducted from Nov. 2000 to Mar. 2001 to identify tomato lines resistant to tomato leaf curl virus (ToLCV). Eighteen lines, reported to be resistant in other parts of the region, were screened along with CLN2026D and H24 as susceptible and resistant checks, respectively. The seedlings were transplanted 32 days after sowing, with the spacing of 50 x 80 cm in the randomized complete block design with three replications.

After 77 days in the field, TLB182, CLN2114DCF1-2-16-8-2-17-0, CLN2114DC1F1-2-42-4-1-9-22-0, CLN2114DC1F1-2-29-20-16-5-12-0, CLN2123DC1F1-111-17-21-2-12 and CLN2116DC1F1-180-31-10-25-16-1 were found to be highly resistant with no indication of symptoms in the field (Table 125). The virus detection test revealed very low concentration of virus on these selected lines. FL699sp, TLCV271/1, FL736 and TY-King showed less than 20% incidence of ToLCV; the remaining lines and susceptible check showed high degrees of infection.

Table 125. *Incidence and severity of ToLCV of tomato lines 11 weeks after transplanting, AVRDC-ARC, sown Nov. 2000.*

Entry	Infected plants (%)	Disease rating[1]
FL582-17	31.7 d[2]	2.01 b-d
FL699sp	6.7 a-c	1.78 b-d
FL699sp+	23.3 d	2.49 bc
FL805	100.0 f	2.83 d
TLCV271/1	5.1 f	1.50 bc
FL438-17	71.5 ab	2.67 cd
FL456-17	21.8 e	2.90 d
FL505	63.3 c	2.49 cd
FL736	13.6 b-d	2.56 cd
FL776	67.9 e	2.41 cd
TY8487	60.0 e	2.64 cd
TY-King	11.7 b-d	2.45 cd
TLB182	0.0 a	0.00 a
CLN2114DC1F1-2-16-8-2-17-0	0.0 a	0.00 a
CLN2114DC1F1-2-29-20-16-5-12-0	0.0 a	0.00 a
CLN2114DC1F1-2-42-4-1-9-22-0	0.0 a	0.00 a
CLN2123DC1F1-111-17-21-2-12	0.0 a	0.00 a
CLN2116DC1F1-180-31-10-25-16-1	0.0 a	0.00 a
CLN2026D	51.7 e	2.87 d
H24	1.8 a	1.00 ab
CV (%)	31.51	41.31

[1]Rating scale: 0 = highly resistant; 3 = highly susceptible.
[2]Mean separation within columns by Duncan's multiple range test at $P \leq .05$.

Evaluation of tomato for ToLCV by artificial inoculation

Twenty tomato lines and varieties were evaluated for ToLCV by insect-vector transmission and grafting inoculation. CLN2026D was used as the susceptible check. AVRDC has developed lines resistant to the Taiwan strain of ToLCV. However, these lines were infected with the Thailand strain of ToLCV last year. Experiments were carried out to confirm their susceptibility by using two inoculation methods, i.e., insect-vector transmission and grafting.

For whitefly transmission, tomato seeds were sown in plastic pots with 5 seeds/pot and 5 pots/entry. The plants were kept in a 40-mesh nethouse for protection from natural transmission. Two weeks after sowing, the pots were moved into whitefly cage containing 500 or more adult whiteflies which were reared on ToLCV-infected tomato plants. Rating was based on visible symptoms and virus detection by DNA hybridization with Thai ToLCV strain probe three weeks after exposure to whitefly transmission. Incidence is based on percentage of plants that showed symptoms over total number of plants. Severity scale was based on the following: 0 = no symptoms; 1 = slight leaf yellowing along margin; 2 = moderate plant stunting/leaf curling; 3 = severe plant stunting/leaf curling.

All entries developed disease symptoms. FL582-17 showed relatively moderate incidence, mild symptoms and low virus detection by DNA hybridization (Table 126). In contrast, FL505 and FL736 showed high incidence, severe symptoms and high virus detection. CLN2114DC$_1$F$_1$-2-16-8-2-17-0, CLN2114DC$_1$F$_1$-2-29-20-16-5-12-0 and CLN2123DC$_1$F$_1$-111-17-21-2-12 showed low incidence and mild symptom but high virus detection. Severity was not correlated with disease incidence and virus detection.

For the second trial, all graft-inoculated plants developed typical symptoms at varying severities. CLN2026D, FL805 and FL505 showed severe symptoms and high virus detection by DNA hybridization. None of entries showed full resistance to the ToLCV race prevalent in Thailand. H24 and CLN2116DC$_1$F$_1$-180-31-10-25-16-1 showed milder resistance than the other entries. We conclude that all tomato lines tested here are susceptible to the Thailand strain of ToLCV, but vary as to the multiplication of the virus and symptom development.

Table 126. *Percent incidence, severity and virus detection score of 18 tomato lines against tomato leaf curl virus (ToLCV) in the screenhouse by whitefly inoculation, AVRDC-ARC.*

Entry	Incidence (%)	Severity[1]	Virus detection
CLN 2026D	76	1.2	2.67
H 24	68	1.1	2.33
FL 582-17	52	0.7	1.67
FL 699sp	84	2.1	1.67
FL 699sp+	80	2.0	2.33
FL 805	96	2.3	1.00
TLCV 271/1	80	1.8	1.33
FL 438-17	40	1.4	2.33
FL 456-17	64	1.4	1.00
FL 505	96	2.6	2.67
FL 736	96	2.7	2.67
FL 776	92	2.2	2.67
TY 8487	56	2.3	3.00
TY-King	84	1.5	2.00
TLB182	76	1.2	2.00
CLN 2114DC$_1$F$_1$-2-16-8-2-17-0	52	1.0	2.00
CLN 2114DC$_1$F$_1$-2-29-20-16-5-12-0	32	0.6	2.00
CLN 2114DC$_1$F$_1$-2-42-4-1-9-22-0	88	1.3	2.00
CLN 2123DC$_1$F$_1$-111-17-21-2-12	48	0.8	2.33
CLN 2116DC$_1$F$_1$-180-31-10-25-16-1	84	1.2	2.00

[1]0 = no symptoms, 1 = slight leaf yellowing along margin, 2 = moderate plant stunting/leaf curling, 3 = severe plant stunting/leaf curling.

Preliminary yield trials of promising mungbean lines

Two preliminary yield trials were conducted from Dec. 2000 to Mar. 2001 involving V and VC mungbean lines developed at AVRDC-ARC to identify promising mungbean lines with stable high yield and other suitable agronomic characters under lowland conditions. Both trials were laid out in randomized complete block design with three replications. The first trial consisted of 49 promising lines while the second had 48 selected from last year's preliminary evaluation.

Out of the 49 lines evaluated in the first trial, 14 yielded 2 t/ha or more (Table 127). The highest yield was observed in V1735 at 2.42 t/ha. although its powdery mildew (PM) incidence was moderate. V2075, on the other hand, had only a 5% PM incidence and produced the second highest yield of 2.39 t/ha. Other notable high yielding lines which have PM incidence of 7.5% or less were V1876, V5197, V1445, V1132, and V1844. Although there was high incidence of PM in some selected lines, the disease occurred during the latter part of the growing season when the pods were starting to mature, thus the effects of PM incidence on yield were low.

Table 127. *Yield data and powdery mildew incidence of high yielding mungbean lines in a preliminary yield trial, AVRDC-ARC, sown Dec. 2000.*

Line	Seed yield (t/ha)	100-seed weight (g)	Pod no./ plant	Seed no./ pod	PM incidence (%)
V-1735	2.42	35.2	14.7	10.8	35.0
V-2075	2.39	36.3	22.7	12.5	5.0
V-3484	2.35	40.8	20.7	11.6	65.0
V-1067	2.34	57.8	14.5	11.0	30.0
V-1947	2.31	29.7	17.3	10.6	57.5
V-6013	2.26	64.5	12.3	11.4	85.0
V-1270	2.24	42.8	20.7	10.8	85.0
V-1673	2.14	45.8	13.5	10.5	82.5
V-4451	2.07	44.3	24.3	11.8	50.0
V-2010	2.07	43.3	12.0	10.1	20.0
V-4785	2.06	30.0	20.2	12.1	2.0
V-6017	2.03	47.3	14.2	10.8	65.0
V-2273	2.00	38.5	15.8	10.3	24.0
V-6083	2.00	27.7	14.5	11.1	45.0
Mean	1.72**	41.3**	15.6**	10.9**	49.3**
CV (%)	24.7	19.2	29.6	10.0	43.0

**Significant at $P \leq 0.01$.

In the second trial involving 48 lines, the highest yield of 2.21 t/ha was obtained from VC 2762 although it PM incidence was moderate at 18.7% (Table 128). Of the 14 lines that yielded 1.5 t/ha and above, four lines, VC3828A, VC1131A , VC1160A, and VC3116A had 0% PM incidence. Twelve other lines were selected for having 0% PM incidence. These materials may be used for incorporating PM resistance to high yielding lines susceptible to the disease.

Table 128. *Agronomic and yield characters, and powdery mildew (PM) incidence of selected mungbean lines, AVRDC-ARC, sown Dec. 2000.*

Line	Days to 50% flowering	Days to 50% pod maturity	Yield (t/ha)	Pods per plant	Seeds per pod	1000-seed wt. (g)	PM incidence
VC2762A	44.3	59.3	2.21	11.1	10.8	60.7	18.7
VC1674A	40.0	56.7	1.87	12.3	10.5	78.5	13.3
VC3828A	44.0	60.3	1.82	10.2	11.7	67.5	0.0
VC1163B	39.3	59.0	1.81	15.9	11.3	64.8	58.3
VC1131A	41.0	58.0	1.81	15.1	12.1	56.5	0.0
VC1160A	41.7	59.0	1.76	13.4	11.3	66.2	0.0
VC1814A	40.3	55.7	1.71	11.2	10.9	57.0	24.7
VC2764A	41.7	57.7	1.66	12.9	12.0	64.7	11.3
VC1000A	40.0	56.3	1.62	9.3	10.7	60.8	16.7
VC3751A	41.0	60.3	1.58	13.9	12.1	58.0	8.3
VC3178A	42.7	59.7	1.58	12.9	11.5	67.5	16.7
VC3116A	42.7	60.7	1.56	14.8	11.7	64.2	0.0
VC1972A	38.3	57.3	1.53	12.5	10.9	53.1	22.3
VC2762B	38.7	56.7	1.52	14.7	11.3	57.4	8.7
VC1163A	42.3	56.3	1.45	11.3	11.0	59.3	0.0
VC1089A	41.3	58.7	1.39	11.3	11.7	53.3	0.0
VC2723A	41.7	59.0	1.32	12.8	10.7	69.8	0.0
VC1210A	43.0	57.7	1.27	10.6	11.1	55.5	0.0
VC3301A	42.3	57.3	1.26	11.8	11.4	53.2	0.0
VC3004A	42.0	59.3	1.23	11.4	10.8	56.4	0.0
VC3513A	40.3	56.7	1.19	13.5	11.8	63.7	0.0
VC1750A	43.0	57.3	1.16	14.4	11.8	46.0	0.0
VC1743A	39.0	57.0	1.16	11.1	12.1	56.6	0.0
VC1178B	40.7	60.3	1.15	10.8	10.6	69.3	0.0
VC3029A	38.3	57.0	1.01	13.9	10	62.2	0.0
VC1158A	38.3	57.0	0.98	8.5	10.5	75.2	0.0
Mean	40.6	57.9	1.37	12.5	11.2	60.9	12.0
CV (%)	6.2	3.6	34.69	31.2	7.4	8.2	–
F-test	**	**	NS	NS	NS	**	–

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Advanced evaluation of promising mungbean lines

Twenty-seven promising lines developed at AVRDC-ARC together with VC1973A, VC2778A and VC1628A as check varieties were evaluated from Nov. 2000 to Feb. 2001. The trial was laid out in randomized complete block design with four replications.

Actual field yield did not differ significantly although the potential yield (yield per plant multiplied by optimal number of plants per ha) showed significant differences when yield was covariated with number of plants harvested (Table 129). VC6469-12-1-4 had the highest seed yield of 3.58 t/ha followed by VC6465-8-1-2, VC6467-10-3-1 and VC6469-12-2-6 as 3.44, 3.42 and 3.42 t/ha, respectively. The best check variety, VC1973A, had 3.13 t/ha. Most of the promising lines showed moderate resistance to powdery mildew. Four promising lines, VC6467-10-3-1, VC6468-11-1, VC6465-8-5-2 and VC6465-8-1-2, showed high degree of resistance while all check varieties were very susceptible. Infection occurred after flowering and became serious at 50% pod maturity.

Table 129. *Yield components of promising mungbean lines, AVRDC-ARC, sown Dec. 2000.*

Line	Actual yield (t/ha)	Potential yield[1] (t/ha)	100-seed weight (g)	Powdery mildew rating[2]	Lodging score[3]
VC6469 12-1-4	2.55	3.58 a[4]	6.38 b-g	3.50 b-g	2.50 a-f
VC6465 8-1-2	2.38	3.44 ab	6.85 abc	2.75 a-e	1.00 a
VC6464 7-3-1	2.62	3.42 ab	7.00 ab	2.75 a-e	3.75 f
VC6469 12-2-6	2.39	3.42 ab	6.90 abc	2.25 abc	3.25 def
VC6465 8-5-2	2.62	3.29 abc	6.01 efg	2.00 ab	1.50 abc
VC6469 12-4-5	2.50	3.24 abc	6.58 a-f	2.75 a-e	2.50 a-f
VC6469 12-3-4	2.53	3.22 abc	7.15 a	2.25 abc	3.25 def
VC6469 12-1-1	2.34	3.18 abc	6.83 abc	2.50 a-d	1.75 a-d
VC6465 7-3-8	2.44	3.16 abc	6.70 a-e	2.50 a-d	3.50 ef
VC1973A (ck)	2.62	3.13 a-d	6.60 a-f	5.00 g	2.00 a-e
VC1628A (ck)	2.41	3.11 a-d	6.22 c-g	5.00 g	2.75 b-f
VC6463 6-1-1	2.25	3.05 a-d	6.43 b-g	2.50 a-d	2.75 b-f
VC6469 12-2-5	2.35	3.03 a-d	6.00 fg	3.00 a-f	2.50 a-f
VC6465 8-3-2	2.49	3.02 a-d	6.44 b-f	2.00 ab	1.75 a-d
Mean	2.30	2.97	6.51	3.04	1.95
CV (%)	14.90	16.10	6.21	30.80	45.66

[1]Yield per plant multiplied by optimal number of plants per ha.
[2]Rating scale: 1 = highly resistant; 5 = highly susceptible.
[3]Rating scale: 1 = no lodging; 5 = severe lodging.
[4]Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

Powdery mildew resistance in mungbean

Five parents and their 20 F_1 and reciprocal crosses were evaluated at AVRDC-ARC from Nov. 2000 to February 2001 for powdery mildew resistance. The trial was laid out in randomized complete block design with three replications. VC1560C was the most resistant parent to powdery mildew and had the best general combining ability while the cross V1104 x VC1560C showed the highest specific combining ability for degree of resistance (Table 130). Infection of powdery mildew (*Erysiphe polygoni*) disease started from seedling stage and became very serious at pod maturity (Table 131).

Table 130. *General combining ability estimates (italics) and specific combining ability estimates of powdery mildew incidence and severity in four parents and their F_1 progenies.*

Parent	V1104	V1560	VC6173B	VC2778
V1104	*-0.33*	-0.49	0.14	0.24
V1560C		*-0.81***	0.60	0.23
VC173B			*0.71**	-0.29
VC2778				*0.43*

*, ** Significant at $P \leq 0.05$ or 0.01, respectively.

Table 131. *Powdery mildew incidence rating[1] among four parents and their 12 F_1 progenies, AVRDC-ARC,sown Dec. 2000.*

Cross	Stage: 3-true leaf	50% flowering	Pod setting	Pod maturity
V1104	1.0	1.7	1.9	3.0 cd[2]
V1104 x VC1560C	1.4	1.8	1.9	2.7 bc
V1104 x VC6173B	1.8	2.2	2.4	4.2 c-f
V1104 x VC2778A	2.0	2.5	2.4	3.7 c-f
VC1560C x V1104	1.0	1.1	1.5	1.1 a
VC1560C	1.0	1.6	1.4	1.6 ab
VC1560C x VC173B	1.4	1.9	2.3	3.7 c-f
VC1560C x VC2778A	1.1	2.4	2.4	3.5 c-f
VC6173B x V1104	1.0	1.9	2.2	3.9 c-f
VC6173B x VC1560C	1.4	2.3	2.7	4.3 d-f
VC6173B	1.8	2.2	2.5	4.5 ef
VC6173B x VC2778A	1.8	2.6	2.8	4.8 f
VC2778A x V1104	1.5	2.7	2.7	4.1 c-f
VC2778A x VC1560C	1.0	2.3	2.7	3.2 c-e
VC2778A x VC173B	1.4	2.8	2.8	4.0 c-f
VC2778A	1.9	2.3	2.5	4.2 c-f

[1]Rating scale: 1 = highly resistant; 5 = highly susceptible.
[2]Mean separation within columns by Duncan's multiple range test at $P \leq 0.05$.

Training

Regional training courses

A total of 27 researchers and extension workers participated in the 19th Regional Training Course in Vegetable Production, Research and Extension held from 26 Oct. 2000 to 25 Mar. 2001. Among the participants, three were from Bhutan, two from Cambodia, five from China, five from Laos, three from Myanmar, one from Philippines, one from Thailand and seven from Vietnam. Fourteen trainees were supported by the Swiss Agency for Development and Cooperation (SDC), eight by the Japan-Association of Southeast Nations (ASEAN) Solidarity Fund (JASF), three by AVRDC-ARC, and two by the Royal Government of Bhutan.

Recognition awards were given to Ms. Kinlay Tshering of Bhutan, Ms. Pham Thi Min Tam of Vietnam, and Ms. Wang Shufen of China for being the top three performers in the class. Likewise, Mr. Tshering Penjor of Bhutan and Mr. Saw Oo Maw of Myanmar were cited for writing the best research papers.

The 20th Regional Training Course opened on 24 Oct. 2001 with 21 participants from six countries: Bhutan, Cambodia, China, Laos, Myanmar and Vietnam. Seventeen trainees are supported by SDC and the four trainees from Bhutan are supported by their government.

In-country trainings

From Jan. to Dec. 2001, five in-country trainings were implemented in Laos and two in Vietnam, all supported by the SDC Human Resource Development Project.

In Laos:

1. "Village Level Training of Rural Women on Vegetable Processing" in Vientiane on 14-18 Mar. 2001. The trainers were two staff of Kasetsart University. A total of 104 women participated.

2. "Strengthening the Linkage between Research-Development-Extension (RDE)" in Vientiane on 2-9 Apr. 2000. Dr. R.L. Navarro, an extension specialist from the Philippines, was invited as lecturer. A total of 35 researchers, extension staff, and progressive farmers participated.

3. "Vegetable Production and Management" in Vientiane on 20-26 May 2001. Some senior staff of Lao government served as instructors to a total of 23 rural extension staff.

4. "Off-season Vegetable Production Technologies" at the Crop Multiplication Center, Veunkham in Vientiane Province, Laos on 18-21 June 2001. Dr. T. Jaunet, former AVRDC-ARC plant pathologist, and some Lao experts lectured to 26 participants composed of extension staff and advanced farmers.

5. "Vegetable Seed Production and Its Technologies" at the Crop Multiplication Center, Veunkham in Vientiane Province on 20-24 Nov. 2001. Drs. Sutevee Suprakarn and Sunanta Janthakul, Professors of Kasetsart University, and Mr. Worawit Sorajjapinum, AVRDC-ARC breeder, lectured to 15 trainees (11 farmers and four extension staff).

In Vietnam:

1. "Vegetable Hybrid Seed Production" at the Research Institute of Fruit and Vegetables (RIFAV), in Hanoi on 8-13 Oct. 2002. Mr. J.T. Chen (AVRDC tomato breeder), Prof. Yang Xing Ping (breeder, Institute of Vegetable Crops, Jiangsu Academy of Agricultural Sciences, China), Prof. Tran Van Lai (RIFAV Director), and Dr. Nga (Hanoi Agricultural University) served as lecturers. There were 37 trainees consisting of national agriculture researchers, extension staff, and seed company personnel from different parts of the country.

2. "Training and Exchanging Experiences on Off-season Vegetable Production" in Ho Chi Minh City on 20-25 Oct. 2001. Drs. Manuel Palada and T.C. Wang, AVRDC crop management specialist and plant pathologist, respectively, served as lecturers. In addition, the Institute of Agricultural Science of South Vietnam (IAS) staff and local representatives presented their information and technologies to the trainees. Fifty participants (25 extension staff and 25 progressive farmers) from all provinces in South Vietnam attended the course.

Germplasm collection, multiplication and exchange

From Jan. to July 2001, 203 samples of germplasm were distributed (198 to China and 5 to Vietnam). This germplasm consisted of 100 mungbean, 80 pepper, 13 tomato, 5 eggplant, and 5 Chinese cabbage lines for evaluation trials. In the latter part of 2001, 180 samples of germplasm were distributed to collaborating countries such as Cambodia, Laos, Myanmar, and Vietnam.

Information and scientific exchange

All of these activities were supported by the SDC-Human Resource Development Project:

1. Translated "How to grow vegetables" and "Off-season Vegetable Production" into Lao language with 500 printed copies each.
2. Audio-visual extension materials on "Off-season Vegetable Production" and "How to grow vegetables" each 15 minutes long were developed into Lao language and multiplied to 20 CD units.
3. The book "Vegetable Production Training Manual", published by AVRDC, was translated into Vietnamese, edited and 1500 copies printed.
4. The book "Practical Field Guide on Vegetable Diseases", written by Dr. L.L. Black, AVRDC, was translated into Vietnamese.

China Program

The collaborative research with 11 agricultural institutes in China continued in 2001 with support from the SDC. The highlights of various studies conducted by these institutes are summarized below.

Oil Crops Research Institute, Chinese Academy of Agricultural Sciences

Evaluation of vegetable soybean germplasm. Twelve vegetable soybean lines from various sources were evaluated for yield potential, tolerance to adverse circumstances, and regional adaptability. Although lines A0035 and Yinmao 8 had the highest yields of 11.6 and 10.2 t/ha, respectively, the percent A pods of the two entries were among the lowest (4.6 and 6.3%). Yinmao 7 had the highest amount of A pods with 20.1% followed by entries 2809 and Tai 75. Yinmao 8 and Tai 75 were among the lines selected from the previous year's research.

Institute of Crop Germplasm Resources-Chinese AAS

International Mungbean Nursery (IMN) trial. In 2001, eight advanced mungbean lines from the 22nd International Mungbean Nursery (IMN) trial were evaluated in six locations from different provinces of China: Shijiazhuang in Hebei, Daqing in Heilongjiang, Nanjing in Jiangsu, Mingguang in Anhui, Weifang in Shandong, and Nanyang in Henan. The results showed that the yields of the eight lines were not significantly different from each other. VC6153B-22 gave the highest average yield of 2.05 t/ha, 5.6% better then the next entry, VC1973A.

Study of bruchid-resistant lines. The evaluation of 23 bruchid-resistant mungbean breeding lines from AVRDC was continued in 2001 for agronomic traits, nutritional qualities, and resistances to Cercospora leaf spot, bruchid, drought, salt, infertile soil, and low temperature. The results showed 15 bruchid-resistant lines: 12 were highly resistant, one resistant, and two moderately resistant. Among these 15 lines, 11 were early maturing, 13 had large seeds with 1000-seed weight over 65 g, six had high (>26%) protein content, six had high (>54%) starch content, eight were drought-resistant, two were salt-resistant, three were poor soil-resistant, and two were resistant to Cercospora leaf spot. Lines VC6089-9, VC6089-10 and VC6091-24-2-2-B-3 showed early maturity, large seed size, high protein and starch. VC6089 A-6, VC6089-11 and VC6317 showed early maturity, large seed size, high protein and drought resistance. VC63.9-22-4-2 showed large seed size and high protein and starch contents.

Academic exchanges. The Chinese Mungbean Domain Development Workshop was attended by 46 scientists from 28 institutes of 16 provinces of China. AVRDC-ARC was represented in the workshop by Dr. Peerasak Srinives and Mr. Worawit Sorajjapinum.

Vegetable Research Institute-Tianjin Academy of Agricultural Sciences

Survey of virus incidence of pepper in Tianjin. Based on a total of 73 diseased pepper leaf samples in 1999 and 2000 from four districts of Tianjin, 414 isolates were obtained. There was an increase in the incidence of tobacco mosaic virus (TMV), potato virus X (PVX), and potato virus Y (PVY) in Tianjin from 1999 to 2000. Cucumber mosaic virus (CMV) and TMV were the major viruses affecting pepper at this time.

Pepper evaluation for blight resistance. Out of 60 pepper lines inoculated, two lines, No. 57 from Japan and No. 41 from AVRDC-ARC, showed high resistance to *Phytophthora infestans*. Both lines were used for backcrossing five times to transfer resistance genes to promising lines.

International Sweet Pepper Nursery (ISPN) trials.

Out of 30 lines included in the trial, none were selected since they did not meet the Chinese preference for larger fruit size. However, some of the lines were selected for heat tolerance and disease resistance.

Institute for Vegetable Research-Shandong Academy of Agricultural Sciences

DNA extraction from garlic. Techniques for DNA extraction from garlic were obtained for the first time in China. Methods were also developed to extract DNA from Chinese cabbage and radish. Twelve useful primers were selected and an effective reaction system and temperature control program were obtained, by which 64 random amplified polymorphic DNA (RAPD) banding patterns of garlic were obtained for genetic analysis and purity testing.

Garlic in vitro conservation. Using a systematic approach for in vitro conservation of garlic, germplasm stored in vitro for 20-25 months survived at a rate of 89-100%, remained genetically stable, and had a virus infection rate of only 0.12–0.20%. A set of culture medium was screened for onion stem-tip meristem culture. The suitable medium for shoot regeneration and rooting were B5-BA 0.5 mg/l + NAA 0.2 mg/l + sucrose 30 g/l and B5+BA 0.01 mg/l + NAA 0.2 mg/l + sucrose 50 g/l. Rate for shoot regeneration and rooting were 65–90% and 35–37% on average, respectively.

Garlic germplasm resources. A virus-free genebank for garlic germplasm resources, as well as a database with information that includes in vitro conservation techniques, molecular information of plant material, and conventional agronomic and morphological characteristics, are being actively planned.

Collection and utilization of allium germplasm.

New and existing germplasm of garlic and onion were planted for observation of agronomic characteristics and yield performance. The crops are currently being harvested and evaluated. Several promising garlic and onion lines were propagated for mass production. A series of virus-free garlic lines were identified for production of bulbs, pedicels and green plants to meet consumer demands.

Institute of Vegetable Crops-Jiangsu Academy of Agricultural Sciences

Screening for heat tolerance in heading Chinese cabbage. Growth chamber studies and screening in the field during summer were used to evaluate heat tolerance for 500 heading Chinese cabbage accessions. Nine accessions showed good tolerance of heat and 16 accessions were moderately tolerant (80% or more heading rate).

Screening for heat tolerance in radish and cabbage. During the last three years, 23 heat-tolerant radishes, 32 bolt-tolerant radishes, and 10 bolt-tolerant cabbage plants were collected and identified. A total of 108 heat-tolerant radishes were identified in the field, and their comprehensive traits investigated with 58 white and 2 red radishes showing tolerance to heat. The efficiency of selecting plants for heat tolerance was improved by adjusting sowing dates and other cultural management practices.

Transgenic research of non-heading Chinese cabbage. After introducing cowpea trypsin inhibitor (CPTI) gene into non-heading Chinese cabbage, the methods of identification and screening of transgenic plants are being researched. A high frequency plant regeneration receptor system was constructed. The induced frequency of the buds was enhanced from 0–2% to 5–15% and the comprehensive gene transformation system mediated with *Agrobacterium* was established. The materials '978' and '979' were transbred with the system and self-crossed to generation 5 and 6 (T5-T6).

Institute of Vegetable and Flower-Northwest Sci-Tech University of Agriculture and Forestry

AVRDC tomato germplasm resources have many good characteristics such as high resistance to diseases, tolerance to heat, and fruit characters suitable for long transport. The main purpose of this project is to evaluate these materials along with Chinese lines, and to combine the best lines in breeding.

Evaluation of AVRDC tomato lines, Chinese germplasm, and their hybrids. In an evaluation of tomato lines, CHT105 and CHT224 showed higher resistance to diseases and pests, and stronger tolerance to heat and transport as compared to lines from China. Z6 screened from CHT224 had small and uniform fruit with pleasing aroma; it is believed to have good market potential. Chinese germplasm showed some favorable traits including big fruit and nice taste. Zhongshu No. 5, Baiguoqiangfeng, and Little Cherry showed desirable fruit quality. Baiguoqiangfeng and Zhongshu No. 6 produced the highest yields. In addition, Bazhou No. 2 gave higher storability and Zaofen No. 2 had much earlier maturity. Among the combinations, Baiguoqingfeng x CLN657 and Hongniuxin x CLN6045-51-1 showed good quality, high yield and resistance to disease. CL143 x Jinfen 65 and CL143 x

Zaofen No. 2 were earlier maturing compared to their parents. In general, AVRDC tomato lines have been shown to be vigorous, resistant to diseases and pests, and tolerant to heat and storage. CL143 and CL5915, two early maturing lines, are currently being used to cross with Chinese lines.

Hunan Plant Protection Institute

Biological and molecular characteristics of TMV-B and CMV-P_1. The main objective of this project is to establish transgenic pepper lines that resist both TMV and CMV. CP genes of TMV-B and CMV-P_1 were inserted into the plant transformation vector pBI121 separately on the sites between BamHI and SmaI. The recombinant plasmids containing CP gene of TMV-B and CMV-P_1 were introduced into *Agrobacterium tumefaciens* LBA4404 and then used to transform into pepper line B-1 with resistance to pepper bacterial wilt. The procedure resulted in the creation of pepper lines resistant to both bacterial wilt and TMV and/or CMV.

Institute of Horticulture-Xinjiang Academy of Agricultural Sciences

The project aims to develop the tomato processing industry by developing new cultivars and promoting extension outreach activities to tomato farmers.

Collection and introduction of tomato breeding materials. Twenty-eight breeding materials from Gansu, Sanxi, Sandong, Liaoning and Anhui were collected, and 75 cultivars from the United States, Japan, Holland and Israel were introduced. The materials are being evaluated in the field.

Two varieties developed by the Institute were submitted to the Crop Review Committee of Xinjiang for confirmation. They will be named Xinfan No. 12 and Xinfan No. 13. The latter has the Tm-2nv gene that could resist TMV and may be used in Shawan, Shezi and Manasi counties where TMV is of greatest concern.

Institute of Vegetables-Zhejiang Academy of Agricultural Sciences

Introduction and utilization of bacterial wilt-resistant tomato accessions from AVRDC. This project aims to develop highly resistant tomato stock with medium to large-sized fruits. In the year 2000 trial, six tomato crosses produced yields over 80 t/ha with firm or very firm fruit. Cross 9051 x 9141 had the highest yield of 105 t/ha, followed by 9053 x 9140, 9554 x 9116, 9047 x 9116, and 9053 x 9148. Three crosses had big and firm fruit suitable for fresh markets in Zhejiang and east China.

Results of year 2001 trial showed that crosses 9185 x 9176 and 9053 x 9140 were most promising. Crosses 9049 x 9176, 9047 x 9116, 9250 x 9162, and 9179 x 9178 also showed excellent yield and good horticultural characteristics. Further variety trials will be carried out using these promising crosses while cross 9185 x 9140 will be released to farmers in very small scale.

Institute of Vegetables and Flowers-Chinese Academy of Agricultural Sciences

***Collection, isolation and purification samples of* Phytophthora infestans.** More than 500 tomato late blight samples were collected from the major tomato production areas of 17 provinces in China and 194 isolates were purified and conserved.

Resistance to metalaxyl. The tomato germplasm from different part of the country were screened for resistance to metalaxyl, a systemic fungicide widely used in the tropics and sub-tropics. Isolates showed resistance to metalaxyl when assayed by in vitro and leaf disc methods. A higher incidence of metalaxyl-resistant isolates were found from south China.

Identification of* Phytophthora infestans *races. All isolates were evaluated according to their disease reactions on five differential hosts of tomato. The predominant physiological races in Beijing, Hebei, Fujian, Chongqing, Guizhong, Sichuang, Guangxi and Hubei provinces were defined basically. Many and complex physiological races were identified among *P. infestans* isolates from China. There were significant differences in races between regions.

Race 1 and race 2 (T1, 2) were detected to be the main physiological races in Beijing, race 0 and race 3 in Hebei; race 1 in Hubei; race 4 in Guizhong; and race 2 (T1, 2) in Sichuang and Guangxi. However there are more races in Fujian and Chongqing, including race T1,2,4; race 1; race 4; race T1,4; race 3; and race 2. Among them, race T1,2,4 and race 1 were the most common in Fujian, and race T1,4 and race 4 in Chongqing. The identification of physiological races in other areas is in progress.

Seed and Seeding Center-Guandong Academy of Agricultural Sciences

This collaboration aims to identify superior vegetable germplasm from AVRDC-ARC through evaluation, and then utilizing selected germplasm in the development of new varieties.

Field and laboratory evaluation of germplasm. A total of 56 tomato and 33 pepper lines were introduced from AVRDC. Fresh market tomato lines CL6047-1-6, cherry tomato CH154 and pepper PBC830 were chosen as the best materials.

Hybrid variety development. Hybrid tomato variety Dongfanghong No. 1 was developed with CL6047-1-6 as the male parent. This variety is indeterminate, resistant to bacterial wilt (BW), and tolerant to heat and some viruses such as TMV and CMV. Fruit is round, firm, and weighs 120 g. It has been released in Guandong, Guangxi, Hainan, and Fujian in China as well as in other countries such as Indonesia, Malaysia and Vietnam.

Using CH154 as the male parent, hybrid cherry tomato variety Hongyueliang was developed. It is semi-determinate and BW-resistant. Fruit is oblong in shape with 6.1ºBrix. It was released in Guandong, Guangxi and Hainan, and is planted in about 1000 ha.

For pepper, hybrid variety Guangjiao No. 2 was developed using PBC830 as the male parent. The variety is highly resistant to BW and tolerant to heat. The fruit is dark green in color with a glossy surface. It was has been widely released in Guandong and Hainan, and to a lesser degree in Indonesia and Vietnam.

Mekong region

Two special projects are being implemented by AVRDC-ARC involving collaborative vegetable research and development in the Mekong Region. The first is the Cambodia, Laos, and Vietnam Vegetable Research Network (CLVNET) funded by the Asian Development Bank. The second is the SDC Human Resource Development Project for the Mekong Region. The latter includes collaboration with China and Myanmar and is funded by SDC. Activities in Vietnam were conducted by the Research Institute of Fruit and Vegetable (RIFAV) in Hanoi, Hue University of Agriculture and Forestry (HUAF), and Institute of Agricultural Science of South Vietnam (IAS) in Ho Chi Minh City.

Research Institute for Fruit and Vegetable (RIFAV)

Ten tomato varieties with tomato leaf curl virus (ToLCV) resistance were collected from America, Middle East, India, and AVRDC. They were evaluated in northern Vietnam and all varieties showed resistance.

Seventeen processing tomato varieties obtained from AVRDC were tested and showed high quality and productivity.

Ten local cucumber varieties were evaluated for productivity and showed high resistance to downy mildew. These lines will be used for breeding purposes.

Six hot pepper varieties were tested. Variety PVR6 gave the highest yield with attractive fruit. Two other varieties, ANC2 and PBC586-2, were also preferred because of their fruit quality and anthracnose resistance.

Additional experiments were conducted to: identify optimal application rates of fertilizer for soybean, Chinese cabbage and fresh market tomato; evaluate the effects of grafting watermelon on pumpkin rootstock; and evaluate the effects of black shade cloth netting for Chinese cabbage production. Furthermore, trials aimed at improving nursery management and vegetable seed production were conducted.

Five demonstration fields were conducted at different locations in northern Vietnam. Pilot demonstrations were conducted on grafting tomato on eggplant rootstock, new promising tomato lines, nursery management, new French bean varieties, and new Chinese cabbage inbred lines.

Hue University of Agricultural and Forestry (HUAF)

Different vegetable crops were being evaluated at HUAF for yield and horticultural characters. Likewise, cultural management practices are being studied and refined to suit the condition of the region.

Eleven hot pepper entries were evaluated. Among the entries, CT8, DH1 and DH3 were selected for good fruit quality, high yield and high marketability. Twelve cucumber, nine vegetable beans, and seven eggplant entries were also evaluated.

Trials were conducted to evaluate the efficiency of spraying chemicals for the control of diseases in vegetables. Plastic mulching on pepper and watermelon showed better performance because of shorter growth period until harvest, increased number and setting of fruit, better quality of fruit, and higher marketable yield. A fertilizer application program was developed for watermelon production.

Leek is a major vegetable in Hue. Experiments conducted by HUAF identified the best season of seeding and planting, best density of plants, and optimal fertilizer strategy for seed production. Farmers adopted the new system and produced enough seeds to meet local production needs.

Institute of Agricultural Science of South Vietnam (IAS)

IAS demonstrated four pilot projects emphasizing disease control methods of tomato and cauliflower. All demonstration pilot projects were highly appreciated by farmers.

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.

Phase II of the training component of the Collaborative Network for Vegetable Research and Development in Southern Africa (CONVERDS) funded by Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung/Deutsche Gesellschaft für Technische Zusammenarbeit (BMZ/GTZ) ended in January 2001. Since its inception, AVRDC-RCA has trained 286 NARES personnel. CONVERDS is now partially supported by United States Agency for International Development (USAID).

The phase III of the project on Tomato Germplasm Improvement Program for Africa was successfully completed on 31 December 2001. During the current project phase (1999-2001), funded by BMZ/GTZ, significant progress has been achieved in breeding tomato varieties with good horticultural traits and resistance to late blight. Lines with resistance to late blight, root-knot nematodes and tomato mosaic virus have been selected and are in the final breeding stage.

Studies initiated in 1997 on germplasm collection, evaluation and management on African indigenous vegetables (AIV) were completed in April 2001. This component was funded by Department for International Development (DFID), United Kingdom. Further research and promotional programs are in progress with AIVs, tomato and vegetable legumes; this work is supported by USAID, United Nations Children's Fund, BMZ/GTZ, and AVRDC resources.

Director: ML Chadha

Research at AVRDC-RCA

Evaluation of late blight-resistant tomato lines for horticultural characteristics

Late blight caused by *Phytophthora infestans* is increasingly becoming an important fungal disease of tomato in the African highlands during the cool-wet season. The objective of the tomato breeding program for the African highlands is to develop multiple disease-resistant lines with good horticultural characteristics. Seeds of 28 new F_7 selections selected earlier for late blight resistance were bulked and the 15 most promising F_8 lines were evaluated for horticultural characteristics with Tengeru 97, Marglobe and Money Maker serving as check varieties. The seedlings were transplanted on 3 Sept. 2001, using a randomized complete block design with three replications; plants were spaced 0.75 x 0.5 m apart. Of the 15 lines tested under field conditions at AVRDC-RCA, the yields of five late blight-resistant lines, 4LBR2K8-1(P1.5)R2, 7LBR-28-4(P1.2)R2, 6LBR-28-3(P1.9)R1, 12LBR-29-4(P1.8)R1, and 13LBR-29-6(P1.1)R2, were comparable or better than check varieties (Table 132). Seeds from the five promising lines were harvested, bulked, and sown in December 2001 for further evaluation. For each line, a few plants are still segregating. The high yields of the five late blight-resistant lines show promise in improving tomato production in the African highlands.

Seed production practices for tomato variety Tengeru 97

Tomato cultivar Tengeru 97, initially developed by AVRDC, is fast gaining popularity in eastern and central Africa where it is preferred for its good yields and firm fruit. However, there is little information on production practices that can maximize multiplication of its seed. An experiment was conducted at AVRDC-RCA in Arusha, Tanzania from July to Nov. 2000. The experiment was laid out in a 3 x 5 factorial randomized complete block design with three replications. The treatments consisted of five levels of nitrogen (0, 60, 90, 120, and 180 kg N/ha) and three

Table 132. *Yield and other characteristics of late blight-resistant F_8 tomato lines, AVRDC-RCA, transplanted 3 Sept. 2001.*

Line	Fruit yield (kg/plant)	Fruit yield (t/ha)	Fruit size (g)	Days to 50% flowering[1]	ToLCV incidence[2] (%)	ToMV[2] incidence[2] (%)	Plant habit[3]
4LBR2k8-1(P1.5)R2	3.30 a[4]	88.0 a	137.1 b	24.3 f	0.0 b	0.0 b	ID
5LBR 28-2(P1.1)R2	1.83 e-i	48.8 e-i	83.4 ef	31.0 c	0.0 b	0.0 b	ID
6LBR28-3-(P1.3)R2	2.00 c-g	53.4 c-g	82.7 e-g	21.0 I	0.0 b	0.0 b	SD
6LBR-28-3(P1.3)R3	1.74 f-i	46.3 f-i	66.4 f-h	26.0e	0.0 b	0.0 b	ID
6LBR-28-3(P1.4)R2	1.47 g-i	39.3 g-i	111.3 cd	24.0 f	0.0 b	0.0 b	ID
6LBR-28-3(P1.4)R1	2.12 b-g	56.6 b-g	97.9 c-e	21.3 hi	0.0 b	0.0 b	D
6LBR-28-3(P1.5)R1	1.98 c-g	52.7 c-g	95.3 de	22.3 g	0.0 b	0.0 b	ID
6LBR-28-3(P1.9)R1	2.45 b-e	65.3 b-e	111.3 cd	28.0 d	0.0 b	0.0 b	ID
7LBR-28-4(P1.2)R2	2.80 ab	74.7 ab	104.0 cd	28.0 d	14.6 a	0.0 b	ID
8LBR-10-3(P1.4)R2	1.20 I	32.1 I	64.6 h	26.0 e	0.0 b	0.0 b	ID
12LBR-29-4(P1.8)R1	2.73 ab	72.7 ab	113.8 c	28.0 d	2.1 b	0.0 b	ID
13LBR-29-6(P1.1)R2	2.64 bc	70.3 bc	114.5 c	33.3 a	2.1 b	25.0 ab	ID
14LBR-30-1(P1.6)R1	1.27 hi	33.8 hi	65.1 gh	26.3 e	0.0 b	0.0 b	ID
14LBR-45-1(P1.10)R1	2.23 b-f	59.4 b-f	72.0 f-h	21.0 i	0.0 b	0.0 b	SD
16LBR-30-3(P1.3)R1	1.89 d-h	50.4 d-h	83.0 e-g	30.3 c	0.0 b	0.0 b	ID
Marglobe	2.57 b-d	68.6 b-d	156.0 a	25.7 e	0.0 b	0.0 b	ID
Tengeru 97	2.51 b-e	67.0 b-e	100.1 cd	32.3 b	0.0 b	0.0 b	ID
Money Maker	2.37 b-f	63.2 b-f	75.0 f-h	22.0 gh	6.3 b	37.5 a	ID
CV (%)	16.6	16.6	10.1	1.89	29.5	42.2	

[1]Days to 50% of plants in plot have flowered.
[2]Incidence of tomato leaf curl virus (ToLCV) and tomato mosaic virus (ToMV) data were arcsine transformed before analysis of variance.
[3]ID = Indeterminate; SD = Semideterminate; D = Determinate.
[4]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

spacings (50, 60, and 75 cm). The seedlings were transplanted on 27 July 2000, in raised double-row beds spaced at 90 cm, in plot sizes measuring 0.9 x 6 m. Urea fertilizer treatments were applied in split applications three and six weeks after transplanting. Seed and fruit yields were not significantly influenced by nitrogen application (data not shown), but variation of spacing had a significant influence on fruit yield/ha, seed yield per plant and per ha, and 1000-seed weight (Table 133). The spacing treatment of 50 cm provided the highest yield of seeds. Fertilization practices should take into account local soil conditions.

Open-pollinated cherry tomato lines

Cherry tomato is a crop that is not yet fully utilized in sub-Saharan Africa as consumers prefer large-fruited tomato types. Under the tomato improvement program for African highlands, AVRDC-RCA has been evaluating yield characteristics of selected AVRDC open-pollinated cherry tomato lines to determine their adaptation potential before dissemination. Twenty-seven cherry tomato lines were evaluated from in the fall seasons of 2000 and 2001. The experiments were laid out in randomized complete block design with three replications in plots measuring 6 x 0.6 m in double rows, with a spacing of 0.5 m between plants. The seeds were sown on 13 July 2000 and 13 June 2001, and transplanted on 9 Aug. 2000 and 19 July 2001, respectively. A fertilization of 20N–4.3P–8.3K kg/ha was applied basally during transplanting, followed by a sidedress application of 54N–0P–0K kg/ha three and six weeks later in split application. Weeding and furrow irrigation were applied as necessary. In 2000, lines CLN1555-106-4 and CLN1561-124-2 gave the highest fruit yields, exceeding 55 t/ha. In 2001, lines CLN155-104-4 and CLN1558-100-10 gave the highest yields, approximately 45 t/ha (Table 134). Line CLN1561-124-2 produced a relatively high number of fruits/plant at 251 and 149 during 2000 and 2001, respectively. There was significant variation for all traits measured among the lines. Fruit yields were generally higher in 2000 compared to 2001. Because of their good yields under Arusha conditions, lines CLN1555-106-4, CLN1561-124-2, CLN155-104-4 and CLN1558-100-10 have good potential for intensive cropping systems in the African highlands and will be further evaluated.

Cabbage varieties for tropical highlands

Evaluation trials on 18 cabbage varieties were conducted at AVRDC-RCA in Arusha, Tanzania from July to Nov. 1999 and 2000. The experiments were laid out in randomized complete block design with three replications in plots measuring 6 x 0.7 m each. The plants were spaced at 50 cm and planted in twin rows. An application of 10N–2.2P–4.2K kg/ha was applied basally during transplanting followed by an application of 23N–0P–0K kg/ha applied as a sidedressing three weeks later. The varieties tested were Conquistador, Glory F_1, Cecile F_1, Drumhead, Glory of Enkhuizen, Sugarloaf, Trista, Romenco, Morris, Copenhagen Market, Golden Acre, and Puma in 1999; and Golden Acre, Field Winner, Matsumo, Fresco, Adelita, Mentor, Glory of Enkhuizen and Marmande in 2000.

In 1999, yields ranged from as high as 93 t/ha for Conquistador and Glory F_1 to as low as 24 t/ha for Puma. Puma matured earliest at 57 days while Drumhead matured the latest at 89 days. Drumhead had the largest head diameter (23 cm) while Sugarloaf recorded the highest soft rot incidence (20%) and head cracking percentage (8%).

In 2000, Fresco F_1 produced the highest yield at 127 t/ha, followed by Mentor (115 t/ha). Golden Acre

Table 133. *Effects of spacing on fruit and seed yield characteristics of tomato variety Tengeru 97, AVRDC-RCA, transplanted 27 July 2000.*

Spacing (cm)	Fruits/ plant	Fruit yield (kg/plant)	Fruit yield (t/ha)	Seed yield (g/plant)	Seed yield (g/fruit)	Seeds/ fruit	Seed yield (kg/ha)	1000-seed wt. (g)
50 X 90	14.1 ab[1]	1.63 a	43.5 a	5.8 a	1.4 a	162.1 a	148.7 a	14.4 b
60 X 90	12.9 b	1.58 a	36.3 b	4.3 b	1.4 a	158.6 a	96.8 b	14.9 a
75 X 90	16.2 a	1.88 a	33.5 b	4.8 ab	1.3 a	153.3 a	85.1 b	14.7 a
CV%	29.7	24.9	20.6	29	21	14.9	30.8	2.5

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Table 134. *Evaluation of cherry tomato lines grown at AVRDC-RCA, Fall 2000 and 2001.*

Lines	Fruit yield (t/ha)		Fruit yield (kg/plant)		Fruits/ plant		Days to 50% fruit maturity[1]	Days to 50% flower[2]	Days to 1st fruit maturity[3]
	2000	2001	2000	2001	2000	2001	2001	2001	2001
CLN1561-64-10	40.5 ab[4]	20.4 c	1.52 ab	0.61 e	228.6 ab	138 ab	72.1 a-d	27 a-e	63 a-c
CLN1561-124-2	55.2 ab	29.2 a-c	2.07 ab	0.88 b-e	251.0 a	149 a	73.3 a-c	29 a-d	66 a-c
CLN1558-2-2	50.4 ab	–[5]	1.89 ab	–	274.1 a	–	–	–	–
CLN1561-124-25	48.9 ab	37.0 a-c	1.83 ab	1.11 a-e	160.6 cd	119 a-e	74.3 ab	22 e	46 ab
CLN1555-106-4	56.4 a	–	2.11 a	–	177.8 bc	–	–	–	–
CLN1555-35-1	42.6 ab	27.4 a-c	1.60 ab	0.92 b-e	129.7 cd	93 c-g	76.7 ab	27 a-e	67 a-c
CLN1561-7-5	39.9 b	36.4 a-c	1.49 b	1.09 a-e	120.7 cd	96 b-g	73.0 a-c	22 de	63 a-c
CH155	47.0 ab	29.0 a-c	1.76 ab	0.87 b-e	105.6 d	80 d-h	74.7 ab	31 a-c	67 a-c
CLN1558-100-10	49.2 ab	45.1 ab	1.84 ab	1.35 a-c	164.9 b-d	100 b-f	71.3 a-d	25 c-e	65 a-c
CLN1561-7-13	45.3 ab	–	1.70 ab	–	182.4 bc	–	–	–	–
CH157	47.0 ab	39.2 a-c	1.76 ab	1.18 a-e	144.6 cd	110 a-e	66.6 cd	21 e	57 cd
CH152	51.8 ab	–	1.94 ab	–	135.7 cd	–	–	–	–
CH154	44.8 ab	36.4 a-c	1.68 ab	1.09 a-e	132.3 cd	103 a-f	69.7 b-d	24 c-e	64 a-c
CLN1559-94-8	49.5 ab	–	1.85 ab	–	155.5 cd	–	–	–	–
CH-7C-14-9-8-0	52.5 ab	–	1.97 ab	–	161.0 cd	–	–	–	–
CH33-7C-9-8-0	–	38.9 a-c	–	1.17 a-e	–	109 a-e	75.7 ab	27 a-e	68 ab
CLN152	–	33.5 a-c	–	1.01 a-e	–	77 d-h	70.7 a-d	22 de	64 a-c
CLN2070A	–	26.4 bc	–	0.79 a-e	–	43 h-j	73.7 a-c	24 c-e	62 bc
CLN2071C	–	27.6 a-c	–	0.83 b-e	–	56 f-i	73.3 a-c	26 b-e	72 a
CLN1561	–	26.7 a-c	–	0.80 b-e	–	126 a-d	70.7 a-d	26 b-e	64 a-c
CLN155-104-4	–	45.9 a	–	1.38 ab	–	123 a-e	74.0 d	26 b-e	67 a-c
CLN1558	–	24.4 c	–	0.73 ae	–	144 ab	65.3 d	22 de	53 d
CLN1859-94-8	–	25.7 c	–	0.77 c-e	–	84 e-h	70.0 b-d	27 a-e	64 a-c
CV (%)	16.9	30.3	16.90	29.00	20.6	28	5.1	5	7

[1]Days to 50% of plants in plot produce mature fruit.
[2]Days to 50% of plants in plot bloom.
[3]Days to first mature fruit in plot.
[4]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
[5]Not tested.

was next highest at 110 t/ha, which was a little surprising since it only produced 30 t/ha in 1999. The lowest yields in 2000 were from Marmande (37 t/ha) and Glory of Enkhuizen (56 t/ha). Glory of Enkhuizen showed the highest soft rot and head cracking percentages at 33 and 12%, respectively; such high levels of rot and cracking were not seen with this variety in 1999. Conquistador, Drumhead, and Marmande were free of soft rot. In 2000, head diameters ranged from 16–17 cm, with the exceptions of Marmande (11 cm) and Glory of Enkhuizen (12 cm).

These experiments showed that some commercial cabbage varieties can adapt to tropical highland conditions in Africa and further evaluation will be needed to determine recommended varieties and expected yields.

Disease-resistant, high yielding sweet pepper lines for Africa

In sub-Saharan Africa, the biggest constraint to pepper production are diseases which in many cases can create yield losses of up to 50%. The use of genetic resistance remains the best control strategy. Since 1997, an ongoing collaborative project between AVRDC-RCA and Institut National de la Recherche Agronomique (INRA) in France has tested multi-disease sweet pepper lines in Tanzania, where screening for resistance to fungal (phytophthora blight) and viral (cucumber mosaic virus, potato virus Y and tobacco etch virus) diseases have been ongoing. Seeds of 35 progenies from intercrosses of the best sub-populations evaluated in 1998 were sown and transplanted in Feb.

2000. Seeds of the 26 best plants (based on disease resistance) in each family were harvested and re-sown on 14 June 2000 to determine the best yielding lines in addition to disease resistance. Transplanting was done on 4 Aug. 2000. The experiment was laid out in randomized complete block design with three replications in double rows of plot sizes measuring 0.9 x 6 m each. Spacing between plants was 50 cm. An application of 36.1N–4.3P–8.3K fertilizer was used as a sidedressing two weeks after transplanting, followed by an additional 16.1N–0P–0K three weeks later.

Lines Tz 22, Tz 16, Tz 1, Tz 12, Tz 4 and Tz 14 showed promising yield characteristics (Table 135). Lines Tz2, Tz 13 and Tz 14 flowered earliest while Tz6, Tz16, Tz12 and Tz1 gave the highest number of fruits per plant. Seeds of the best plant in each subpopulation were harvested and will be used for further testing of horticultural characteristics.

Cultural practices for African nightshade

Nightshade (*Solanum scabrum, S. villosum* or *S. americanum*) is an important indigenous vegetable in many parts of Africa. The crop requires cool climates and moist soil to grow well, but otherwise it requires very little input. It could become an important cash crop for growers if suitable varieties and cultural practices can be developed. Evaluation trials were conducted at AVRDC-RCA in Arusha, Tanzania from Aug. to Dec. 2000 and 2001 to determine optimum cultural practices and yield potential of 31 nightshade lines.

Evaluation of lines, spacings and N fertilization

In year 2000, two lines of nightshade, SS 52 and SS 47, were used to evaluate the effect of spacing and N

Table 135. *Yield and horticultural traits of sweet pepper lines evaluated at AVRDC-RCA, transplanted 4 Aug. 2000.*

Line	Days to 50% flowering[1]	No. of fruits/plant	Fruit yield (kg/plant)	Fruit yield (t/ha)	Fruit length (cm)	Fruit width (cm)
Tz 1	53.3 ab[2]	7.1 a-d	1.1 a-c	28.3 a-c	10.7 ab	4.5 bc
Tz 2	36.7 c	3.6 e	0.9 a-e	24.0 a-e	8.7 e-h	5.7 ab
Tz 3	43.3 bc	2.4 e	0.4 e	11.0 e	9.8 b-g	4.2 c
Tz 4	50.0 a-c	4.8 b-e	0.9 a-d	25.7 a-d	9.3 b-h	6.5 a
Tz 5	43.3 bc	3.9 de	0.9 a-e	23.0 a-e	8.4 gh	6.0 ab
Tz 6	50.0 a-c	9.6 a	0.8 b-e	21.4 b-e	8.6 f-h	6.3 ab
Tz 7	46.7 a-c	3.6 e	0.5 de	13.5 de	9.5 b-h	5.3 a-c
Tz 8	60.0 a	2.8 e	0.6 c-e	15.2 c-e	9.4 b-h	6.3 ab
Tz 9	43.3 bc	3.3 e	0.6 c-e	14.8 c-e	9.7 b-g	5.1 a-c
Tz 10	56.7 ab	7.9 ab	0.7 b-e	19.7 b-e	9.4 b-h	5.5 a-c
Tz 11	43.3 bc	3.4 e	0.7 b-d	18.5 b-e	8.5 gh	5.4 a-c
Tz 12	43.3 bc	7.4 a-c	1.0 a-c	27.4 a-d	8.7 f-h	6.2 ab
Tz 13	36.7 c	5.0 b-e	0.8 b-e	20.9 b-e	10.5 a-c	6.4 a
Tz 14	36.7 c	4.5 c-e	0.9 a-e	24.6 a-e	9.2 c-h	6.1 ab
Tz 15	53.3 ab	4.9 b-e	0.8 b-e	21.0 b-e	8.9 d-h	6.1 ab
Tz 16	46.7 a-c	7.5 a-c	1.1 ab	29.5 ab	11.2 a	6.2 ab
Tz 17	53.3 ab	4.7 b-e	0.7 b-e	24.5 a-d	9.7 b-g	5.4 a-c
Tz 18	60.0 a	3.6 e	0.8 b-e	19.6 b-e	9.7 b-g	6.1 ab
Tz 19	46.7 a-c	2.8 e	0.9 a-e	21.7 b-e	9.2 c-h	5.2 a-c
Tz 20	53.3 ab	4.1 de	0.9 a-e	23.6 a-e	8.7 f-h	5.6 a-c
Tz 21	43.3 bc	5.1 b-e	1.3 a	23.8 a-e	8.1 h	5.1 a-c
Tz 22	46.7 a-c	5.2 b-e	0.5 de	35.6 a	9.4 b-h	5.0 a-c
Tz 23	60.0 a	3.7 e	0.9 a-e	13.5 de	9.5 b-h	5.2 a-c
Tz 24	46.7 a-c	3.5 e	0.7 b-e	20.1 b-e	10.2 a-e	5.6 a-c
Tz 25	60.0 a	3.8 e	0.8 a-e	22.5 a-e	10.2 a-d	5.9 a-c
Tz 26	43.3 bc	4.8 b-e	0.8 a-e	22.4 a-e	10.1 a-f	5.4 a-c
CV(%)	14	36	32.3	32.3	7.9	16.1

[1]Days to 50% of plants in plot have flowered.

[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

fertilization on leaf yield. The experiment was a 2 x 2 x 4 factorial laid out in randomized complete block design with three replications; there were two rows of each line per plot. The treatments consisted of two spacings of 30 and 50 cm, and urea applications of 100, 150, and 200 kg N/ha.

SS 52 significantly outyielded SS 47. The spacing of 30 cm gave significantly higher yields compared to 50 cm. The N application effects were inconclusive, as SS 52 responded positively to higher urea treatments, but no clear response could be identified for SS 47 (Table 136). This study concludes that 30 cm is the best spacing for nightshade. Fertilizer inputs are dependent upon genotype, but in general, low fertilizer inputs will lead to relatively low but satisfactory yields.

Table 136. *Leaf yields (t/ha) of two* Solanum scabrum *lines as affected by nitrogen and spacing[1], at AVRDC-RCA, transplanted early August 2000.*

N	SS 52			SS 47		
(kg/ha)	30 cm	50 cm	Mean	30 cm	50 cm	Mean
0	5.63	4.27	4.95 b[2]	4.07	2.80	3.43 ab
100	7.51	5.14	6.33 ab	2.90	2.72	2.81 b
150	8.26	4.78	6.49 ab	5.14	2.73	3.94 a
200	10.13	4.86	7.50 a	4.47	3.29	3.87 a
Mean	7.87 a	4.76 b		4.14 a	2.89 b	

[1]Among interactions, Genotype x Spacing was significant at $P \leq 0.05$; all others were nonsignificant. CV (%) = 21.5 for all treatments.

[2]Mean separation by Duncan's multiple range test at $P \leq 0.05$.

Evaluation of lines

Experiments were laid out in randomized complete block design with three replications. In both years, seedlings were transplanted at the beginning of August. Rows were spaced 90 cm apart in 2000 and 60 cm in 2001. For both years, plants were spaced 40 cm apart in rows. In year 2000, 50N–4.3P–8.3K kg/ha fertilizer was applied as a sidedressing two weeks after transplanting followed by an application of 30N kg N/ha urea fertilizer two weeks later. In year 2001, 100N–10.8P–20.8K kg/ha fertilizer was applied as a sidedressing two weeks after transplanting followed by an application of 50 kg N/ha of urea two weeks later. The experiment in 2001 was divided into two trials to obtain comprehensive yield data at different locations with slightly different soil fertility within the research farm.

Leaf yields varied markedly among the lines in both years. In the 2000 trial, lines SS 49, SS 52, and *S. americanum* showed leaf yields greater than 21 t/ha. In Trial 1 of 2001, lines SS 40, *S. villosum, S. americanum* and SS 25.1 produced the highest yields, ranging from 16 to over 30 t/ha (Table 137). In Trial 2 of 2001, SS 47(SN15) and SS 52(SN 14) showed the best yields. The climate was much colder in 2000 compared to 2001.

Table 137. *Yields of African nightshade lines, AVRDC-RCA, transplanted early August 2000 and 2001.*

	Leaf yield (t/ha)		
	2000	2001	
Line[1]	Trial 1[2]	Trial 1[3]	Trial 2[4]
SS 47	12.2 bc[5]	8.57 b	–[6]
SS 47 (SN15)	–	–	28.05 a
SS 05.1	–	9.16 b	–
SS 25.1	–	16.23 ab	–
SS 52	22.3 a	13.76 ab	12.50 a
SS 52 (SN14)	–	–	20.30 a
SS 08	–	12.09 b	–
S.americanum	21.5 a	16.96 ab	–
S.americanum (SN1)	–	–	7.64 a
SS 02.1	–	9.43 b	15.28 a
SS 19	–	15.22 ab	11.94 a
SS 40	19.3 ab	30.61 a	–
SS 40 (SN12)	–	–	11.39 a
SS 04.2	–	15.63 ab	9.30 a
SS 13	–	5.47 b	–
SS 18	–	15.55 ab	–
SS 01	–	5.58 b	–
SS 06	–	10.23 b	11.66 a
SS09	–	–	11.94 a
S. villosum	10.90 c	22.07 ab	–
S. villosum (ex-Tengeru)	–	12.21 b	–
SS 15	–	11.33 b	–
SS 09	–	8.01 b	–
SS 49	25.90 a	16.72 ab	–
SS49 (SN13)	–	–	9.24 a
SS49 (N6)	–	–	11.39 a
SS49 (N5)	–	–	6.94 a
SS49 (N4)	–	–	12.10 a
SS Hai Kilimanjaro	19.30 ab	–	–
SS Hai Kilimanjaro (SN2)	–	–	9.24 a
SS Hai Kilimanjaro (SN3)	–	–	9.31 a
CV (%)	21.9	25.5	22

[1]SS = *Solanum scabrum.*

[2, 3, 4]Mean values of six, four, and two harvests, respectively.

[5]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

[6]Not tested.

Garlic lines for sub-Saharan Africa

Garlic production in sub-Saharan Africa is low as a result of poor yields, lack of virus-resistant varieties, and inadequate markets. These constraints have created a need to identify superior genotypes for adaptation. Garlic is vegetatively propagated and may have many viruses that reduce yield. AVRDC routinely eliminates viruses through meristem-tip culture.

Ten AVRDC virus-indexed garlic clones and one check entry (Kenya 2) were evaluated in the open field at AVRDC-RCA in Arusha, Tanzania from June to Nov. 2001. The experiment was laid out in randomized complete block design with four replications. Cloves were planted on beds raised 15 cm high, 60 cm wide and 100 cm long. Furrow irrigation was applied once a week, and 50N–10.8P–20.8K kg/ha was applied six weeks after planting. Harvesting was done 137 days after planting, and the bulbs were cured for one week before data analysis.

Results showed that VFTA325, G50-1-1-2, VFTA158, G98-6-1-1, Kenya 2, VFG176, and VFG180 produced yields greater than 20 t/ha (Table 138). VFTA 325 showed the best bulb yield, bulb size, bulb length and diameter, and the highest plant height at maturity. VFG34 gave the highest number of cloves/bulb and split bulbs. VFTA 275 showed the highest top setting percentage at 66%. Thrips infested 41-55% of bulbs, depending on entry.

The yield results are slightly higher than previously reported (*AVRDC Report 2000*) and may be attributed to conducive environmental factors during the growth period. VFTA 275 showed the best yield characteristics in year 2001 whereas VFG180 which recorded the best yields in year 2000. These and other promising lines will be further evaluated for yield characteristics at AVRDC-RCA to determine whether virus re-infection will reduce yields substantially.

Spacing studies of African eggplant

African eggplant (*Solanum aethiopicum*) is an important traditional vegetable in several parts of sub-Saharan Africa but the production technology is still lacking. This experiment was conducted in Arusha, Tanzania from July 2000 to Feb. 2001. The experiment was laid out in a 4 x 4 factorial randomized complete block design with three replications. Plots were 6 m long, with two rows planted for each accession. In-row spacing treatments of 50, 60, 70, or 80 cm were used with rows spaced 90 cm apart. An application 20N–4.3P–8.3K kg/ha was basally applied during transplanting, followed by a sidedressing of 55.2N–0P–0K kg/ha three, six and nine weeks after transplanting in split application. Furrow irrigation and other cultural practices were carried out as necessary. Six harvests were made in total.

Table 138. *Yield and horticultural characteristics of garlic accessions grown in the open field at AVRDC-RCA, transplanted June 2001.*

Accession	Bulb yield (t/ha)	Bulb weight (g)	Neck thickness (mm)	Cloves/ bulb	Bulb length (mm)	Bulb diameter (mm)	Mature plant ht. (cm)	Top setting (%)	Bulb splitting (%)	Thrips incidence[1] (%)	Bulb shape
VFTA325	28.7 a[2]	38.5 a	29.7 bc	17.5 ab	43.3 a	44.9a	32.0 a	10.7 bc	2.5 a	41.5 b	Flat globe
VFG34	13.9 cd	22.3 c	18.2 de	21.0 a	34.4 d	36.6 d	22.0 cd	0.0 c	82.5 a	53.5 a	Thick flat
G98-6-1-1	22.5 ab	27.3 bc	27.1 bc	11.5 de	34.8 d	37.5 d	22.8 c	0.0 c	25.0 c-e	47.5 ab	Thick flat
VFG173	13.5 cd	23.8 c	19.0 de	15.9 b-d	33.6 d	38.1 cd	22.9 cd	5.7 bc	42.5 bc	41.0 b	Thick globe
VFG176	21.5 a-c	36.9 a	29.4 bc	9.9 e	41.9 a	43.5 ab	28.4 b	79.0 a	67.5 ab	48.8 ab	Thick flat
VFG180	21.3 a-c	32.5 ab	31.6 b	9.3 e	38.8 bc	41.3 a-d	24.4 c	18.0 b	2.5 e	54.8 ab	Flat globe
G98-9	16.1 b-d	31.3 ab	30.0 bc	13.4 b-e	38.1 bc	38.8 b-d	23.6 cd	0.0 c	12.5 de	49.8 ab	Globe red
VFTA275	11.2 d	25.8 bc	24.4 c-e	15.8 b-d	34.8 d	40.1 b-d	21.4 cd	66.0 a	45.0 bc	54.0 a	Flat globe
VFTA158	23.0 ab	35.3 a	38.1 a	9.5 e	40.5 ab	42.5 a-c	23.6 cd	13.7 bc	10.0 de	55.0 a	Thick flat
G50-1-1-2	25.3 a	37.8 a	29.9 bc	12.5 c-e	41.6 d	38.8 b-d	23.9 c	0.0 c	12.5 de	48.0 ab	Flat globe
Kenya 2 (ck)	22.4 ab	20.8 c	23.9 c-e	16.7 a-c	36.4 cd	36.7 d	20.3 d	0.0 c	37.5 cd	52.3 a	Flat globe
CV (%)	20.5	15.5	14.4	20.48	4.8	7.32	8.8	52.4	57	12.4	

[1]Thrips incidence was rated on a scale of percent infestation on surface of leaf. 0% no infestation; 50% moderate; and 100% severe infestation.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Accession DB_3 produced the most fruits per plant, fruit yield, and the longest fruit length when compared to other accessions (Table 139). Manyire Green showed the largest fruit size and the longest pedicel, but gave the least number of fruits and lowest yield. Spacing did not significantly influence the number of fruits per plant and fruit size, but gave significantly higher fruit yields at 50 cm. The yield results confirm the observations made in 1999 (*AVRDC Report 2000*) that showed that DB_3, AB_2 and Tengeru White are promising accessions which should be promoted for wider adaptation and cultivation.

Seed production of vegetable soybean

Vegetable soybean has potential in developing countries, especially in Africa, where it remains relatively unknown. Vegetable soybean can effectively diversify the cropping system, enhance soil productivity, improve farmer's income, and provide additional protein, vitamins and minerals to the diet. It can be cultivated in the tropics throughout the year with greater yields realized in summer. However, different accessions are adapted to different seasons and localities, which necessitates the cultivation of an appropriate line at a specific location. Significant interactions between genotypes and season have been observed for various agronomic characteristics. This suggests a need to select genotypes for specific environments. Research work on the introduction and evaluation of vegetable soybean was initiated at AVRDC-RCA in 1997. Evaluation experiments on yield adaptation were conducted during 1997, 1998, and 2000 on AVRDC vegetable soybean lines. The fresh pod yield ranged from 8.0 to 9.8 t/ha while the number of pods per plant were significantly higher in AGS329 and AGS338 than other lines tested. The taste analysis results were found to be acceptable in all lines. On the basis of fresh pod yield characteristics and organoleptic tests by various groups, lines AGS339, AGS329, AGS338, and AGS292 were selected for further evaluation, utilization and promotion.

Two separate trials to assess the seed production potential of the four promising lines were carried out during May to Nov. 2000. The experiments were laid out in randomized complete block design with three replications in beds measuring 6 x 0.45 m and 4 x 1.2 m for trial 1 and trial 2, respectively. The spacing between plants was 10 x 15 cm in two rows for the first trial and in 5 rows for the second trial. The first trial was sown and harvested without any fertilizer application while the second trial received four levels of 20N–4.3P–8.3K fertilizer application which however, did not influence seed yields.

The results of the two trials were combined as shown in Table 140. The seed yield ranged from 3.3

Table 139. *Evaluation of yield and horticultural characteristics of African eggplant accessions as affected by spacing, at AVRDC-RCA, July 2000–Feb. 2001.*

Accession[1]	Fruits/ plant	Fruit size (g)	Fruit yield (kg/plant)	Fruit yield (t/ha)	Pedicel length (cm)	Fruit length (cm)	Fruit diameter (cm)
Manyire Green	26.3 c[2]	51.9 a	1.36 b	28.7 b	3.58 a	4.06 c	4.43 a
Tengeru White	43.8 b	37.4 bc	1.60 ab	33.6 ab	3.08 b	4.06 c	4.67 a
AB_2	40.4 b	43.3 ab	1.65 ab	35.1 ab	2.00 c	4.87 b	2.52 c
DB_3	56.6 a	31.0 c	1.75 a	37.0 a	2.19 c	6.20 a	2.96 b
CV (%)	24	25.5	25	25.8	12.5	13.7	12.7
Spacing (cm)[3]							
50	37.7	41.5	1.45	39.4 a	2.84	4.89	3.68
60	44.6	38.3	1.63	36.3 ab	2.72	4.69	3.70
70	39.1	44.2	1.58	30.1 b	2.71	4.69	3.68
80	45.7	39.6	1.71	28.5 c	2.59	4.93	3.52
CV (%)	24	25.5	25	25.8	12.5	13.7	12.7

[1]For all accessions, mean values of four spacing treatments are used.
[2]Mean separation in columns within accession or spacing treatments by Duncan's multiple range test at $P \leq 0.05$.
[3]For all spacings, mean values of the four accessions are used.

Table 140. *Seed characteristics and yield of vegetable soybean lines evaluated at AVRDC-RCA, in two trials (combined data) conducted from May to Nov. 2000.*

Lines	Seed yield (kg/ha)	Seed yield (g/plant)	Dry matter yield (g/plant)	Seeds/ plant	Pods/ plant	Seeds/ pod	Pod length (cm)
AGS 338	4123	24.74	10.10 a[1]	44 a	19	1.67	4.0 a
AGS 339	3511	21.07	11.69 a	28 b	21	2.00	2.7 c
AGS 329	3305	19.83	7.29 b	28 b	18	2.00	3.4 b
AGS 292	3272	19.63	11.10 a	28 b	19	1.67	4.0 a
F-test	NS	NS	*	NS	NS	NS	**
CV (%)	21	21.00	13.00	22	9.2	27.64	6.2

NS,*,** Nonsignificant or significant at $P \leq 0.05$, 0.01, respectively.
[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

to 4.1 t/ha with AGS 292 and AGS 338, respectively. The number of seeds/plant was slightly higher in AGS338 than the other lines, while the pod length was significantly higher in AGS292. The seed yield results in these experiments indicate potential for multiplication of these lines in the African highlands.

Yield response of spider flower plant to spacing and nitrogen levels

Spider flower plant (*Cleome gynandra*) is an important crop in the everyday diet of rural households where it is widely grown, but is increasingly becoming scarce in the markets, especially in urban areas. AVRDC-RCA aims to improve its production potential. An experiment to evaluate the response of the crop to different spacing and nitrogen (N) levels was conducted at AVRDC-RCA in July–December, 2000. The experiment was laid out in 3 X 5 factorial, using a randomized complete block design with three replications. There were three spacings between plants (25, 50, and 75 cm) and five nitrogen levels (0, 60, 90, 120, and 150) kg N/ha. Seeds were sown in twin rows spaced 90 cm apart in beds of 6.0 x 0.9 m. Furrow irrigation was applied as necessary.

A spacing of 25 cm gave the highest leaf yield (fresh weight), dry matter, seed yields and 100-seed weight (Table 141). Fertilizer application did not show any significant differences in yield and other horticultural characteristics.

Training

Training in Sudan

Three intensive in-country vegetable production courses were held in Yambio, Rumbek and Aweil East counties in southern Sudan on 22–29 Jan., 30 June to 6 July, and 17–22 Nov. 2001. One hundred and thirty participants from self-help groups and NGOs attended the courses organized by AVRDC-RCA in collaboration with United Nations Children's Fund (UNICEF) Operation Lifeline Sudan. Following these training courses, 934 kg of vegetable seeds as well as publications and extension handouts were distributed to training participants, local authority representatives and farmers in collaboration with UNICEF Household Food Security Project. Seventy percent of the training participants rated the course excellent and very useful.

Table 141. *Leaf yield and seed characteristics of spider flower plant in response to spacing, AVRDC-RCA, July–Dec. 2000.*

Spacing (cm)	Yield (kg/plant)	Yield (t/ha)	Pods/ plant	Seeds plant	Seeds pod	Seed yield (g/plant)	seed yield (kg/ha)	100-seed weight (g)
25	0.15	7.82 a[1]	125	5357	42	7.7	413	146 a
50	0.17	4.53 b	175	8360	49	11.7	312	138 ab
75	0.15	2.66 c	174	9287	54	12.6	224	135 b
CV (%)	20	14	24	33	17	36	42	2.67

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Regional Vegetable Production Training Course

The 8th Regional Vegetable Production Training Course for sub-Saharan African countries was held from 10 July to 9 Nov. 2001. Nineteen participants (female = 11; male = 8) from NARES in 14 countries, namely Malawi (1), Seychelles (1), Kenya (1), South Africa (1), Zambia (1), Namibia (1), Lesotho (2), Swaziland (1), Uganda (1), Rwanda (1), Mauritius (1), Botswana (1), Sudan (1), and Tanzania (5) attended the training course. A course evaluation by the training participants found the lectures and practicals useful and helpful for them to improve the quality of their duties upon returning to work.

Tomato and indigenous vegetable processing courses

Tomato and indigenous vegetable processing courses were conducted for rural farmers and women's groups in Arusha, Tanzania on 5–6, 12–13, and 22–23 Nov. 2001. Fifty-nine women attended the training courses where they learned new skills on how to make tomato products and preserve indigenous vegetables for long-term utilization.

Field Day

A Farmer's Field Day was conducted at AVRDC-RCA on 24 Oct. 2001. The event featured technology demonstrations and a vegetable show. One hundred and twenty-five farmers, research scientists and personnel from NARES and the private sector attended. Demonstrations were followed by a question-and-answer session with the aim of addressing farmers' problems.

Workshops

Workshop on vegetable research and development in West Africa

A workshop on vegetable research and development in West Africa was conducted at AVRDC-RCA on 5–6 Feb. 2001. The major objectives of the workshop were to identify the current status and constraints of vegetable production systems, prioritize research areas, prepare a work plan, and present a national policy and future strategies for vegetable research and development. Representatives of 11 West African countries that include Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Gambia, Ghana, Mali, Niger, Nigeria, Senegal and Togo made a presentation on the status of vegetable research and development in their respective countries. During this workshop, the West African Vegetable Network (WAVNET) was conceived and AVRDC was requested by all participants to be the coordinating agency.

National review and planning workshop in Mauritius

A national review and planning workshop on "Vegetable Research and Development" was held in Mauritius on 12–13 Sept. 2001, in collaboration with the Mauritius Agricultural Research and Extension Unit. The objective of the workshop was to identify the current constraints to vegetable production, prioritize the vegetable research and development agenda, and develop a workplan for strategies in vegetable R&D in Mauritius. Thirty-four participants from AVRDC-RCA, Agricultural Research and Extension Unit of Mauritius, Food and Agricultural Research Council, Southern Planter's Association, Agricultural Development & Marketing Association, Ministry of Agriculture-Agricultural Services, Agricultural Marketing Cooperative Federation, and Mauritius Sugar Research Institute attended the workshop.

Organizational Statement

Our Mission

Improve nutrition and reduce poverty in the tropics 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

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
- Safeguard genetic resources for worldwide use within the framework of international undertaking
- Provide globally accessible, user-friendly, science-based information

Staff

Administration

Dr. Samson C. S. Tsou, Director General, <cstsou@netra.avrdc.org.tw>
Dr. Jürgen Friedrichsen, Deputy Director General, cum Acting Director of Administration <jfrie@netra.avrdc.org.tw>
Dr. Meisaku Koizumi, Assistant Director General (Project 7 Coordinator), <koiz_arc@ksc.th.com>
Mou-sen Fu, Assistant Auditor, <jimfu@netra.avrdc.org.tw>
Shaw-wei Chai, Associate Comptroller, <nancy@netra.avrdc.org.tw>
Jeng-hua Chen, Superintendent, Technical Service Office[3], <jhchen@netra.avrdc.org.tw>
Sui-fang Wu, Superintendent, Food and Dormitory Services Unit, <lydia@netra.avrdc.org.tw>

Program I: Vegetables in cereal-based systems

Dr. S. Shanmugasundaram, Program Director, <sundar@netra.avrdc.org.tw>

Bulb Allium Unit

Dr. S. Shanmugasundaram, Plant Breeder (Project 2 Coordinator), <sundar@netra.avrdc.org.tw>
Shin-jiun Cherng, Principal Research Assistant, <sjcherng@netra.avrdc.org.tw>
Swee-suak Ko, Principal Research Assistant, <rachelko@netra.avrdc.org.tw>

Legume Unit

Dr. S. Shanmugasundaram, Plant Breeder (Project 3 Coordinator), <sundar@netra.avrdc.org.tw>
Miao-rong Yan, Research Assistant, <yanmr@netra.avrdc.org.tw>

Pepper Unit

Sheue-chin Shieh, Research Assistant, <jin@netra.avrdc.org.tw>

Plant Pathology: Mycology Unit

Dr. Lowell L. Black, Plant Pathologist, <llblack@netra.avrdc.org.tw>
Dr. Tien-chen Wang, Associate Specialist, <tcwang@netra.avrdc.org.tw>

Plant Pathology: Virology Unit

Dr. Sylvia K. Green, Plant Pathologist, <skg@netra.avrdc.org.tw>
Dr. Seung-Ryong Cheong, Associate Plant Pathologist (Seconded Scientist from Korea), <cheongsr@netra.avrdc.org.tw>
Wen-shi Tsai, Principal Research Assistant, <wenshi@netra.avrdc.org.tw>
Su-ling Shih, Principal Research Assistant, <suling@netra.avrdc.org.tw>

Plant Physiology Unit

Dr. C. George Kuo, Plant Physiologist, <gkuo@netra.avrdc.org.tw>
Dr. Chien-an Liu, Assistant Scientist - Molecular Biology, <liuchien@netra.avrdc.org.tw>
Huei-mei Chen, Associate Specialist, <hmchen@netra.avrdc.org.tw>
Shiow-wen huang, Principal Research Assistant[1], <wen@netra.avrdc.org.tw>
Chun-ling Wang, Principal Research Assistant (Project)[1]
Jean-yu Lin, Principal Research Assistant (Project)[2] <jean@netra.avrdc.org.tw>
Li-chien Weng, Principal Research Assistant (Project)[2] <claire@netra.avrdc.org.tw>
Yen-wei Wang, Principal Research Assistant (Project)[2] <vivian@netra.avrdc.org.tw>

Tomato Unit

Dr. Peter H. Hanson, Associate Plant Breeder (Project 1 Coordinator), <hansp@netra.avrdc.org.tw>
Jen-tzu Chen, Associate Specialist, <jtchen@netra.avrdc.org.tw>

Program II: Year-round vegetable production systems

Dr. Lowell L. Black, Program Director, <llblack@netra.avrdc.org.tw>

Crop and Soil Management Unit

Dr. Volker Kleinhenz, Associate Scientist for Crop and Soil Management Unit[1]
Dr. Chin-hua Ma, Associate Specialist, <mach@netra.avrdc.org.tw>
Dr. Manuel C. Palada, Visiting Scientist[1,2]
Dolores R. Ledesma, Assistant Specialist, <didit@netra.avrdc.org.tw>
Deng-lin Wu, Research Assistant, <dlwu@netra.avrdc.org.tw>

Entomology Unit

Dr. N. S. Talekar, Entomologist (Project 5 Coordinator), <talekar@netra.avrdc.org.tw>
Mei-ying Lin, Principal Research Assistant, <turtle@netra.avrdc.org.tw>
Fu-cheng Su, Research Assistant, <sufc@netra.avrdc.org.tw>

Nutrition and Analytical Laboratory

Dr. Samson C. S. Tsou, Biochemist, <cstsou@netra.avrdc.org.tw>
Ray-yu Yang, Assistant Specialist, <ryy074@netra.avrdc.org.tw>

Olericulture Unit

Lien-chung Chang, Associate Specialist, <lcchang@netra.avrdc.org.tw>
Dr. Manuel C. Palada, Visiting Scientist[1,2]

Plant Pathology: Bacteriology Unit

Dr. Jaw-fen Wang, Associate Plant Pathologist, <jfw@netra.avrdc.org.tw>
Chih-hung Lin, Principal Research Assistant, <chlin@netra.avrdc.org.tw>
Ying-ju Tsai, Research Assistant, <dinah@netra.avrdc.org.tw>

Socioeconomics Unit

Dr. Mubarik Ali, Associate Agricultural Economist (Project 6 Coordinator), <mubarik@netra.avrdc.org.tw>
Dr. Katinka Weinberger, Research Associate - Socioeconomist, <weinberg@netra.avrdc.org.tw>
Mei-huey Wu, Principal Research Assistant, <mhwug@netra.avrdc.org.tw>
Ying-yen Shih, Research Assistant (Project)[2]<yingyen@netra.avrdc.org.tw>

Program III: Collaboration in research and germplasm management

Dr. C. George Kuo, Program Director (Projects 9 and 12 Coordinator), <gkuo@netra.avrdc.org.tw>

Computer Services Unit

Hsien-yang Tien, Assistant Specialist, <tien@netra.avrdc.org.tw>
Yuh-ling Chen, Research Assistant, <shirley@netra.avrdc.org.tw>

Genetic Resources and Seed Unit

Dr. Liwayway M. Engle, Geneticist and Head (Project 8 Coordinator), <lmengle@netra.avrdc.org.tw>
Dr. Takanori Sato, Associate Geneticist (Seconded Scientist from Japan), <ryutoku@netra.avrdc.org.tw>
Yung-kuang Huang, Principal Research Assistant, <ykhuang@netra.avrdc.org.tw>
Jia-chain Shieh, Research Assistant, <jcshieh@netra.avrdc.org.tw>
Ching-huan Chang, Research Assistant, <jessica@netra.avrdc.org.tw>
Shu-chuan Lin, Research Assistant[2] (Project), <smile@netra.avrdc.org.tw>

Information and Documentation Unit: Library

Fang-chin Chen, Chief Officer, <fcchen@netra.avrdc.org.tw>

Communications and Training Office (CTO)

David G. Abbass, Associate Information Officer (Project 10 Coordinator)[1]
Tom Kalb, Information and Training Officer and Head, (Project 11 Coordinator)[3], <kalb@netra.avrdc.org.tw>
Chris Cottorone, Associate Information Officer[2], <chris@netra.avrdc.org.tw>
Ronald G. Mangubat, Assistant <mangubat@netra.avrdc.org.tw>
Yi-ming Chen, Principal Research Assistant, <ymchen@netra.avrdc.org.tw>

Technology Promotion and Services Unit

Li-ju Lin, Principal Research Assistant, <mandy@netra.avrdc.org.tw>

Regional Programs

Asian Regional Center, Bangkok, Thailand

Dr. Romeo T. Opeña, Director[1]
Dr. Meisaku Koizumi, Acting Director and CLV Network Coordinator[4], <koiz_arc@ksc.th.com>
Dr. Thierry X. Jaunet, Associate Plant Pathologist[1]
Efren Altoveros, Training and Information Officer[2], <ealtoveros@yahoo.com>

Africa Regional Program, SADC-AVRDC-CONVERDS, Arusha, Tanzania

Dr. Madan Mohan Lal Chadha, Director, <avrdc-arp@cybernet.co.tz>
Dr. Rémi Nono-Womdim, Associate Plant Pathologist[1]
Dr. Mel O. Oluoch, Training Specialist at AVRDC-ARP <avrdc@cybernet.co.tz>

AVRDC' s "Peri-urban Vegetable Production Systems" Project Philippines Site

Dr. James R. Burleigh, Philippines Site Coordinator[1], (c/o Dr. Gerard Bruin, Philippine Site Director <jburleigh@csuchico.edu>)[b]

AVRDC/CIRAD "SE-Asia Peri-urban Agriculture Project," Hanoi, Vietnam

Dr. Hubert de Bon, Production Systems Specialist and Project Coordinator (Seconded Scientist from France), <hubertdebon@hn.vnn.vn>

Outreach Programs

Indonesia – AVRDC Vegetable Research Program

Dr. Prabowo Tjitropranota, Director, Central Research Institute for Horticulture, Jalan Ragunan 29, Pasar Minggu, Jakarta, Indonesia

Korea AVRDC Outreach Program

Mr. Won-Jin Kim, Director General, <shd@rda.go.kr>, National Horticultural Research Institute, Rural Development Administration, 475 Imok-Dong, Jangan-gu, Suwon 440-310, Korea

Malaysia – AVRDC Vegetable Research Program

Dr. Md Sharif bin Ahmad, Director General, Malaysian Agricultural Research and Development Institute, Kuala Lumpur, Malaysia

Philippines – AVRDC Outreach Program

Adoracion A. Virtucio, Project Director, <bpi_eg98@laguna.net>, Los Baños National Crop Research and Development Center (BPI-LBNCRDC), BPI Region IV, Los Baños, Laguna 4030, Philippines

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[1] **Left during 2001.**
[2] **Arrived during 2001.**
[3] **Promoted in 2001.**
[4] **Additional assignment.**

Trainees at Headquarters

Bulb Alliums Unit

Yu-ting Yang, Undergraduate Student Trainee, Taiwan (12 July 2001–11 Sept. 2001)

Communication and Training Office

Chia-hao Mah, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Tsung-hua Wu, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yun-sheng Chen, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Chan Phaloeun, Production Intern, Cambodia (11 Dec. 2001–14 Dec. 2001)
Khiev Bunnarith, Production Intern, Cambodia (11 Dec. 2001–14 Dec. 2001)
Men Sarom, Production Intern, Cambodia (11 Dec. 2001–14 Dec. 2001)
Sakhan Sophany, Production Intern, Cambodia (11 Dec. 2001–14 Dec. 2001)
Sok Songly, Production Intern, Cambodia (11 Dec. 2001–14 Dec. 2001)
Ty Channa, Production Intern, Cambodia (11 Dec. 2001–14 Dec. 2001)

Crop and Soil Management

Thanh Hai Vu, Research Intern, Vietnam (15 Nov. 2000–30 Oct. 2001)
Joseph C. Manicad, Undergraduate Student Trainee, Philippines (01 May 2001–20 June 2001)
Ya-jui Su, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Entomology Unit

Kim Chien Nguyen, Research Intern, Vietnam (10 Oct. 2000–09 Oct. 2001)
Aliou Diongue, Graduate Student, Senegal (19 Jan. 2001–14 Feb. 2001, 26 June 2001–07 Sept. 2001)
Liljana Georgievska, Graduate Student, Republic of Macedonia (19 Jan. 2001–14 Feb. 2001)
Maria Gharuka, Graduate Student, Solomon Islands (19 Jan. 2001–14 Feb. 2001)
Chanida Ammaranan, Research Intern, Thailand (04 February 2001–17 Feb. 2001)
Nitinkumar C. Patel, Research Intern, India (04 Feb. 2001–03 Mar. 2001)
Sebastian Kalbfleisch, Graduate Student, Germany (17 Mar. 2001–26 Apr. 2001)
Chan Lin, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Chung-jer Shen, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Chung-you Yen, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Sheng-fen Tzeng, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Xiao-min Dai, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yih-lin Hsieh, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Min Kwon, Research Intern, Korea (03 Oct. 2001–31 Oct. 2001)
Huy Chung Nguyen, Research Intern, Vietnam (20 Nov. 2001–19 Nov. 2002)
Prakit Somta, Graduate Student, Thailand (02 Dec. 2001–30 June 2002)

Genetic Resources and Seed Unit

Wittaya Sastawittaya, Research Intern, Thailand (14 Nov. 2000–16 Feb. 2001)
Sudchai Locharoen, Research Intern, Thailand (01 Dec. 2000–28 Feb. 2001)
Glen Melvin P. Gironella, Undergraduate Student Trainee, Philippines (01 May 2001–20 June 2001)
Katherine S. Salazar, Undergraduate Student Trainee, Philippines (01 May 2001–20 June 2001)
Hue Thi Hoang, Research Intern, Vietnam (01 July 2001–29 Sept. 2001)
Chiung-ying Jih, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Hsien-shen Kuo, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Jia-ying Chen, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Lin-ying Huang, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Mei-yun Wu, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Pou-ieng Hong, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Yi-hsang Wu, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Ying-sheng Lee, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yu-chung Lee, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yu-ling Chen, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Shang-jung Lin, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Ryoko Kawai, Undergraduate Student Trainee, Japan (10 Aug. 2001–31 Oct. 2001)
Hari Har Ram, Research Intern, India (31 Oct. 2001–01 Dec. 2001)
Pichittra Kaewsorn, Research Intern, Thailand (11 Nov. 2001–28 Feb. 2002)

Legume Unit

Ja-hwan Ku, Research Intern, Korea (01 Feb. 2001–30 June 2001)
Marilo L. Lopez, Undergraduate Student Trainee, Philippines (01 May 2001–20 June 2001)
Chen-yi Lin, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Nutrition and Analytical Laboratory

Hathaikarn Srimai, Research Intern, Thailand (01 Dec. 2000–28 Feb. 2001)
Anne Hvid Karsten, Research Intern, Denmark (07 Feb. 2001–07 June 2001)
Ulla Kidmose, Visiting Scientist, Denmark (01 Apr. 2001–04 Apr. 2001)
Kirsten Brandt, Visiting Scientist, Denmark (01 Apr. 2001–04 Apr. 2001)
Hung-yu Lin, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Jy-yi (Ann) Lo, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Li-heng Shsu, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Mei-ryn Hu, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Olericulture, Crop and Soil Management

Manuel C. Palada, Visiting Scientist, USA (01 Sept. 2000–28 Feb. 2001, 15 June 2001–15 Dec. 2001)

Pepper Unit

Damtew Mamo Dubale, Research Intern, Ethiopia (01 Oct. 2001–29 Mar. 2002)
Andras Andrasfalvy, Visiting Scientist, Hungary (05 Feb. 2001–17 Feb. 2001)

Plant Breeding and GRSU

Makoto Kamijo, Research Scholar, Japan (03 Apr. 2000–31 Mar. 2001)
Tai Thanh Duong, Special Purpose Trainee, Vietnam (15 June 2001–22 June 2001)
Plant Pathology: Bacteriology, Mycology, Virology
Atchara Pathanadech, Research Intern, Thailand (16 June 2001–14 July 2001)
Dagne Belay Anteneh, Research Intern, Ethiopia (01 Nov. 2001–30 Apr. 2002)
Leake Mesfin Kidane, Research Intern, Ethiopia (01 Nov. 2001–30 Apr. 2002)
Vannak An, Research Intern, Cambodia (01 Nov. 2000–31 Oct. 2001)

Plant Pathology: Bacteriology Unit

Ming-chung Shih, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Shu-ying Cheng, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Sue-hua Shei, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Plant Pathology: Mycology Unit

Thi Thu Huong Le, Graduate Student, Germany (01 May 2001–31 Oct. 2002)
Chih-wei Wang, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Liang-kun Chen, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yi-yen Wu, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Phindile M. Dlamini, Graduate Student, Swaziland (10 July 2001–07 Sept. 2001)

Plant Physiology Unit

Ngoc Tri Nguyen, Research Intern, Vietnam (15 Nov. 2000–05 Nov. 2001)
Anjello M. Esteban, Undergraduate Student Trainee, Philippines (01 May 2001–20 June 2001)
Chih-wen Chan, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Socio-economics Unit

Bernd Hardeweg, Graduate Student, Germany (02 July 2001–15 July 2001)
Augustina Florence Robinson Aoun, Graduate Student, Dominica (08 Aug. 2001–07 Oct. 2001)

Technology Promotion and Services

Julien Vongsavang Sananikone, Undergraduate Student Trainee, France (05 June 2001–29 Aug. 2001)
Shu-yen Lin, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yu-tzu Huang, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)

Tomato Unit

Michael N. Ngugi, Prodution Intern, Kenya (21 May 2001–27 May 2001)
Shun-yuan Tang, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Yu-tsung Lin, Undergraduate Student Trainee, Taiwan (02 July 2001–31 Aug. 2001)
Abera Tesfaye Yesuf, Research Intern, Ethiopia (01 Oct. 2001–29 Mar. 2002)

Staff publications

CIRAD, GRET, VASI, RIFAV. 2001. Les défis de l'agriculture périurbaine, De nouvelles demandes urbaines. In: Regards sur le périurbain de hanoi. Contribution à l'exposition Hanoi, le cycle des métamorphoses. UMR Regards, VTGEO, CIRAD, CNRS, CNST, IMV, Ambassade de France au Vietnam, p.16–19.

Murgai, R., **M. Ali,** and D. Byerlee. 2001. Productivity Growth and Sustainability in Post-Green Revolution Agriculture in the Indian and Pakistan Punjabs, World Bank Research Observer 16(2):199–218.

Ali, M. 2001. Mungbean: Taiwan, In Sharing Innovative Experience (Volume 2): Examples of Successful Initiatives in Science and Technology in the South. United Nation Development Program and Third World Academy of Sciences. p. 116–125.

Ali, M. and F. Porciuncula. 2001. Urban and Peri-urban Agricultural Production in Metro Manila: Resources and Opportunities for Vegetable Production. Technical Bulletin No. 26, Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan. 45 pp.

Ali, M., and V.T.B. Hau. 2001. Vegetables in Bangladesh: Economic and Nutritional Impact of New Varieties and Technologies, Technical Bulletin No. 25, Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan. 55 pp.

Ali, M., **Umar Farooq**, and **Ying Yen Shih**. Vegetable Research and Development in the ASEAN Region: A Guideline for Setting Priorities. Paper presented in the AARNET Forum 2001, 24–26 September 2001, AVRDC Shanhua, Tainan, Taiwan.

Burleigh, J.R. and L.L. Black. 2001. Supporting Farmers towards Safe Year-round Vegetable in Manila, Urban Agriculture Magazine 1(3):15–16.

Fan Ming-jen, Jau-yueh Wang, Shuen-fang Lo, Ting Rong Shu and **L.M. Engle**. 2001. Analysis of the genetic diversity of *Capsicum* spp. (pepper) using random amplified polymorphic DNA analysis. Jour. Agric Res. China 50(4): 29–42 (In Chinese, English summary).

Engle, L.M., Collection and Conservation of Indigenous Vegetable Germplasm to Enhance Biodiversity and Maintain Livelihoods in ASEAN. Paper presented in the AARNET Forum 2001, 24–26 September 2001, AVRDC, Shanhua, Tainan, Taiwan.

Green, S.K., W.S. Tsai, **S.L. Shih,** and **L.L. Black**, A. Rezaian, M.H. Rashid, M.M.N. Roff, Y.Y. Mying, and L.T.A. Hong. 2001. Molecular characterization of begomoviruses associated with leaf curl disease in Bangladesh, Laos, Malaysia, Myanmar, and Vietnam. Plant Disease 85(12):1286.

Green, S.K., Molecular characterization of Tomato Leaf Curl and Ageratum yellow vein begomovirus in Taiwan. 2001. American Phytopathological Society, Plant Disease 85(12):1286.

Nono-Wondim, R., I.S. Swai, and **Chadha, M.L.** 2001. Occurrence of chilli veinal mottle virus in *Solanum aethiopicum* in Tanzania, American Phytopathological Society, Plant Disease 85(7).

Shanmugasundaram, S., **Miao-Rong Yan**, and **Ray-Yu Yang**. 2001. Association Between Protein, Oil and Sugar in Vegetable Soybean. p. 157–160. In: Proc. of the Second International Vegetable Soybean Conference, 10-12 August 2001, Tacoma, Washington, USA.

Shanmugasundaram, S. 2001. Global Extension and Diversification of Fresh and Frozen Vegetable Soybean. p. 161–165. In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

Shanmugasundaram, S. and **Miao-Rong Yan**. 2001. Mechanization of Vegetable Soybean Production in Taiwan. p. 167–172. In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

Shanmugasundaram, S. and **Miao-Rong Yan**. 2001. Vegetable Soybean Varietal Improvement at AVRDC. p. 173–177. In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

Yan, Miao-Rong and **S. Shanmugasundaram**. 2001. Vegetable Soybean Seed Production - Recommendations. p. 191–194. In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

Ray-Yu Yang, **Samson C.S. Tsou**, **S. Shanmugasundaram** and **Miao-Rong Yan**. 2001. Quality of Lipoxygenase-null Vegetable Soybean Lines at Vegetable and Grain Stages. p. 195–199. In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

Srisombun, S. and **S. Shanmugasundaram**. 2001. The History of Vegetable Soybean Development, Current Status and Future Development in Thailand. p. 183–186 In: Proc. of the Second International Vegetable Soybean Conference, 10–12 August 2001, Tacoma, Washington, USA.

Shanmugasundaram, S. 2001. Collaborative Exchange and Evaluation of Improved Vegetable Cultivars for Adaptation in ASEAN Region. Paper presented in the AARNET Forum 2001, 24–26 September 2001, AVRDC, Shanhua, Tainan, Taiwan.

Kim, Young-Jin, **S. Shanmugasundaram**, Song-Joong Yun, Ho-Ki Park and Moon-Soo Park. 2001. A Simple Method of Seedling Screening for Drought Tolerance in Soybean. Korean J. Crop Sci. 46(4):284–288.

Shanmugasundaram, S. 2001. Current Status and Future Prospects of World Soybean Production and Utilization. p. 1-16. Paper presented in the International Symposium “Development Strategy for Self-Production of Soybean [Glycine max (L.) Merrill]”, 18 September 2001, National Honam Agricultural Experiment Station, Rural Development Administration, Iksan, Jeollabuk-do, Korea.

Shanmugasundaram, S. 2001. Perspectives of the NARS on Future Vegetable Research Strategies. Resource paper presented at SAVERNET-II Final Workshop, 3–8 June 2001 held in Bangkok, Thailand.

Weinberger, Katinka. 2001. What determines micronutrient demand of the poor?—A case study from rural India, Quarterly Journal of International Agriculture 40(4):343–358.

Weinberger, Katinka and Johannes J. Ting. 2001. Women Participation in Loca Organizations: Conditions and Constraints, World Development 29(8):1391–1404.

Weinberger, Katinka. 2001. What Role does Bargaining Power Play for Participation of Women: A Case Study in Rural Pakistan, Journal of Entrepreneurship 10(2):209-221.

Weinberger, Katinka. 2001. Demystifying Women Participation: An Analysis in Rural Chad. In: P. Webb and K. Weinberger (eds.). Women Farmers, Enhancing Rights, Recognition and Productivity. Frankfurt: Peter Lang. p. 189-201.

Webb, Patrick, Jennifer Coates and **Katinka Weinberger**. 2001. Despite Discrimination: The Success of Women Farmers in a World of Constraints. In: P. Webb and K. Weinberger (eds.). Women Farmers: Enhancing Rights, Recognition and Productivity, Frankfurt: Peter Lang, p. 1-11.

Webb, Patrick and **Katinka Weinberger** (eds.). 2001. Women Farmers: Enhancing Rights, Recognition and Productivity, Frankfurt: Peter Lang.

Financial statements

Audited financial statements for the year are available
from the Office of the Director General, AVRDC

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF ASSETS, LIABILITIES AND FUNDS
(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	31 December	
	2001	2000
ASSETS		
CASH	$2,445,789	$2,720,758
ADVANCES AND OTHER RECEIVABLES	503,072	146,194
PREPAYMENTS	312,297	61,264
LONG-TERM INVESTMENT	1,756,326	2,149,865
TOTAL ASSETS	**$5,017,484**	**$5,078,081**
LIABILITIES AND FUND BALANCES		
ADVANCE RECEIPTS OF GRANTS	$7,268	–
RECEIPTS FOR CUSTODY	355,668	392,052
RESERVES FOR EMPLOYEE BENEFITS	1,028,181	1,134,996
FUNDS		
Core fund	412,169	666,711
Working capital fund	900,000	900,000
Restricted core fund	151,736	512,438
Special projects fund	1,890,644	1,166,507
Self-sustaining operation fund	271,818	305,377
Total Funds	3,626,367	3,551,033
TOTAL LIABILITIES AND FUNDS	**$5,017,484**	**$5,078,081**

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENTS OF CHANGES IN CORE FUND

(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	31 December	
	2001	2000
ADDITIONS		
Contributions		
Republic of China	$3,390,437	$4,498,516
Japan	382,000	562,000
Federal Republic of Germany	336,406	361,941
Thailand	101,932	116,921
Republic of Korea	75,000	74,983
Australia	98,495	127,069
Philippines	34,686	44,900
France	108,000	221,000
Total contributions	4,526,956	6,007,330
Grants	–	1,510
Other	1,474,396	1,221,585
Translation adjustment	(166,068)	(268,690)
Total Additions	5,835,284	6,961,735
DEDUCTIONS		
Operating expenditures	5,642,289	6,261,739
Loss for decline value on long-term investment	328,825	–
Capital expenditures	62,435	148,790
Total Deductions	6,033,549	6,410,529
NET INCREASE (DECREASE) IN FUND	(198,265)	551,206
FUND BALANCE, BEGINNING OF YEAR		
As previously reported	666,711	165,763
Translation adjustment	(56,277)	(50,258)
As restated	610,434	115,505
FUND BALANCE, END OF YEAR	**$ 412,169**	**$ 666,711**

(With TN Soong & Co report dated 15 March 2002)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENT OF CHANGES IN RESTRICTED CORE FUND

(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	Year Ended 31 December	
	2001	2000
ADDITIONS		
From German Agency for Technical Cooperation	$ –	$472,210
DEDUCTIONS		
Transfers to core fund as contributions of Federal Republic of Germany	336,406	361,941
NET INCREASE (DECREASE) IN FUND	(336,406)	110,269
FUND BALANCE, BEGINNING OF YEAR		
As previously reported	512,438	435,527
Translation adjustment	(24,296)	(33,358)
As restated	488,142	402,169
FUND BALANCE, END OF YEAR	**$151,736**	**$512,438**

(With TN Soong & Co report dated 15 March 2002)

THE ASIAN VEGETABLE RESEARCH AND DEVELOPMENT CENTER

STATEMENT OF CHANGES IN SPECIAL PROJECTS FUND

(Prepared on a Modified Cash Basis and Expressed in US Dollars)

	Year Ended December 31, 2000					Year Ended December 31, 2001			
Sponsors	Balance Beginning of Year	Translation Adjustment	Additions	Deductions	Balance End of Year	Translation Adjustment	Additions	Deductions	Balance End of Year
AVRDC-HQ									
Asian Development Bank	$160,829	$ –	$ 51,569	$ 181,473	$ 30,925	$ –	$ 188,947	$ 299,664	($ 79,792)
Australia	21,797	(327)	16,277	9,613	28,134	–	21,810	42,269	7,675
DFID/UK	3,184	–	306,636	253,640	56,180	–	139,713	182,876	13,017
GTZ/BMZ/Germany	402,535	(30,831)	234,773	584,704	21,773	895	1,191,762	525,317	689,113
Japan	501,062	–	368,000	560,750	308,312	–	368,000	187,141	489,171
COA & NSC/ROC	(12,768)	(153)	860,191	842,879	4,391	529	1,186,031	1,173,447	17,504
RDA/Korea	47,267	–	-	18,657	28,610	–	20,000	21,887	26,723
USAID	94,997	–	752,944	819,932	28,009	–	324,427	179,288	173,148
UNICEF	–	–	115,970	47,846	68,124	–	132,271	91,421	108,974
Others	64,277	(1,541)	253,939	213,170	103,505	(2,870)	487,914	280,813	307,736
BY AVRDC-ARC									
SDC/Swiss	297,960	–	324,205	262,385	359,780	–	67,105	395,580	31,305
Japan - ASEAN	–	–	63,681	3,391	60,290	–	18,788	79,078	–
Others	130,431	–	318,014	379,971	68,474	–	237,816	200,220	106,070
Totals	**$1,711,571**	**($32,852)**	**$3,666,199**	**$4,178,411**	**$1,166,507**	**($ 1,446)**	**$4,384,584**	**$3,659,001**	**$1,890,644**

(With TN Soong & Co report dated 15 March 2002)

Meteorological information

Meteorological data (monthly mean) collected at the AVRDC weather station, 2001.

	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	66	23.9	13.5	24.2	18.1	23.0	21.3	2.33	3230	43.4	2.9
February	78	25.0	15.6	24.1	18.1	22.5	21.0	2.63	3909	0.0	3.4
March	74	27.4	17.2	28.5	22.0	22.5	23.7	2.37	4437	58.9	4.5
April	76	28.9	20.2	27.4	20.8	26.3	24.8	2.07	4243	39.0	3.8
May	76	31.4	23.9	30.7	25.4	28.9	27.4	1.90	4264	582.8	4.8
June	73	32.9	24.8	31.6	26.6	29.9	28.2	2.13	5261	549.0	5.8
July	74	33.4	25.3	31.9	26.9	30.6	29.1	2.35	4625	254.2	5.3
August	74	34.4	25.5	32.6	27.9	31.3	29.9	1.60	5153	158.1	5.2
September	79	31.2	24.0	30.6	25.9	29.1	27.7	2.43	3768	573.0	4.6
October	76	31.1	21.8	28.9	24.8	28.0	26.9	1.70	3921	0.0	4.0
November	72	27.5	16.1	25.0	21.2	24.5	23.3	2.05	3516	6.0	3.6
December	77	25.0	15.0	23.6	19.6	23.1	21.7	1.99	3066	12.4	3.2