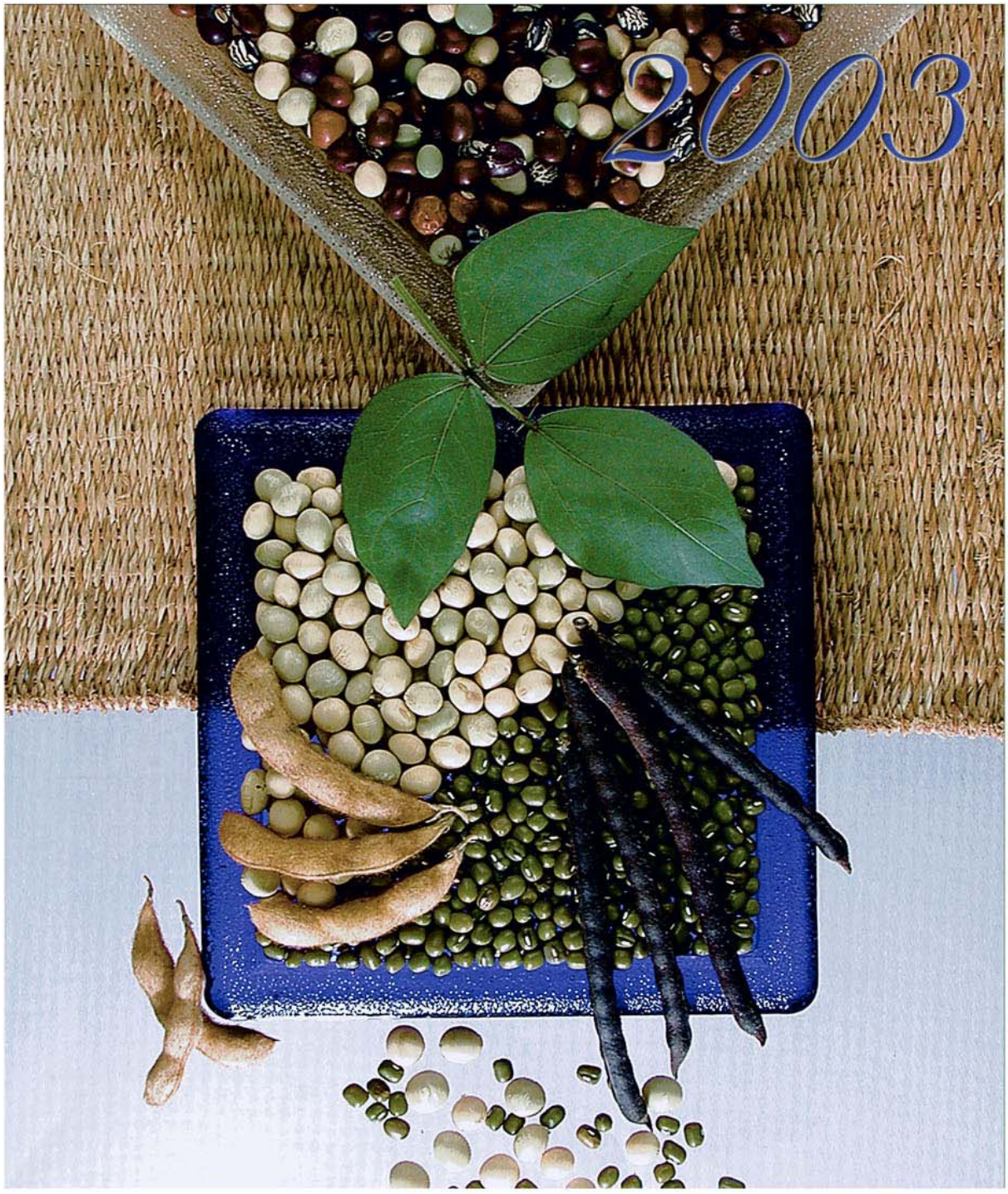
AVRDC Report



AVRDC

The World Vegetable Center

AVRDC Report 2003

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About the cover:
AVRDC is a world leader in the development of vegetable legume varieties. Our mungbean varieties are currently being sown on over 3 million ha in Asia. Much of the world's grain soybean and nearly all of its vegetable soybean varieties originated from our germplasm. These legumes are increasing farmers' incomes, improving the diets of the poor (particularly women and children), and enriching the fertility of the soil.

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Foreword

AVRDC—The World Vegetable Center is pleased to present our accomplishments for 2003. This year marked the beginning of the rebirth of our center. Declines in funding and scientific staffing have been reversed, donor interest has been revived, our global outreach has been expanded, and our research facilities have begun undergoing major renovation.

In 2003 our scientists made significant advancements that are leading to increased yields, improved stability of vegetable supplies, and greater food safety in the developing world. Among the many success stories described herein is the release and dissemination of our improved mungbean varieties across Asia. Millions of families will sow these mungbean lines this year, leading to higher incomes, better nutrition, and more fertile soils. Also among our accomplishments in 2003 is the release of new tomato lines that, for the first time ever, offer to farmers both exceptional fruit quality and resistance to tomato leaf curl virus. Another breakthrough occurred when, through the use of molecular markers, we identified sources of resistance to anthracnose in cultivated pepper that will make it easier for seed companies to add this trait to varieties.

The world's media regularly release reports about the importance of vegetables in diets to reduce risks of cancers and age-related diseases. In 2003, our scientists conducted an exhaustive search of anti-oxidant properties among over 100 types and varieties of vegetables. Superior types were identified and protocols for testing anti-oxidants were developed to aid breeders in developing varieties that can add years to our lives. In 2003 we also developed technologies that allow for pesticide-free and low nitrate production of leafy vegetables.

Working with partner agencies, AVRDC collected several hundred more accessions of indigenous vegetables last year. Nearly forgotten, these traditional vegetables are becoming important crops for the future, particularly in HIV/AIDS-stricken communities in Africa. AVRDC's genebank, already the largest and most diverse source of vegetable germplasm in the world, now maintains over 53,000 accessions in trust for the global community.

In this document you will see extensive reports from our outreach centers in Tanzania and Thailand as well as from our new substation in West Africa. Looking to the near future, new substations are being planned in Latin America and Central Asia. As the world's only international center focused on vegetables, we will not neglect any region that calls for our expertise and technologies. I invite you to read this document and partner with us to alleviate poverty and malnutrition in the developing world.

Thomas A. Lumpkin
Director General

Bulb Allium Unit

Early maturing, high-yielding onion lines for short-day environment in the tropics

The AVRDC onion breeding program seeks to improve the productivity of onions in tropical production areas. Short-day onions are emphasized, and focus is placed on selections displaying earlier maturity and improved bulb yields for main season production.

A total of 77 elite lines of three groups were evaluated: 22 lines for early maturity (with 3 check varieties), 24 yellow bulb lines for high yield (with 3 checks) and 31 red bulb lines for high yield (with 2 checks). The experiment used completely randomized designs with 2 replications and 60 plants per plot. A preliminary observation trial was also evaluated, including unreplicated plots of 54 yellow, 43 red and 4 white onion lines. Seeds were sown in plug flats (128 cells/flat) on 20 September 2002. On 13 November 2002, the seedlings were transplanted in 1-m-wide beds of three rows with 15 cm and 10 cm between rows and plants respectively. The date of crop maturity was recorded when 50% of plants in the plot had fallen tops. Superior lines from earlier evaluations have been recombined, and unreplicated evaluation plots including 34 F_1, 91 F_2, and 287 F_3 families were sown on 2, 9 and 18 September 2002, and transplanting on 23–24 October and 7 November 2002. At maturity, large bulbs were selected for high yield potential and/or early maturity.

Significant differences were found between lines evaluated for early maturity in days to maturity, although the earliest were not significantly earlier than the check variety Superex. Overall average maturity dates of the high yielding yellow onion lines were little different from the early maturing group (137 vs. 134 days from sowing), while the average days to maturity of the high yielding red onion group was substantially later (146 days).

While marketable yields of the earliest maturing onion lines were generally low, and none were equivalent to the check variety Superex, a few displayed yields superior to the check variety Texas Grano 502 (Table 1). The line AC695(A)-C is particularly promising, in that yield, bulb size, and percentage of marketable bulbs are equal or better than Texas Grano 502, while maturing two weeks earlier. Two other lines, AC571(C)-A-N, and AC691(A)-1-0 similarly performed as well as Texas Grano 502, and displayed very high percentages of marketable bulbs.

In selecting among open-pollinated yellow lines, some populations developed at AVRDC are performing well in comparison to Texas Grano 502, though they still fall short of the commercial hybrid most widely grown in Taiwan, California 606 (Table 2). The line TA490(A)-C yielded well, and matured one week earlier than the standard checks. Additional lines in the early maturity trial were also quite promising with re-

Table 1. *Performance of selected early maturing onion lines.*[1]

Entry	Marketable yield (t/ha)	Average bulb weight (g)	Marketable bulb no. (%)	Days to maturity	Bulb color
AC709(B)-N	46.0 d[2]	188 cd	73.2 c	114 a	Yellow
AC695(A)-C	92.5 b	315 b	91.7 b	121 a	Yellow
AC712(A)-A-N	58.5 cd	214 c	98.1 a	121 a	Yellow
AC546(E)-B-C	33.5 d	145 d	75.1 c	121 a	White
AC571(C)-A-N	84.5 bc	304 b	94.6 a	126 bc	Yellow
AC691(A)-1-0	86.5 b	301 b	94.9 a	131 c	Yellow
Superex (ck)	106.0 a	381 a	87.0 b	118 ab	Yellow
Texas Grano 502 (ck)	71.5 c	322 b	72.1 bc	135 c	Yellow
Mean of 25 lines	57.9	249	70.7	134	
CV (%)	10.1	10.0	13.7	3.72	

[1]Transplanted 13 November 2002 at AVRDC.

[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

gard to yield potential and bulb size, compared to standard checks, while maturing slightly earlier. Some selections out of CAL606 are maintaining the yield potential, bulb size, and maturity of the source hybrid, while possibly improving the percentage of marketable bulbs.

Table 2. *Performance of selected high yielding yellow onion lines.*[1]

Entry	Market. yield (t/ha)	Avg bulb wt (g)	Market. bulb no. (%)	Days to maturity
CAL606(D)-C	103.5	376 ab[2]	93.0	131 a
TG502(ER)-C	84.5	338 ab	82.9	131 a
TA490(A)-C	83.0	312 ab	87.9	126 a
TA1001(A)-B-C	81.0	311 ab	77.8	146 b
CAL606(E)-C	79.0	301 b	87.9	131 a
Granex429(C)-C	75.5	335 ab	73.3	131 a
California 606 (ck)	100.0	395 ab	89.2	131 a
Texas Grano 502 (ck)	89.5	412 a	73.3	131 a
Granex 429 (ck)	72.0	329 ab	72.4	131 a
Mean of 27 lines	59.6	268.0	67.1	137
CV (%)	23.1	17.0	26.8	3.79

[1]Transplanted 13 November 2002 at AVRDC.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

In contrast, the best entries in this year's red onion trials show very significant improvement over the check variety Red Creole, as represented by an in-house reselection RedCreole(1)-0 (Table 3). At least four lines display yields 50% greater, and bulb sizes 70% larger than the commercial check. Maturities continue to be late in achieving these levels of productivity. Three of these superior selections derive from the same germplasm source,TA471. It should be noted that these elite red onion lines are displaying bulb sizes averaging 300 g, almost equal to yellow onion commercial check variety Texas Grano 502, even though the overall trial average bulb size of red onion entries was 171 vs. 268 g for yellow onions. A total of 3801 bulbs of F_2 and 118 F_3 lines (41%) were selected for further research. OC232-F-C (G429 × AC 132) and OC152-2-0 (TA195 × TA383) performed best among the F_3 families, with estimated yields of 70.8 tons/ha and 51.5 t/ha for yellow and red onions, respectively. Because of the hazard of inbreeding depression in onions, these selected lines have been sib-multiplied to maintain yield performance.

Table 3. *Performance of selected high-yielding red onion lines.*[1]

Entry	Market. yield (t/ha)	Avg bulb wt (g)	Market. bulb no. (%)	Days to maturity
TA471(1)-A-C	79.0 a[2]	302 ab	77.2 ab	146 a
TA471(A)-C-N	77.0 a	302 ab	82.2 ab	153 a
TA471(A)-1-0	62.3 b	260 b	69.2 ab	150 a
AC521(1)-A-N	60.0 bc	313 a	64.0 b	153 a
TA381(A)-A-N	55.0 bcd	198 cd	86.4 a	146 a
TA215-E-A-C	50.5 bcd	212 c	81.7 ab	131 b
AC724(A)-A-N	46.8 bcd	180 cde	76.1 ab	153 a
TA364ST-E-B-N	44.5 cd	178 cde	76.6 ab	150 a
RedCreole(1)-0	41.0 d	175 cde	70.0 ab	146 a
Red Creole (ck)	9.0 e	136 e	17.8 c	153 a
Mean of 32 lines	33.3	171.2	55.5	146
CV (%)	21.3	12.0	21.2	2.8

[1]Transplanted 13 November 2002 at AVRDC.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

Ten hybrid combinations made for yield improvement in red onions were evaluated against the check cultivar Red Creole in a completely randomized design with 2 replications, and 30 plants per plot. Seed was sown on 2 September 2002, and transplanted to the field on 22 October 2002. The best eight combinations are presented in Table 4. Marketable yield and average bulb size of these hybrids are markedly superior to the check variety. They are similar or superior in yield to the high yielding parent, but show earlier maturity. OC436 (AC724(B)-C × TA381(A)-C) had the highest yield and highest percentage of marketable bulbs (77.4%), while OC439 (AC724(B)-C × AC521(l)-O) displayed the earliest maturity, 136 days after transplanting. Selection for improved globe-shaped bulbs, and F_2 seed production for further research in these materials are continuing.

A major limitation to successful onion seed production in the tropics is the lack of low temperatures required for bulb vernalization. To address this bottleneck, several parents having a low vernalization requirement were identified, and crossed with high yielding lines. Progenies have been selected over several years, and in 2002 two trials were established with 26 F_4 lines in one trial, and 24 F_5 lines in the other; four check varieties were included in each. Seed was sown on 16 September 2002, and plants were transplanted into the field on 29 and 30 October 2002. A randomized complete block design (RCBD) was employed with 2 rep-

Table 4. *Performance of selected hybrid onions.*[1]

Entry	Parent		Marketable yield (t/ha)	Avg bulb wt (g)	Marketable bulb no. (%)	Days to maturity
	Female	Male				
OC436	AC724(B)-C	TA381(A)-C	61.0 a[2]	274 abc	77.4 a	148 bc
OC437	AC724(B)-C	TA471(A)-N	57.5 ab	257 bc	62.6 bc	143 cd
OC444	TA471(A)-N	RedCreole-A-N	53.0 ab	297 ab	53.7 cd	153 abc
OC441	TA471(A)-N	AC319-C-F-C	50.5 abc	247 bc	71.3 ab	143 cd
OC439	AC724(B)-C	AC521(1)-0	47.5 abc	211 cd	69.7 ab	136 d
OC447	RedCreole-A-N	TA471(A)-N	43.0 bc	325 a	40.3 de	153 abc
OC446	RedCreole-A-N	TA381(A)-C	42.5 bc	233 bc	49.1 cd	157 ab
OC445	RedCreole-A-N	AC521(1)-0	36.0 cd	226 c	48.3 cd	153 abc
Red Creole (ck)			15.0 ef	161 de	26.8 e	160 a
Mean of 11 lines			45.1	248	55.5	150
CV (%)			16.3	12.0	14.4	3.0

[1]Transplanted 22 October 2002 at AVRDC.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

lications and 30 plants per plot. In comparison to the check varieties, the marketable yields of all lines in these trials were comparable to the red onion checks, but inferior to the yellow onion checks (data not shown), largely due to the low percentages of marketable bulbs as a result of bolting and small bulb size. Eight F_4 and five F_5 lines had marketable yields similar to Texas Grano 502 (50.5 t/ha), ranging from 34.5–48.0 t/ha and 31.5–39.0 t/ha respectively. Average bulb size was large (195.8 g), indicating that we have succeeded in generating early bolting onion lines with competitive yield and horticultural traits. Small quantities of seed of one yellow line (OC53-11-1-A-N) and one light red line (OC3-20-B-A-N) are available for testing by interested cooperators. One year's lead should be anticipated in requests of larger samples.

Development of onions with good storability

There are several challenges onion farmers face to maximize their returns: 1) the harvest season is quite brief, resulting in great fluctuations in spot market price; 2) transporting bulbs to distant markets can be expensive; and 3) ambient storage often leads to severe losses due to diseases and weight reductions. AVRDC has sought to mitigate this situation by developing lines that display greater stability under ambient storage. A key objective of our research is to improve the storability of lines adapted to the principal, cool-dry growing season in tropical areas. Because of varied market preferences in onion bulb traits, as well as variations in yield potential and storability within bulb color classes, both red and yellow onions are included in our efforts. While short-day, red onions showed superiority in storability in our trials, some long-day, yellow onions grown in other conditions are known to also have good storability. The red onion variety Red Creole is used as our check for storability, while the yellow onion varieties Texas Grano 502, Superex, and California 606 serve as the standard checks for yield.

Twenty-eight elite lines from the AVRDC breeding program were evaluated for yield performance and storability of onion, using a randomized complete block design (RCBD) with 2–6 replications and 30–60 plants for each plot. Thirty-eight F_1 and 119 F_3 lines were evaluated without replication. Seeds were sown and transplanted to the field on the same day and in the same manner as other yield trials discussed here (see section on breeding onions for improved yield). Yield data were recorded after full ripening, and marketable bulbs were kept in nylon net bags for storage testing. Those bags were placed on shelves in a well-ventilated storage room under ambient conditions (28°C, 75% RH) for five months, beginning on 5 or 9 May 2003. Forty-nine lines along with 3 check varieties were replicated 2–4 times with 40 bulbs per replication, and arranged randomly on the storage shelves. In addition to 78 sib-mated lines, 15 F_1, 35 F_2, and 312 F_3 lines were screened for storability without replication. Bags were inspected and rotated each month, and the number and weight of good bulbs were recorded. Results after four and five months of storage are presented in Table 5. As in previous years, storage losses resulted from diseases (black mold, Fusarium rot, soft rot, etc.),

insect damage (root mites, etc.) as well as physiological weight loss and early sprouting.

Cumulative losses were typically 54–100% greater after five months of storage compared to four months. Storage losses in the best red lines ST(E)-B-LR and ST(R)D-A-C were less than half of those experienced by the check varieties on both evaluation dates. The first line is also comparable in bulb size and maturity to the hybrid check varieties California 606 and Texas Grano 502. Most other lines have significantly smaller bulbs than the yellow check varieties, but are generally equivalent in size to the Red Creole check.

One yellow line, TA377-AL-C, produced bulbs averaging almost 200 g; although still smaller than the yellow checks, this deficiency may be outweighed by the loss after five months of storage, which amounts to only 45% of its initial fresh weight, as compared to losses of about 85% in California 606 and Texas Grano 502.

Thirty-eight new cross combinations were made to improve the storability of yellow onion and the bulb size of red onion. The average storage loss is 22% while check varieties California 606 and Red Creole recorded 75.0% and 29.4% losses after four months storage, respectively. OC490 (OC215-7-0 × TA377-CST-G-N) and OC494 (OC239-6-0 × Red Creole-A-N) had the best performance of storability, bulb size, and maturity for yellow and red onions, respectively (Table 6). But the marketable bulb percentage was low because of premature bolting of female parent lines. One additional backcross should improve this trait. After four months of storage, 68 lines were selected from 136 F_3 lines and will be used for further evaluation and improvement. Average storage loss of the selected lines was 17.6%, compared to 37.5% over all 136 entries. After storage, the best 15 lines had bulbs greater than 150 g in size, with only 15.1% losses; this constitutes an 11% rate of selection among the F_3 families.

Table 5. *Promising lines of onions with good storability.*[1]

Entry	Bulb color	Storage loss after 4 mos.[2] (%)	Storage loss after 5 mos.[3] (%)	Average marketable wt (g)	Days to maturity
ST(E)-B-LR	Light red	14.8 a[4]	25.6 a	224 ab	135
ST(4)-AST-LR	Light red	23.0 ab	42.7 abc	133 de	124
ST(R)D-A-C	Red	8.1 a	26.2 a	134 de	124
AC319HT-MST-1ST-0	Red	21.1 a	51.4 bc	110 e	143
AC319-C-HST-A-N	Red	27.5 ab	40.0 ab	119 de	146
ST(E)-B-Y	Yellow	20.5 a	39.4 ab	118 de	135
ST(4)-AST-Y	Yellow	26.9 ab	50.0 bc	158 cde	124
TA377-CST-AST-AST-N	Yellow	27.6 ab	49.3 bc	164 cd	131
ST(4)-BST-C	Yellow	28.8 ab	42.2 abc	126 de	124
TA377-AL-C	Yellow	30.4 ab	46.3 bc	196 bc	131
Red Creole (ck)	Red	52.5 bc	65.0 cd	146 de	153
Texas Grano 502 (ck)	Yellow	65.0 c	85.6 d	255 a	131
California 606 (ck)	Yellow	68.1 c	87.5 d	251 a	131
Mean of 31 lines		45.3	63.8	154.0	
CV(%)		32.5	33.9	15.9	

[1]Transplanted 13 November 2002 at AVRDC.

[2]Evaluated on 13 August 2003 after 4 months of storage under ambient conditions.

[3]Evaluated on 16 September 2003 after 5 months of storage under ambient conditions.

[4]Mean separation in columns by Duncan's multiple range test at $P < 0.05$.

Table 6. *Selected onion hybrids with good storability.*

No.	Parent		Bulb Color	% Loss 4 mos.[1]	% Loss 5 mos.[2]	Avg wt (g)	Marketable bulbs (%)	Days to maturity
	Female	Male						
OC473	TA271P(2)ST-1-A-N	TA471(1)-0	Light red	30.0	53.3	255	41.3	125
OC494	OC239-6-0	Red Creole-A-N	Red	5.9	11.8	179	54.0	143
OC475	OC215-C	TA377-CST-G-N	Yellow	10.4	19.4	167	52.6	125
OC490	OC215-7-0	TA377-CST-G-N	Yellow	11.1	19.4	231	61.8	153
OC469	AC448P(3)ST-3-A-C	AC835(A)-C	Yellow	15.0	36.7	249	50.0	153
OC488	OC206-5-0	TA377-CST-G-N	Yellow	20.0	25.0	217	57.1	153
OC470	AC448P(3)ST-3-A-C	TA377-CST-AST-C	Yellow	23.0	37.7	162	43.1	125
OC460	AC835(A)-C	TA377-CST-AST-C	Yellow	27.0	32.4	189	72.7	125
OC461	TA470-A-N	TA377-CST-AST-C	Yellow	27.3	45.5	282	14.0	153
OC471	AC448P(3)ST-3-A-C	TG502ST	Yellow	33.3	58.3	295	36.3	153
OC459	AC835(A)-C	TA377ST-W-N	Yellow	45.5	50.0	226	80.6	125
Red Creole (ck)			Red	29.4	43.1	134	33.3	160
California 606 (ck)			Yellow	75.0	97.5	292	100.0	125
Texas Grano 502 (ck)			Yellow	72.5	92.5	265	73.1	125
Mean of 41 lines				22.0	32.0	214	55.0	140
Range				0–100	0–100	130–320	14.1–100	125–160

[1]Evaluated on 14 August 2003 after 4 months storage under ambient conditions.
[2]Evaluated on 13 September 2003 after 5 months storage under ambient conditions.

Effect of virus re-infection on yield and storability of virus-free shallot

Like garlic, most of the shallot produced in tropical areas is propagated vegetatively, and a new crop is established using vegetative bulblets saved from the prior crop. Consequently, the storability of shallot bulbs is important for stable annual production. AVRDC has produced several virus-free shallot lines through meristem culture to eradicate viruses that reduce yield. These lines are maintained virus-free in an insect-proof, 60-mesh nethouse. In previous studies in garlic, when virus-free lines were multiplied for two years without protection, they were found to be re-infected with virus, and in some cases sustained significant yield reductions. This trial was designed to evaluate the effect of virus re-infection on yield and storability of virus-free shallot after being grown in unprotected, open field conditions.

A total of 32 lines, including 10 virus-free (VP0) lines, 17 lines vegetatively propagated twice in open field plantings (VP2), 2 lines noted for good storability, 1 high yield line, and 2 check lines, were planted at AVRDC on 7 October 2002. Plants were set in two rows on 0.75-m-wide beds with rows spaced 20 cm apart and plants spaced 15 cm within rows. A RCBD was used, with 30 plants per plot and 2 replications. Yield data were recorded at harvest after full ripening, and bulbs were placed in nylon net bags for storage test. Those bags were hung in well-ventilated and protected conditions at ambient temperatures for four months. Assays for presence of virus either at the beginning or the end of the field trial were not conducted.

No differences were found in the average performance of 10 VP0 shallot lines with their VP2 counterparts. While VP0 lines had an average yield of 20.6 t/ha and 51.2% storage loss, VP2 lines yielded an average of 19.6 t/ha and lost 49.9% of their original fresh weight in storage. After storage for four months, six lines displayed storability superior to check varieties and similar to selected good storage line S31V(9)HT (Table 7). Only one of them was a virus-free shallot (VP0) line. None of these six lines bolted after four months, while about 30% of the bulblets of the check variety S25 had begun flowering. VFTA551-V2-1 and VF95-3-5 had final yields after storage of 26.5 and 25.7 t/ha, while check varieties S28 and S25 yielded the equivalent of 16.6 and 7.6 t/ha, respectively. The line VFS95-3-5 is particularly promising, in that it produced equally high yields in previous years' trials, and produces large, red bulbs, which are preferred by most consumers in tropical areas.

Table 7. *Promising lines of shallots with good storability.*[1]

Entry	Bulb color	Average bulblet no./plant	Average bulblet wt (g)	Average plant wt (g)	Yield (t/ha)	Storage loss[2] (%)	Final yield[2] (t/ha)
VFTA647-5-1	Orange	30 a[3]	8.3 ab	250 a	32.3 ab	23.4 a	24.7 a
VFTA647-V3-1	Orange	27 a	8.1 ab	220 a	32.0 ab	25.2 a	23.9 a
VFS70[4]	Orange	17 bc	11.2 a	190 ab	28.7 bc	24.2 a	21.7 a
VFTA551-V2-1	Red	26 ab	9.7 ab	250 a	36.2 a	26.7 a	26.5 a
VFS95-3-5	Red	16 c	11.6 a	185 abc	34.4 ab	25.2 a	25.7 a
S31V(9)HT	Red	28 a	8.2 ab	230 a	31.7 ab	26.8 a	23.2 a
S28 (ck)	Orange	15 c	4.0 b	140 bc	23.6 c	29.6 ab	16.6 b
S25 (ck)	Red	31 a	10.0 ab	120 c	13.4 d	43.3 b	7.6 c
Mean of 32 lines		15	12.0	146	22.2	45.0	13.1
CV (%)		26	21.2	19.1	13.6	13.3	16.5

[1]Transplanted 7 October 2002 at AVRDC.
[2]Evaluated on 29 May 2003 after 4 months of storage under ambient conditions.
[3]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
[4]Seed bulb from virus-free shallot line in protected nethouse.

BC_1 polycross test of onion lines for use in interspecific (*A. cepa* × *A. fistulosum*) backcrosses to develop Stemphylium leaf blight-resistant onion

Stemphylium leaf blight (SLB) is a major disease of onion in the world. Durable resistance to SLB has not been found in cultivated onion (*Allium cepa*), but has been identified in *A. fistulosum*. Therefore, crosses were made between *A. cepa* and *A. fistulosum* to introduce resistance genes to onion. The self-pollinated progenies from hybrids and backcrosses were mostly sterile and had very poor seed set. To combine the SLB resistance from *A. fistulosum* and good bulbing from *A. cepa*, compatibility tests were pursued to identify *A. cepa* parents that could increase seed productivity in backcross progenies, so that large populations could be used in selection for bulbing and disease resistance.

Individual F_4 plants of the cross CF5 (TA207 × AF468) (*A. cepa* × *A. fistulosum*) were chosen for use as the female parents in this test because of their relatively good seed set, resistance to SLB, bulbing ability, and pollen fertility. Seventeen diverse open-pollinated onion lines were selected and transplanted in pots for use as pollen parents. Crosses were made in the AVRDC greenhouse from February to April 2001, using one to two umbels from each parent. After harvest in May, seeds were sown and transplanted to field with five check varieties (two *A. fistulosum*, two *A. cepa* and one CF5 interspecies progeny) on 13 September and 9 November 2001. Plants were established in two rows on 1.5-m-wide beds, with 30 cm spacing between rows and 20 cm between plants within rows. Plastic mulch was used to control weeds. When the plants produced umbels, a single net cage was placed over all hybridized plants, and houseflies were introduced to enhance seed production. Pollen source was thus restricted to this set of 'BC_1' hybrids, and constitutes a rudimentary polycross nursery. Observations of these parent plants were recorded for plant type, flowering, bulbing behavior, and SLB reaction (induced via natural infection). Pollen grains were collected from 1–2 flowers of each umbel and examined for viability using acetocarmine stain. Seeds were harvested from female parent lines in May 2002 and polycross progenies were sown on 26 September 2002. Plants within each progeny are effectively half sibs of their respective female parent plant, and with pollen restricted to the other BC_1 plants in the test. Seedlings were artificially inoculated *Stemphylium* spore suspension in 19 November and scored on a 1–5 scale for SLB reaction on 25 November 2002. Only resistant (SLB scale 1–2) plants were transplanted to field in 5 December 2002 for further BC_1F_2 seed production and pollen fertility testing in April 2003.

The amount of seeds harvested from the 17 initial backcross combinations ranged from 4 seeds to well over 1000 (6.61g). From the seeds sown, 399 plants were obtained, with germination rates ranging from 10.9 to 68.8% (Table 8). The greatest amount of seed was harvested from the family CFBC164, while the

best germination rates were produced by families CFBC154 and CFBC166. The average pollen fertility was 67.1%, ranging from 41.8 to 96.9%. Two combinations reverted to vegetative plant type of *A. cepa* or *A. fistulosum* and failed to flower; while all other families displayed both plant and flower morphologies intermediate between the two species parent types. All progenies had some bulbing response, but behaviors were variable within families CFBC152, CFBC162, CFBC163, CFBC165 and CFBC166 (Table 8). Among good bulbing combinations, CFBC159 and CFBC160 had the fewest SLB symptoms and the most viable pollen, with 78.5 and 79.7% fertility.

Ignoring plants which produced no flowers, only CFBC151 and CFBC166 produced no seeds under the isolated, polycross pollination. Seed harvested from each backcross family ranged from 7 seeds to 6.5 g, and these displayed germination rates ranging from 18.2 to 80.5% (Table 9). From the seeds sown, a total of 1,007 plants were obtained. Disease reactions in these BC_1F_2 polycross progenies were predominantly rated as moderate resistant or susceptible (SLB scale 3–4), while *A. fistulosum* received scores of highly resistant and resistant (SLB scale 1–2) and *A. cepa* lines were scored as susceptible or highly susceptible (SLB scale 4–5). Out of twelve combinations, excluding those combinations with poor seed set, the distributions of resistance in seven were similar to the interspecies check CF5(8)-HR-B-C, four families segregated and produced several resistant plants, and one (CFBC163) had similar percentage of resistant plants as resistant check TA198-HRA-HR-C. Average pollen fertility of highly resistant plants selected from seven combinations was 86.8%, as measured in plants which bolted in their first year from seed. Except for CFBC164, pollen fertility of resistant plants in these progenies is improved and similar to *A. cepa* (Table 9).

Based on these progeny tests for SLB response, five onion lines were selected for use as recurrent

Table 8. *Performance of BC_1F_1 interspecies progenies of the selected cross CF5 (TA207 × AF468).*[1]

No.	Male parent	Seed (g)	Germ. (%)	Plant no.	Plant type[2]	Bulb color[3]	Bulb size[4]	Bulblet no.[5]	Flower type[2]	Flower no.	Pollen amt[6]	Fertility (%)[7]	SLB score[8]
CFBC150	AC47	0.75	57.8	37	CF	R	5	1-2	CF	2	3	55.0	3
CFBC151	AC449-S-S(2)-A-N	4 seed	25.0	1	AC	LR	2	2	-	0	-	-	1
CFBC152	AC464	0.86	39.1	28	CF	LR	3,5	1-2	CF	3	3	55.9	2
CFBC153	AC503ST-B-N	0.57	64.1	40	CF	R	5	1-2	CF	2	4	43.3	3
CFBC154	AC546	0.5	68.8	41	CF	LR	2	1-2	CF	3	4	96.9	2
CFBC155	AC685	0.4	17.2	11	CF	LR	2	1-2	CF	2	4	69.7	2
CFBC156	AC686	0.53	37.5	23	AC,CF	R	3	2.6	CF	2	4	70.1	3
CFBC157	AC692	0.32	26.6	16	AC,CF	R	3	2	CF	1	3	78.7	3
CFBC158	AC694	12 seed	8.3	1	CF	LR	2	1	CF	1	5	82.8	1
CFBC159	AC702	0.71	40.6	28	CF	LR	3	1-2	CF	2	5	78.5	2
CFBC160	AC713	1.55	51.6	32	FC	LR	3	2	CF	3	4	79.7	1
CFBC161	AC724	7 seed	14.3	1	AF	P	2	2.3	-	0	-	-	0
CFBC162	AC748	1.1	46.9	28	FC	LR	2,3	2-4	CF	3	4	41.8	0
CFBC163	Red Creole	1.68	57.8	40	FC	LR,R	2,3	2-4	CF	3	4	48.3	2
CFBC164	TA1000	6.61	34.4	23	CF	LR	2	2-4	CF	3	4	74.8	1
CFBC165	TA1005	0.16	10.9	7	FC	LR	2	2-4	CF	3	5	64.4	2
CFBC166	TG502	0.8	68.8	42	FC, CF	R	3,5	2	CF	2	2	67.3	3

[1]Transplanted 13 September and 9 November 2001 at AVRDC.

[2]AC = onion type; AF = Welsh onion type; CF = intermediate type similiar to onion; FC = intermediate type similiar to Welsh onion.

[3]R = red; LR = light red.

[4]1 = no bulbing, similar to *A. fistulosum*; 2 = slight bulbing tendency but thick neck like *A. fistulosum*; 3 = small bulb with thick neck; 4 = medium-sized split bulb (similar to shallot); 5 = single bulb.

[5]Rated by percentage of plants bolting: 0 = no bolting, 1 = <5%, 2 = 5–30%, 3 = 30–50%, 4 = >50%.

[6] Pollen amount comparing with onion: 1 = few pollen in anther after squeezed; 2 = few visible pollen; 3 = some pollen; 4 = slightly less pollen than onion; 5 = same as onion.

[7]Percentage of pollen stained in acetocarmine observed under microscope.

[8]Stemphylium leaf blight infection in field: 0 = no symptoms, 1 = ≤ 5% infection; 2 = 6–25% infection; 3 = 26–50% infection; 4 = >50% infection.

parents in our interspecific backcross breeding program. AC546 and AC685 increased the frequency of resistant and highly resistant progenies, and improved pollen fertility, but did not significantly improve bulbing. AC464, AC686 and Red Creole improved bulbing behavior and pollen fertility, as well as improving the percentage of resistant plants. Because of low pollen fertility in the BC_1F_1 (Table 8), one generation of selfing may be needed when AC464 and Red Creole are used in a backcross program.

Because of the low percentage of resistant plants (0–29%) in test populations, large progeny population sizes are needed to successfully combine the characteristics of Stemphylium leaf blight resistance, bulbing, and pollen fertility. Progress in combining all three traits remains slow and tentative. The pollen parents that produced the best bulbs in the BC_1F_1 generation (CFBC151 and CFBC153) produced no resistant progenies in the next generation. Seeds of BC_2F_1 and BC_1F_3 will be produced for further study.

Multi-location evaluation of promising garlic lines

Garlic has been an important component of vegetable cuisines for many centuries, and is consumed at various stages and phases of growth. It is most widely consumed as cloves of the stored bulb, but the green leafy tops, or even flower shoots may be the target of production and harvest. AVRDC's garlic collection includes cloves that have been selected for use in varying applications, and the performances of many have been improved through the process of virus eradication. The yield of garlic varies widely with location due to infection by virus diseases and environmental differences. The objective of this study is to evaluate selected virus-free and other high yielding garlic clones to determine their yield in different locations.

Nine promising garlic lines and two check varieties, Hsilo and Flowering Garlic, were evaluated at AVRDC and in farmers' fields in Shei-jia and Tze-tong, which are major seed bulb production areas for southern and central Taiwan. The trials were planted on 15, 18 and 28 October 2002, respectively in the above three locations. The plot size at AVRDC and Shei-jia was 0.75-m-wide beds with single 10-m-long rows; each row

Table 9. *Compatibility performance and Stemphylium blight resistance in polycross BC_1F_2 families.*[1]

No.	Pedigree	Seed amount (g)	Germ. (%)	Plant no.	SLB reaction[2] (% of plants) 1	2	3	4	5	Fertility (%)[3]
CFBC150	CF5(8)-HR-A/AC47	11 seed	18.2	2	50	50	0	0	0	-
CFBC152	CF5(8)-HR-A/AC464	5.4	71.9	94	5	15	28	47	5	97.2
CFBC154	CF5(8)-HR-A/AC546	5.24	70.3	98	1	12	20	62	4	90.9
CFBC155	CF5(8)-HR-A/AC685	1.04	66.4	87	1	13	39	39	8	90.8
CFBC156	CF5(8)-HR-A/AC686	1.77	80.5	111	4	7	41	43	5	-
CFBC157	CF5(8)-HR-A/AC692	1.47	60.9	88	1	2	28	63	6	-
CFBC158	CF5(8)-HR-A/AC694	7 seed	57.1	4	0	0	75	25	0	-
CFBC159	CF5(8)-HR-A/AC702	3.75	66.4	89	0	3	15	54	28	88.2
CFBC160	CF5(8)-HR-A/AC713	1.95	75.0	96	0	0	21	65	15	-
CFBC161	CF5(8)-HR-A/AC724	0.21	29.2	7	0	0	29	71	0	-
CFBC162	CF5(8)-HR-A/AC748	0.9	73.4	47	0	0	26	70	4	-
CFBC163	CF5(8)-HR-A/Redcreole	1.55	67.2	118	13	16	35	34	3	94.6
CFBC164	CF5(8)-HR-A/TA1000	6.5	71.9	95	0	7	25	65	2	87.7
CFBC165	CF5(8)-HR-A/TA1005	2.93	55.5	71	0	6	44	48	3	58.3
CF5(8)-HR-B-C (interspecies ck)		1.33	45.3	100	0	1	20	74	5	-
TA198-HRA-HR-C (*A. fistulosum*)		-	95.3	32	0	28	47	25	0	-
TA204-HRA-HR-C (*A. fistulosum*)		-	87.5	32	59	22	19	0	0	-
CAL606 (*A. cepa*)		-	69.5	32	0	0	0	19	81	-

[1]Transplanted 5 December 2002 at AVRDC.

[2]1 = no symptoms, 2 = <5% infection; 3 = 6–25% infection; 4 = 26–50% infection; 5 = >50% infection.

[3]Percentage of pollen stained in acetocarmine observed under microscope.

had 200 plants representing one replication. In Tze-tong, the bed width was 2 m and each bed had eight 3-m-long rows. Each row had 25 plants and 200 plants per bed represented one replication. A split-plot design arranged in randomized complete block was used with three replications. The trial block at the Shei-jia location was covered with a screen net.

One hundred plants per plot were harvested in Shei-jia and Tze-tong for green garlic yield on 17 and 20 February 2003, respectively. Remaining plants were harvested and recorded for bulb yield on 2, 11 and 14 April 2003 at Shei-jia, AVRDC and Tze-tong, respectively. Horticultural traits of garlic bulbs were observed on 13 October 2003, after storage under ambient conditions at AVRDC for six months.

The multi-location trial was analyzed statistically using the SAS general linear model (GLM) procedure. F-tests indicated that all characters measured (green garlic leaf yield, stored bulb yield and size, and clove number and weight) varied significantly with location (Table 10). The Tze-tong location produced higher yields of both green garlic and bulbs than the other locations, but with smaller bulb size and more cloves per bulb. Compared to results at AVRDC, the net covering in Shei-jia may have led to an increase in the average number of cloves per bulb but had no significant effect on yield or bulb size (Table 11).

Highly significant differences were observed between genotypes and genotype by location interaction for all the variables (Table 10). The line VFG180P produced the highest green garlic yields in both locations tested, with 42.5 t/ha in Tze-tong, and 29.5 t/ha in Shei-jia. Compared to the two check varieties, the lines G123-32, Hsilo 1.0KradS5 and VFG180P had significantly higher green leaf yields in Tze-tong; only VFG180P was superior to both checks in Shi-jia.

The highest bulb yield was 18.0 t/ha of VFG173P in Tze-tong; this line was the highest yielder in the AVRDC trial as well, but was not exceptional in Shei-jia. The line VFG180P was again significantly superior to the check varieties in all three locations (Table 11).

Across all locations, the two lines VFG180P and VFG173P had the highest average green leaf yields with 36.0 and 31.1 t/ha, and average bulb yields of 13.5 and 13.8 t/ha, while the check varieties Hsilo and Flowering Garlic produced 23.4 and 17.7 t/ha of green garlic and 9.7 and 7.2 t/ha of bulbs. Significant genotype by location interactions were due largely to variable performance across locations of some of the weaker entries in the trials.

VFG180P typically has larger bulb and clove size of 58 mm and 4.5 g, making it a preferred choice for garlic bulb production, while VFG173 produces more cloves per bulb (averaging 36.4 over three locations), suggesting that it may serve best for green garlic leaf production. Both of these superior varieties are the product of AVRDC's virus eradication program.

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Table 10. *Variance analysis of multi-location garlic trial for yield and other horticultural traits, 2002–2003.*

Source of Variance	df	Green garlic yield	Mean squares				
			df[1]	Bulb yield	Bulb diameter	Clove number	Clove weight
Location (L)	1	1638.02 *	2	39.39 *	218.62 *	131.92 **	15.46 **
Rep (R)	2	57.99 NS	2	1.03 NS	13.73 NS	5.30 NS	1.06 NS
R X L	2	67.89	4	5.25	18.26	1.89	0.38
Genotype (G)	10	290.73 **	10	85.22 **	218.24 **	470.18 **	8.07 **
G X L	10	40.07 **	20	17.99 **	35.32 **	25.19 **	0.90 **
Error	65	10.98	60	2.93	7.82	6.27	0.32

NS, *, **Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.
[1]Missing data in some genotypes.

Table 11. *Yield and other horticultural traits of garlic lines grown in three locations in Taiwan, 2002–2003.*

Variety	Green garlic yield (t/ha)	Bulb yield (t/ha)	Bulb diameter (mm)	Avg clove no.	Avg clove weight (g)
AVRDC					
Hsilo 1.0KradS5	-	10.6 b	52.5 bc	16.0 bc	2.9 cde
G123-32	-	9.5 bc	54.8 ab	15.3 bc	3.2 cde
G44-1 0.75Krad S3	-	8.9 bc	50.2 c	17.1 b	2.3 def
G98-9 0.75KradM3	-	9.2 bc	52.8 bc	17.0 b	2.7 c-f
VFG174P	-	10.0 b	52.8 bc	15.3 bc	3.4 bcd
VFG176P	-	9.2 bc	52.2 bc	14.1 bcd	3.5 bc
VFG177P	-	4.4 d	44.7 d	7.1 e	4.9 a
VFG173P	-	13.8 a	55.1 ab	27.8 a	1.7 f
VFG180P	-	12.3 a	56.7 a	11.8 cd	4.8 a
Hsilo (ck)	-	9.0 bc	54.8 ab	10.7 de	4.5 ab
Flowering garlic (ck)	-	7.9 c	44.0 d	14.5 bcd	2.1 ef
Subtotal mean		9.5 AB	51.9 A	15.2 C	3.3 A
CV (%)		10.0	3.8	15.0	19.0
Shei-jia					
Hsilo 1.0KradS5	20.0 bc[1]	11.4 ab	55.8 ab	13.0 c	4.0 ab
G123-32	20.8 bc	10.7 ab	58.1 a	16.7 c	3.5 bc
G44-1 0.75Krad S3	16.2 c	7.8 ab	50.1 bc	16.3 c	2.5 cd
G98-9 0.75KradM3	16.8 c	8.1 ab	53.0 abc	26.2 b	1.6 de
VFG174P	24.2 ab	4.1 cd	54.5 abc	14.6 c	3.7 bc
VFG176P	20.7 bc	9.4 ab	56.1 ab	13.7 c	4.2 ab
VFG177P	7.6 d	3.5 d	-	-	-
VFG173P	23.0 abc	9.5 ab	53.5 abc	41.9 a	1.1 e
VFG180P	29.5 a	11.7 a	58.2 a	11.8 c	5.2 a
Hsilo (ck)	16.6 c	7.4 bc	53.2 abc	11.7 c	4.0 ab
Flowering Garlic (ck)	17.5 bc	8.8 ab	48.4 c	14.9 c	2.6 cd
Subtotal mean	19.4 B	8.4 B	54.0 A	18.1 B	3.2 A
CV (%)	19.1	24.6	5.9	15.4	21.7
Tze-tong					
Hsilo 1.0KradS5	31.2 d	12.2 bc	52.0 bcd	15.7 de	2.7 bc
G123-32	36.4 bc	15.0 ab	55.4 ab	19.9 cd	2.5 cd
G44-1 0.75Krad S3	30.3 d	13.1 b	51.6 bcd	21.8 c	1.9 de
G98-9 0.75Krad M3	24.4 e	7.9 de	46.2 de	26.7 b	1.2 fg
VFG174P	33.3 cd	9.2 cd	46.5 cde	16.1 de	2.3 cd
VFG176P	24.7 e	4.9 ef	41.9 e	13.5 e	2.1 de
VFG177P	12.8 g	1.8 f	32.0 f	7.9 f	1.6 ef
VFG173P	39.1 ab	18.0 a	52.3 bc	39.5 a	1.1 g
VFG180P	42.5 a	16.7 a	59.4 a	18.3 cde	3.4 a
Hsilo (ck)	30.1 d	12.8 b	54.6 ab	15.2 de	3.2 ab
Flowering Garlic (ck)	17.9 f	4.9 ef	34.8 f	16.9 de	0.9 g
Subtotal mean	29.3 A	10.6 A	48.3 B	19.3 A	2.1 B
CV (%)	9.8	18.0	6.6	12.7	14.2
Mean of all entries	24.3	9.5	51.3	17.5	2.9
CV (%)	13.6	18.0	5.5	14.3	19.7

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$. Lower case comparisons conducted within each location, upper case location subtotal comparisons made across three locations.

Crucifer Unit

Broccoli for the hot-wet season

Broccoli is becoming increasingly popular around the world for its flavor, potential cancer-fighting ability, and nutritional qualities. In the hot-wet season of the tropics, most varieties suffer from low yields, poor head development, and diseases such as damping-off, black rot and soft rot. The objective of this study was to evaluate a large collection of broccoli genotypes in order to identify promising types.

Evaluation trials consisting of 134, 142, and 159 accessions were sown on 30 April, 16 June and 30 July, and transplanted to the field on 26 May, 9 July and 25 August 2003, respectively. Plants were grown on 150-cm-wide raised beds, in double rows with 50 cm between rows and plants within rows. Each plot consisted of 20 plants. Nonreplicated plots were used. Plant beds were mulched with a layer of rice straw on top. Weekly applications of pesticide mixtures were made to manage insects and diseases. Yield and time between transplanting and harvest were recorded for each entry (Table 12). Horticultural characteristics were evaluated and chlorophyll contents of matured leaves and harvest-ready heads were measured in the field by using a chlorophyll meter (Table 13).

In the first trial, 119 accessions successfully germinated and were grown for transplanting. The trial initially faced monsoon conditions (496 mm of rain fell up to 26 June), followed by unusually hot-dry weather (46 mm of rain fell from 27 June until 31 July; 30.9°C mean temperature in July). Although most entries in this trial suffered from black rot disease, there were 28 heat-tolerant varieties that yielded over 10 t/ha during the harvest period from 11 to 30 July.

In the second trial, 129 accessions were transplanted to the field. An unusual spell of hot-dry weather occurred during the early growth period of the second trial, and then a total of 185 mm of rain fell on 4 and 5 August, seriously damaging the early maturing varieties, which were beginning to form heads. Later, a period of moderately rainy and hot (30.0°C mean temperature in August) conditions induced serious soft rot disease infections. Yields overall were very low and only 9 varieties produced yields over 10 t/ha during the harvest period from 29 August to 12 September.

In the third trial, 142 accessions were transplanted to the field. Relatively hot-dry weather occurred throughout this trial. Only 81 mm of rain fell from 25 August to 31 October, and mean monthly temperatures for September and October were 29.5 and 26.6°C, respectively. Harvests began on 6 October and 4 extra-early varieties yielded over 10 t/ha by 9 October (45 days after transplanting), 37 cumulative varieties met the 10 t/ha goal by 15 October, 55 varieties by 20 October, 92 varieties by 24 October, and finally 115 cumulative varieties by 30 October. Cool weather of approximately 25°C after 15 October 2003

Table 12. *Maturity, yield and average head weight of selected broccoli accessions in three summer trials.*[1]

		Trial I			Trial II			Trial III		
Acc.	Variety	Maturity (DAT)	Yield (t/ha)	Avg head wt (g)	Maturity (DAT)	Yield (t/ha)	Avg head wt (g)	Maturity (DAT)	Yield (t/ha)	Avg head wt (g)
BR005	Satomidori	51	10.8	405	52	3.6	362	49	10.3	388
BR070	SF1201	54	7.4	316	59	3.0	254	49	11.6	434
BR071	SF1202	52	13.4	504	55	4.4	326	49	13.0	486
BR072	CNB-45	51	13.7	514	52	2.4	282	49	12.6	472
BR073	CNB-50	-	-	-	-	-	-	44	14.6	548
BR076	DG473	54	9.8	366	52	10.2	383	49	12.3	462
BR094	KY0554	51	8.6	324	52	2.8	330	44	12.9	485
BR116	RN1204	47	10.3	413	52	6.4	385	44	13.1	491
BR117	RN1203	52	11.3	424	52	10.1	402	44	11.3	422
BR120	RN1205	52	13.0	520	59	6.4	385	49	14.2	532

[1]Date transplanted: I = 26 May 2003; II = 9 July 2003; III = 25 August 2003 at AVRDC.

was favorable for head formation for those varieties with moderate maturity.

From these three trials, 10 outstanding varieties, namely CNB-45, CNB-50, DG473, KY0554, RN1203, RN1204, RN1205, SF1201 and SF1202, and including the Satomidori as check, were selected for their heat tolerance and early maturity (Tables 12 and 13). These varieties will be further evaluated in three advanced yield trials under open field conditions next summer. Four elite varieties, namely CNB-45, DG473, RN1203 and Satomidori, will be evaluated under protective structures during the hot-wet season in a replicated trial.

Table 13. *Horticultural characteristics of ten selected broccoli accessions.*[1]

Acc.	Variety	Stem length (cm)	Head thickness (cm)	Head length (cm)	Head width (cm)	Bead size (cm)	Chlorophyll[2] head	Chlorophyll[2] leaf	Side shoot production
BR005	Satomidori	3.0	5.0	16.3	16.5	Mod. to fine	323	360	Few
BR070	SF1201	3.1	4.9	16.8	15.9	Mod. to fine	318	357	Few
BR071	SF1202	3.2	5.2	19.9	19.5	Moderate	339	356	Few to mod.
BR072	CNB-45	3.6	4.9	17.0	16.7	Large	304	421	Moderate
BR073	CNB-50	3.1	5.6	17.4	19.2	Fine	300	360	Mod. to many
BR076	DG 473	3.1	4.6	16.4	17.1	Moderate	345	409	Mod. to many
BR094	KY0554	3.2	5.2	16.3	16.4	Mod. to fine	285	305	Moderate
BR116	RN1204	2.8	5.2	16.3	20.3	Fine	277	342	Mod. to many
BR117	RN1203	2.9	4.7	15.5	18.3	Mod. to fine	281	328	Few
BR120	RN1205	3.2	5.1	17.4	17.7	Moderate	307	355	Few

[1]Data from three trials transplanted 26 May, 9 July, and 25 August 2003 at AVRDC.
[2]Index mean of chlorophyll content for five sampled plants measured by Field Scout CM 1000 Chlorophyll Meter of Spectrum Technologies, Inc.

For more information, contact: Peter Hanson

Genetic Resources and Seed Unit

Collection and conservation of indigenous vegetable genetic resources

AVRDC serves as a vegetable germplasm conservation center. Through its Genetic Resources and Seed Unit (GRSU), it holds in trust for the global community a valuable collection of vegetable germplasm. The Center maintains the germplasm required in all kinds of vegetable research work and at the same time protects this germplasm from getting lost in nature due to economic development. The long-term objective of GRSU is to assemble a comprehensive collection of the Center's principal crops, as well as the major vegetable crops in each of the different geographical regions including indigenous species.

Starting in 1999, GRSU intensified its activities on the conservation of indigenous vegetable germplasm. AVRDC, the Asian Development Bank (ADB) and eight Asian countries are collaborating on the project RETA 6067 "Promoting Utilization of Indigenous Vegetables for Improved Nutrition of Resource-Poor Households in Asia." The eight countries are Bangladesh, Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Thailand and Vietnam. One of the expected outputs of the project is the maintenance of indigenous vegetable germplasm and related information collected through RETA 5839 "Collection, Conservation and Utilization of Indigenous Vegetable Germplasm" to support research and utilization and the collection of additional indigenous vegetable germplasm. The project addresses the problem of food security, particularly nutritional security, and the loss of biodiversity.

Through RETA 5839, a total of 4,408 accessions of indigenous vegetable germplasm were collected in Bangladesh, Indonesia, Philippines, Thailand and Vietnam. The materials are conserved in the country of origin. More than 2,500 accessions have been transferred to AVRDC for long-term conservation.

In-country training

Through RETA 6067, workshops on "In-country Training on Indigenous Vegetable Germplasm Collecting, Conservation and Management" were held in Cambodia (9–11 April 2003), Lao PDR (12–15 May 2003) and Malaysia (23–26 June 2003). A training module for the course was developed.

The training module developed included both lectures and practicals. The lecture topics were: 1) Introduction to collection, conservation and utilization of indigenous vegetables (IVs); 2) Introduction to concepts of germplasm conservation; 3) Collecting IV Germplasm; 4) Regeneration of IV Germplasm; 5) Germplasm characterization; 6) Vegetable seed preservation and storage; and 7) Documentation. The practicals included the following: 1) Introduction to IVs; 2) Market visit; 3) Collecting IVs; 4) Processing of collected materials; and 5) Characterization of vegetable germplasm.

Fifty-four personnel from national agricultural research and extension systems (NARES) were trained. Additional hands-on training was provided to members (four to five personnel per country) of the collecting teams during actual collecting expeditions.

Germplasm collecting expeditions

Expeditions were conducted in the provinces of Bolikhamsay, Khammouane, Luang Prabang, and Oudomxay in Lao PDR (16–25 May 2003) and Peninsular Malaysia, Sabah and Sarawak (1 September to 10 October 2003) and in Kampong Chan and Kampong Thom, Cambodia. Collecting teams consisted of 4 to 5 trained staff of NARS (National Agricultural Research System) and AVRDC. An expert in collecting germplasm served as team leader. Standard collecting and ethnobotanical and indigenous information forms were used to gather information related to the germplasm.

Germplasm collection housed at AVRDC

AVRDC conserves in trust for the global community a total of 53,347 accessions (Table 14). Collecting expeditions were conducted in Cambodia, Lao PDR and Malaysia based on strategies discussed during the inception meeting of project RETA 6067. A total of 230 new accessions were collected from the provinces of Oudomxay, Luang Prabang, Borikhamxay, and Khamouane in Lao PDR. Collecting information and duplicates of 178 accessions, including 31 species collected from 45 sites and 33 farmers in the northern provinces, were received at AVRDC for conservation (Table 15). The rest are with the Hat Dok Keo Horticultural Research Center, Lao PDR. A total of 224

accessions were collected from the states of Terengganu, North Sembilan, and Johor in Peninsular Malaysia, and 104 accessions were collected from Sabah. An expedition was also mounted in Sarawak. A total of at least 500 accessions including at least 29 species have been collected from Malaysia. Details of the collecting expeditions are not yet available.

The total number of accessions now being maintained at AVRDC is shown in Table 14. The number of accessions added in 2003 to the collection being maintained at AVRDC is 3888, including 32 genera and 42 species from 30 countries.

Table 14. *Accessions of vegetable germplasm conserved at AVRDC, as of 31 December 2003.*

Crop	Accessions	
	Added in 2003	Total
Principal crops		
Glycine	1,117	15,312
Capsicum	48	7,569
Lycopersicon	-1[1]	7,230
Vigna radiata	10	5,658
Solanum	104	2,908
Brassica	11	1,767
Allium	-	1,078
Subtotal	1,280	41,522
Other Crops		
Vigna unguiculata	-	1,388
Luffa	4	704
Phaseolus	2	635
Amaranthus	21	508
Vigna mungo	-	478
Cucumis	3	475
Cucurbita	11	463
Abelmoschus	36	411
Vigna unguiculata ssp. *sesquipedalis*	-	377
Lagenaria	2	292
Lablab	-	268
Pisum	-	223
Vigna unguiculata ssp. *unguiculata*	1	110
Others	2,528	5,493
Subtotal	2,608	11,825
Total	3,888	53,347
No. of genera	32	153
No. of species	42	434
No. of countries	30	151

Documentation of indigenous knowledge

It is interesting to note that in Lao PDR, the young shoots of wild bitter gourd (*Momordica charantia*) are used as vegetable in the province of Oudomxai, in the same manner that the same plant parts are extensively used in the Philippines. In Oudomxai, the young shoots are used as pot herbs. Eggplant (*Solanum melongena*) and other species related to it (*S. torvum, S. nigrum* and putatively *S. sisymbrifolium* and *S. xanthocarpum*) are extensively cultivated in the provinces visited, thus accounting for the largest number of germplasm collected during the expedition. It was noted that in some farms in Luang Prabang, a bewildering array of genotypes of *S. melongena* exhibiting variation in leaf, flower, and fruit characteristics are being cultivated inter-mixed in the same field. Infor-

Table 15. *Accessions of indigenous vegetables received by AVRDC from northern Lao PDR.*

Species/Crop	Accessions
Amaranthus spp.	4
Anetum graveolens	2
Benincasa hispida	1
Brassica spp.	1
Cajanus cajan	1
Capsicum spp.	20
Celosia argentea	2
Coriandrum sativum	3
Cucumis sativus	2
Cucurbita moschata	11
Eryngium foetida	3
Lablab purpureus	4
Lactuca sativa	1
Lagenaria siceraria	2
Luffa aegyptiaca	4
Lycopersicon esculentum	4
Momordica charantia	13
Ocimum basilicum	4
Ocimum spp.	5
Passiflora foetida	3
Phaseolus vulgaris	2
Psophocarpus tetragonolobus	2
Raphanus sativus	1
Solanum melongena	55
Solanum nigrum	1
Solanum spp. (orange)	11
Solanum spp. (yellow)	2
Solanum torvum	5
Spilanthes paniculata	4
Vigna unguiculata	2
Total	175

mation from the farmers revealed that several distinct varieties were originally grown side by side, and seeds from the harvest, most likely products of crossing among the genotypes, were used for the succeeding seasons. The pattern of variation observed in the plants suggests continuing recombination and segregation. It would be interesting to observe the population in the future to determine the composition, and if selection among the many segregants will be done by the farmers. In the provinces visited, shoots of wild passionfruit (*Passiflora foetida*) were commonly gathered from plants growing in the wild and used as vegetable.

In the provinces of Peninsular Malaysia visited (Negri Sembilan, Johor, and Terengganu), the immature fruit of *Moringa oleifera* is considered by the male population as an aphrodisiac. Contrast this to the Philippines, where the leaves are believed to increase milk production in lactating mothers, and in Taiwan where infusions from the stem are believed to expel body fat globules. It is observed that the diversity of species and genotypes of indigenous vegetables is extremely limited in areas where estate crops like oil palm and rubber are cultivated, compared to that found in other countries of Southeast Asia. A possible cause is the massive clearing of the land to be used for cultivating the plantation crops. Of the few vegetable species to be found growing in the said areas, the most interesting is the wild form of *Momordica charantia*, which seems to thrive under these conditions. A possible reason for its common occurrence in these conditions is the manner of seed dispersal (fruits dehisce and seeds with sweet aril are eaten by birds or carried off by large ants).

An interesting classification of indigenous vegetables used commonly in Malaysia is the 'ulam', loosely meaning indigenous vegetables that are most often gathered from natural growth and eaten either fresh as salad, blanched, cooked as pot herbs, or cooked to impart a distinct flavor to dishes. Notable examples are 'ulam raja' (*Cosmos caudatus* or *C. bipinnatus*), ferns like 'pakis merah' (*Nephrodium inophyllum*), 'bunga kantan' (*Etlingera elatior* of the Zingiberaceae family) leaves of 'ubi kayu'(*Manihot esculenta*) of which a particular narrow-leafed variety is preferred, 'terung pipit' fruits *(Solanum torvum*), and fruits of perennial species like 'petai' (*Parkia speciosa*) and 'jering' (*Archidendron jiringa*).

In Sabah, the vines of *Momordica charantia* are dried and used to make an infusion which is used as bath water by women who have just given birth. Accordingly, this practice traces its roots from the Chinese influence. Another is the use of Chinese boxthorn (*Lycium chinense*) as a vegetable.

In the vegetable markets of Kota Kinabalu and other big towns in Sabah, 'sayur manis' (*Sauropus androgynus*) is sold as tender shoots in bundles with very few leaves, reminiscent of asparagus spears. Farmers harvest the *Sauropus* plants by pruning every two weeks, thus insuring that tender shoots have emerged and are ready for harvest. This method of harvesting and selling *Sauropus* has only been observed in Sabah. In other parts of Southeast Asia, *Sauropus* is sold and cooked as green leaves.

A common leafy vegetable observed in the markets of Sabah is 'sayur bengali' (*Erechtites hieracifolia*). This species grows extensively as a volunteer in gardens and backyards, and the young leaves and shoots are cooked as 'ulam'.

The fruits of *Solanum indica* are used by some people in Keningau in Sabah to impart flavor to cooked dishes, reminiscent of the way monosodium glutamate enhances flavor of food.

The young shoots of *Cassia occidentalis* and *Cassia alata* are used as vegetables both in Peninsular Malaysia and in Sabah. Leaves are gathered from natural growths along roadsides in the case of *C. alata*, or from plants growing near coastlines in the case of *C. occidentalis*.

In conclusion, the diverse array of vegetable species including indigenous types provides materials from which one can choose genotypes to diversify production systems for income generation, diversify diets for improved health and nutrition, and to develop novel varieties of crops for commercialization. The newly acquired materials have not been regenerated and therefore are not yet available for distribution.

Distribution of vegetable germplasm

AVRDC regularly distributes both improved and unimproved vegetable germplasm to collaborating NARES and to various requesting parties. Outgoing seeds are monitored at GRSU.

Seeds received at GRSU from various units of the Center are prepared for shipment, inspection and phytosanitary certification by the Taiwan Bureau of Animal and Plant Health Inspection and Quarantine. Each shipment is accompanied by a Material Transfer Agreement.

Table 16. *Recipients of germplasm from AVRDC in 2003.*

Recipient	No. of samples	Total
External		8,748
Korea	1,781	
India	1,346	
Taiwan	1,133	
Thailand	1,125	
USA	426	
Vietnam	268	
Philippines	214	
Lao PDR	142	
Pakistan	139	
China	128	
Others (61)[1]	2,046	
Regional Center/Program		223
AVRDC ARC	47	
AVRDC RCA	176	
Internal		215
Technology Promotion Unit	107	
Biotechnology Unit	40	
Legume Unit	29	
Pepper Unit	12	
Virology Unit	8	
Bulb Allium Unit	4	
Crop and Ecosystem Management Unit	4	
GRSU	4	
Tomato Unit	4	
Mycology Unit	3	
Total		9,186

[1] Afghanistan, Argentina, Australia, Bahamas, Bangladesh, Benin, Bhutan, Bolivia, Burkina Faso, Cambodia, Canada, Egypt, Ethiopia, Finland, France, Germany, Ghana, Greece, Haiti, Hong Kong, Indonesia, Iran, Israel, Italy, Ivory Coast, Japan, Kenya, Lesotho, Malawi, Malaysia, Martinique Islands, Mauritius, Mayotte, Mexico, Micronesia, Mozambique, Myanmar, Nepal, Netherlands, New Caledonia, North Korea, Panama, Samoa, Seychelles, Singapore, Solomon Islands, South Africa, Spain, Sri Lanka, Sudan, Suriname, Sweden, Tahiti, Tanzania, Togo, Trinidad and Tobago, Turkey, United Kingdom, Venezuela, Virgin Islands, and Zambia.

A total of 8971 accessions including breeding lines were sent out from AVRDC of which 97.5% went to 71 countries and the other 2.5% to AVRDC regional centers in Thailand and Africa (Table 16). Of the total seed distribution, 2.3% was used by headquarter scientists in screening for resistance to insect pests and diseases. Seeds were also dispatched to other genebanks for safety duplication of conserved material (Table 17).

Regeneration and characterization of vegetable germplasm

Since the collection of germplasm at GRSU is primarily utilization-oriented and secondarily conservation-oriented, we maintain a large active collection for distribution purposes. Our pepper and tomato collections are the largest and most comprehensive active collection of each crop's germplasm in the world.

To enhance utilization, evaluation data must be available. Morpho-agronomic characterization is usually done routinely during multiplication for long-term storage. Characterization follows closely the crop descriptors used by IPGRI (International Plant Genetics Resources Institute). Characterization is also done to identify the correct species of an accession.

Evaluations for traits of immediate importance to breeders (e.g. resistance to pests, diseases and abiotic stresses, improved quality, etc.) are done with the participation of researchers from several disciplines (e.g. entomologists, pathologists, virologists, physiologists, chemists, etc.). In this way, invaluable genepools that can be channeled into breeding programs can be identified. Accessions have been used by AVRDC scientists and others to develop new cultivars that are resistant to disease and tolerant to environmental

Table 17. *Recipients of materials from the Genetic Resources and Seed Unit in 2003.*

Classification	No.	Samples	Purpose
Genebanks	3	1,265	Duplicate storage, research (genetic identification, core collection, evaluation, RAPD, breeding and genetics)
Government organizations	27	1,168	Trials, screening for resistance to rust, bacterial, insects, early maturity
Universities	15	1,029	RAPD, demonstration materials, identifying resistant genes in species, trials, research
Private individuals	9	137	Trials, home garden
Private companies	6	44	Trials
Seed companies	2	34	Trials, observation and crossing, research
Units of AVRDC	10	220	Trials, screening for resistance to insect pests, and diseases
Total		3,682	

stresses in the tropics. The newly developed lines, together with unimproved germplasm accessions are in turn used by national programs either directly as cultivars for production or as parent stocks in their own breeding programs.

In 2003, regeneration and characterization of 1638 accessions of 43 species were completed at GRSU (Table 18). Regeneration of accessions was done under net cages to prevent insect mediated pollination in some species and to allow introduction of honeybees as pollinators for *Brassica* species. Protocols developed at the GRSU were followed.

In *Capsicum*, 225 accessions including 6 species were characterized. For the analysis of quantitative data, missing or mixtures were treated as missing data. Standardization of value by log10 function was done before cluster and canonical discriminant analysis. However, basic statistic value including mean, range, and standard deviation values were calculated from original values. To know the correlational relationship between characters, correlation coefficient values were calculated. Characters showing significance in canonical discriminant analysis were used in the cluster analysis. All analysis of quantitative characters was performed using a PC-SAS package.

Cluster analysis for qualitative characters was done with NTSYSpc v2.0 using simple matching coefficient and the unweighted pair group method arithmetic mean algorithm (UPGMA). The phenogram was used to determine clusters with high similarity coefficients. After that, to find main characters having ability to divide into sub-clusters, the mode of the characters in each sub-cluster was calculated.

Cluster and canonical discriminant analysis for Capsicum

Table 19 shows the mean, range, and standard deviation of quantitative characters in *Capsicum*. Among 13 characters, days to flower showed the highest standard deviation, followed by corolla length, mature leaf width, and cotyledonous leaf length. These results suggest that the raw values be transformed into standardized values before analysis.

Table 20 shows the significant correlation coefficient value between characters and canonical component. Non-significant character was only cotyledonous shape index. In Can1 component, higher value having positive effects were corolla length, corolla shape index, and mature leaf width. Negative correlation coefficients in Can1 component were in pedicel length,

Table 18. *Germplasm accessions regenerated in 2002-2003 at AVRDC headquarters.*

Genus	Species	Accessions
Abelmoschus	*manihot*	2
Allium	*sativum*	157
	cepa cvg. *aggregatum*	15
Amaranthus	*caudatus*	2
	dubius	6
	hypochondriacus	5
	spinosus	1
	tricolor	10
	viridis	2
Anethum	*graveolens*	15
Basella	*alba*	10
Brassica	*juncea*	15
	rapa	21
Cajanus	*cajan*	36
Capsicum	*annuum*	128
	baccatum	21
	chacoense	5
	chinense	38
	frutescens	36
	pubescens	6
Celosia	*argentea*	10
Cleome	*gynandra*	20
Corchorus	*capsularis*	4
	olitorius	6
Cucumis	*sativus*	16
Eryngium	*foetidum*	9
Glycine	*max*	805
Lablab	*purpureus*	23
Lycopersicon	*esculentum*	4
	peruvianum	1
	sp.	43
Momordica	*balsamina*	1
	charantia	2
	sp.	1
Moringa	*oleifera*	29
	stenopetala	1
	peregrina	1
	drouhardii	1
Ocimum	*americanum*	4
	basilicum	2
	tenuiflorum	3
Phaseolus	*lunatus*	1
Solanum	*aethiopicum*	5
Spilanthes	sp.	15
Talinum	*triangulare*	1
Vigna	*radiata*	99
Total		1638

Table 19. *Mean, range, and standard deviation of characters in 225 accessions of* Capsicum.

Characters	Mean	Range	Std. dev.
Cotyledonous leaf length (cm)	17.72	10.00–26.80	2.84
Cotyledonous leaf width (cm)	6.48	2.00–9.60	0.85
Shape index of cotyled. leaf*	0.37	0.20–0.60	0.05
Mature leaf length (cm)	12.42	3.23–21.19	3.08
Mature leaf width (cm)	6.82	1.97–13.96	2.34
Shape index of mature leaf*	0.54	0.36–0.81	0.08
Days to flower (days)	74.05	45.00–166.00	19.74
Corolla length (mm)	12.09	4.20–26.10	3.13
Corolla width (mm)	0.55	0.18–1.12	0.18
Shape index of corolla*	0.04	0.03–0.07	0.01
Pedicel length (mm)	1.90	0.54–4.98	0.78
Pedicel width (mm)	2.00	0.74–4.18	0.62
Shape index of pedicel*	1.30	0.31–5.38	0.86

*Those with asterisk have no unit of measurement.

Table 20. *Significant correlation coefficient value between characters and canonical component.*

	Canonical component		
Characters	Can1	Can2	Can3
Cotyledonous leaf length	–0.09	–0.01	0.17
Cotyledonous leaf width	0.03	0.17	0.00
Mature leaf length	–0.63	–2.82	1.09
Mature leaf width	0.56	6.07	–1.67
Shape index of mature leaf	–0.51	–2.77	1.14
Days to flower	–0.25	0.28	0.05
Corolla length	0.99	1.18	-3.32
Corolla width	–0.01	–2.84	6.81
Shape index of corolla	0.74	1.97	–4.88
Pedicel length	–0.78	–0.30	0.69
Pedicel width	0.19	1.56	–3.85
Shape index of pedicel	0.16	–0.89	4.70

mature leaf length, and leaf shape index. Mature leaf width, corolla length, corolla shape index, and pedicel width showed higher positive effect in Can2 component. Corolla width and pedicel shape index had high positive correlation with Can3 component, while corolla shape index and pedicel width had high negative correlation. Characters of leaf and corolla are important characters in Can1 and Can2, and corolla and pedicel characters have major effects on Can2 and Can3. These characters of leaf, corolla, and pedicel are important in the analysis of quantitative traits. Among them, corolla and pedicel characters are more significant in the classification of *Capsicum* species. Corolla width, pedicel length, and pedicel width are not included in the descriptor used at AVRDC, and based on the analysis above, the descriptor should be modified to include them.

Canonical discriminant analysis using 13 quantitative characters shows that Can1, Can2, and Can3 can explain 100% of the variation. Corolla and pedicel characters were again shown to be important and should be added as descriptors. The first canonical component explains 64.2% of total variation, and the other canonical components explain 21.2% and 14.4% of total variation, respectively. Using the cumulative contribution to total variation Can1 and Can2 component can explain 85.5% of total variation in quantitative characters.

Quantitative characters were subjected to cluster analysis. Using the mean and standard deviation values it was shown that Cluster 1 group has big mature leaf, short days to flowering, big corolla, short pedicel length, and thick pedicel characters. Cluster 2 has small leaf, early days to flowering, big corolla, and small pedicel characters. The main characters in Cluster 3 are small leaves, long days to flowering, small corolla, long pedicel, and short pedicel width. Cluster 4 has big leaves, late days to flowering, big corolla, and long and thick pedicel.

Members of the species *Capsicum annuum* were distributed in Cluster 1 and 2, *C. frutescens* and *C. chacoense* species in Cluster 3 and *C. baccatum*, *C. chinense*, and *C. pubescens* in Cluster 4 (Fig. 1).

Cluster 1 contains only *Capsicum annuum*. The main species of Cluster 2 was *C. annuum* followed by *C. baccatum*. Majority of Cluster 3 were *C. frutescens* and *C. chinense*. Cluster 4 has two major species, *C. chinense* and *C. baccatum*.

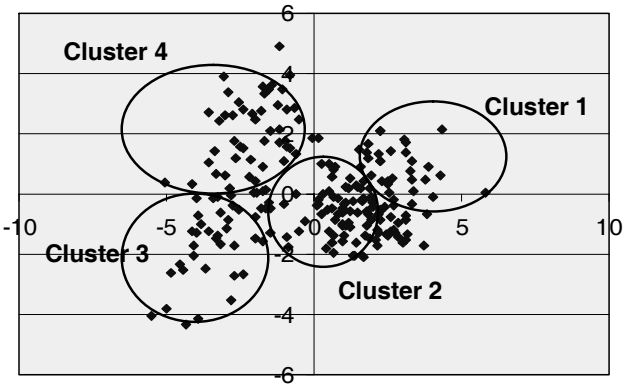

Fig. 1. *Scatter plot based on the first two canonical values from canonical analysis of 225 accessions of* Capsicum.

Analysis of qualitative data by cluster analysis

Cluster analysis by NTSYSpc v2.0 produced the dendrogram in Fig. 2. Similarity coefficient value of 0.53 can divide the 225 accessions into six clusters based on 28 qualitative characters. Cluster 1 contains *Capsicum annuum*, Cluster 2 contains *C. chacoense, C. baccatum*, and *C. frutescens*, Cluster 3 contains *C. chinense* and Cluster 4 contains *C. pubescens*. A few accessions having purple flowers in *C. annuum* separated to Clusters 5 and 6 (Fig. 2).

Cluster 1 group can be divided into 4 sub-clusters at similarity coefficient value of 0.60 (Fig. 3). To know the main factors that subdivided 124 accessions of *C. annuum* into 4 sub-clusters, value of mode of each sub-clusters were calculated and compared with each characters. Stem pubescence density, stem pubescence type, leaf pubescence, annular constriction at junction of calyx and peduncle, hypocotyl color and anther color were the characters that subdivided Cluster 1 into four sub-clusters.

Cluster 2 subdivides 58 accessions of *C. baccatum* and *C. frutescens* into two sub-groups. The traits involved are hypocotyl color intensity, plant growth habit, leaf pubescence type, leaf shape, plant stature, number of pedicels per axil, corolla color, calyx margin, corolla spot, anther color, filament color, fruit position, fruit blossom end appendage, and fruit set.

Cluster 3 can be divided into two sub-clusters at similarity coefficient value of 0.55 (Fig. 4). Thirteen characters (stem pubescence density, stem pubescence, leaf pubescence type, leaf shape, leaf color, plant stature, nodal anthocyanin, branching habit, number of pedicels per axil, calyx margin, annular constriction at junction of calyx and peduncle, filament color, stigma position in relation to anthers at full anthesis) had the ability to subdivide the group of 37 accessions of *C. chinense* into two sub-clusters.

Cluster 4 contains *C. pubescens* (Fig. 5). Cluster 5 and 6 contain four accessions of *C. annuum* having purple flowers.

In conclusion, morpho-agronomic characterization can be done during regeneration. This generates information that can be used in systematic grouping of accessions. Using a combination of the PC-SAS package for cluster analysis of quantitative data and NYSYSpc v 2 for qualitative data, accessions can be systematically subdivided into groups that can be used in nominating accessions to the core collection.

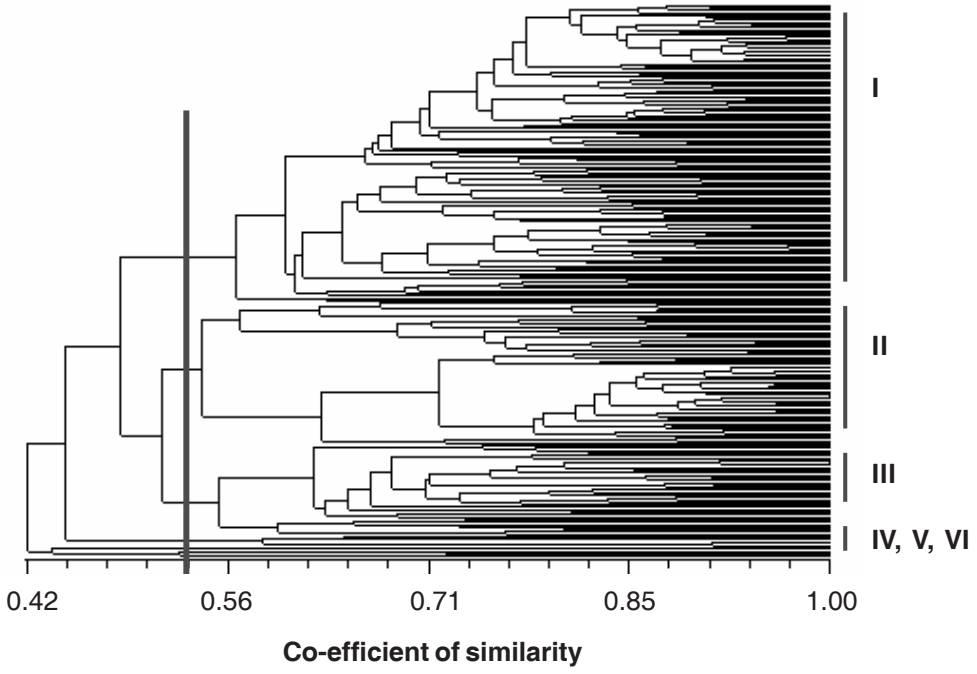

Fig. 2. *Dendrogram of 225 accessions of* Capsicum *species based on 28 qualitative characters.*

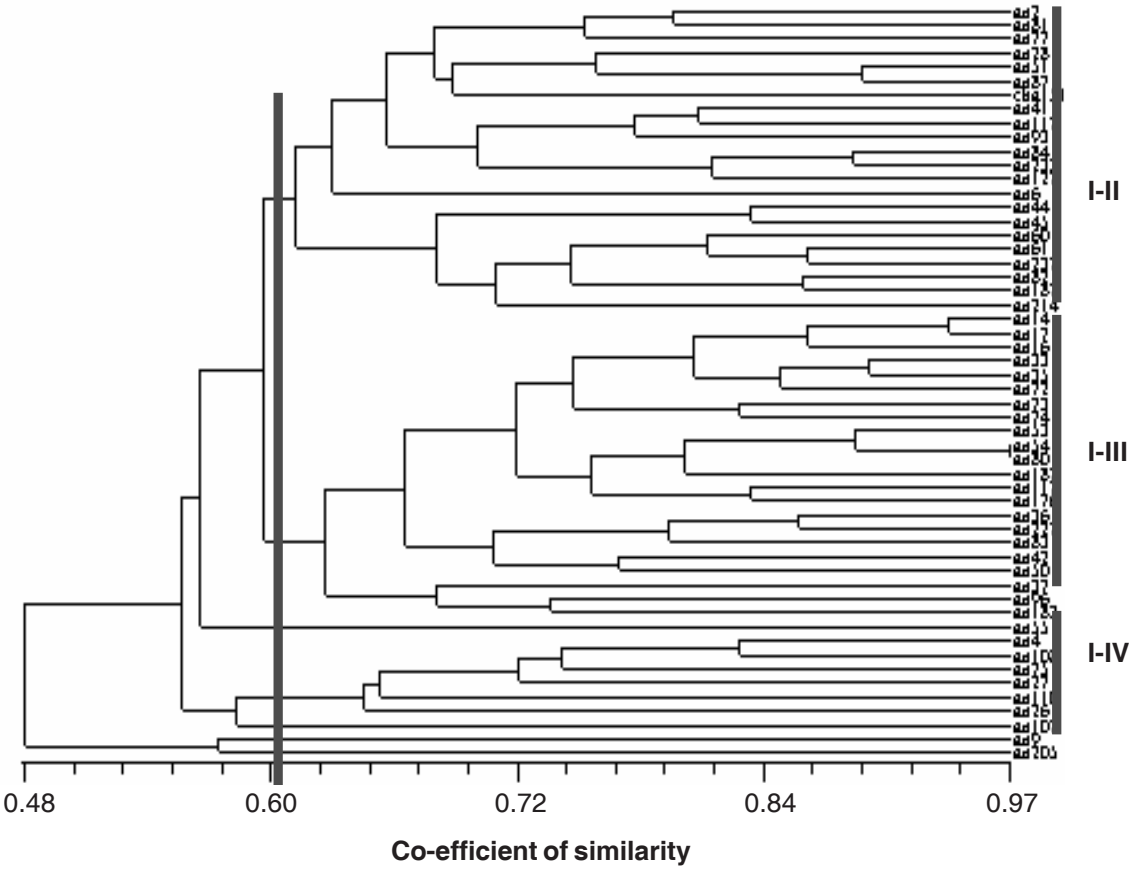

Fig. 3. *Dendrogram of second sub-cluster of Cluster 1 containing* Capsicum annuum.

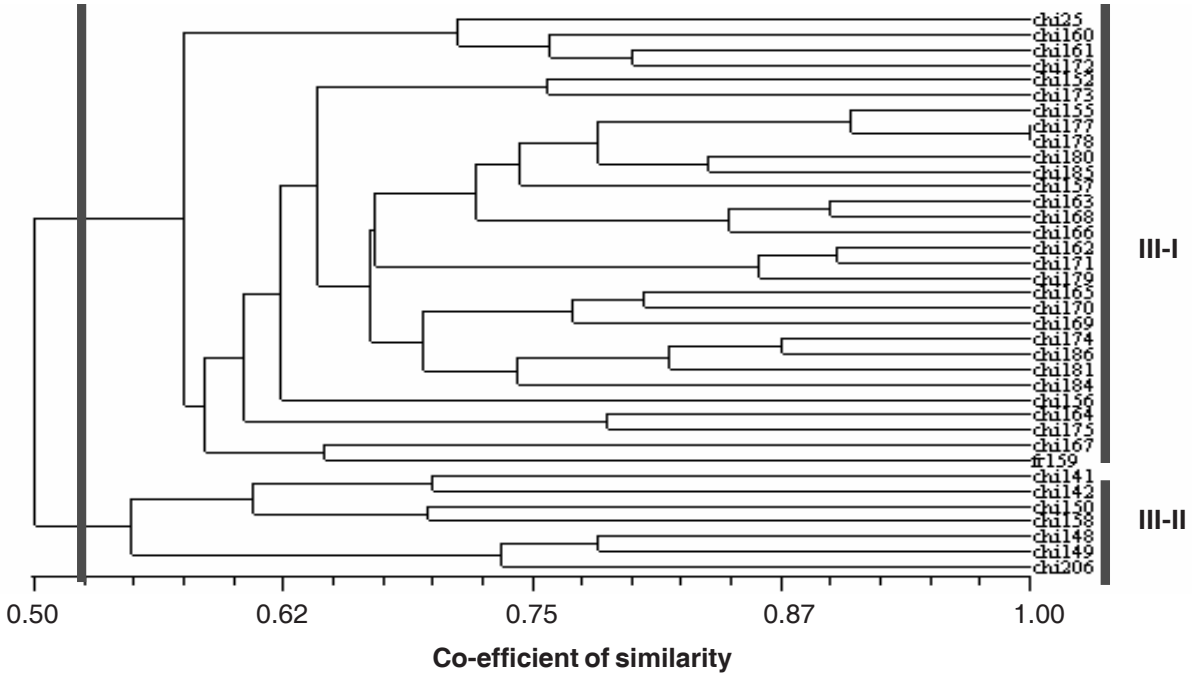

Fig. 4. *Dendrogram of Cluster 3 containing* Capsicum chinense.

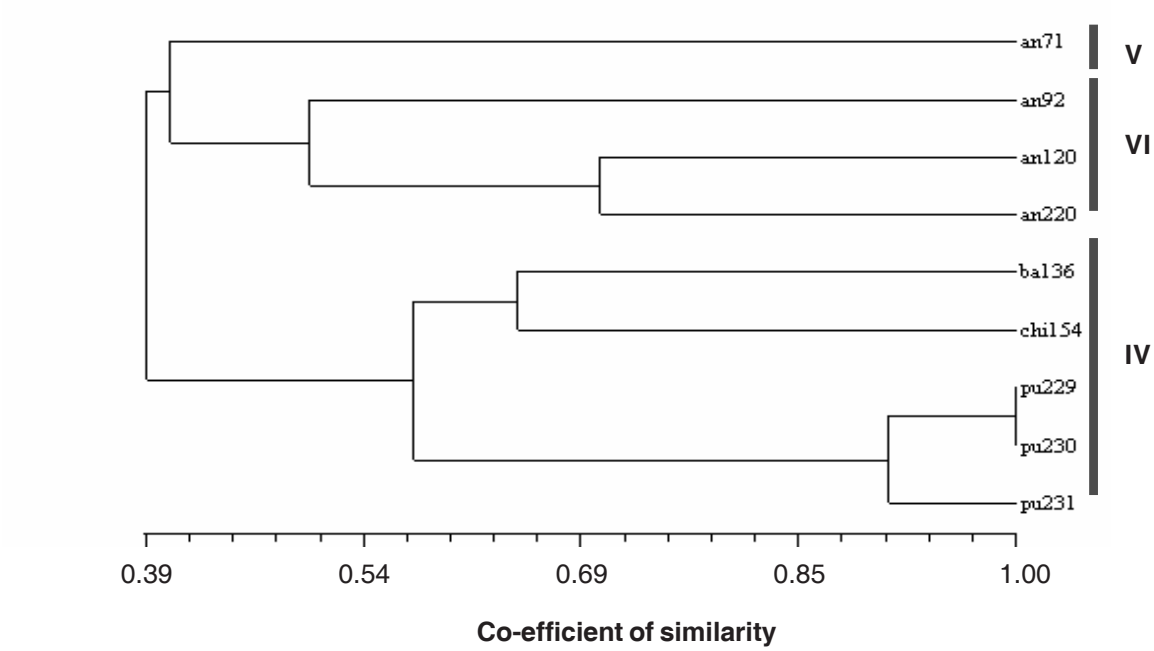

Fig. 5. *Dendrogram of Clusters 4, 5 and 6 containing* Capsicum pubescens *and* C. annuum.

New sources of resistance to anthracnose and Phytophthora blight in *Capsicum*

The regeneration plots for vegetable germplasm at AVRDC are used as an observational nursery for breeders seeking sources of materials for evaluation. In 2003, selected *Capsicum* accessions were evaluated for resistance to anthracnose and Phytophthora blight through the collaborative activity between AVRDC and the Rural Development Administration (RDA), Korea entitled "Multiplication and Characterization of Vegetable Germplasm", which is part of the project "Development of Technologies for Improvement of Vegetable Cultivars for the Subtropical and Temperate Areas."

Anthracnose and Phytophthora blight are major problems to the cultivation of pepper (*Capsicum annuum*) throughout the world. Anthracnose disease is due to several species of *Colletotrichum* (*C. gloeosporiodes* and *C. acutatum* are the major species) while Phytophthora blight is caused by *Phytophthora capsici.*

Resistance to anthracnose has so far been reported only in *Capsicum baccatum* and *C. chinense*. As a result, breeders have to resort to interspecific hybridization to introduce anthracnose resistance to most improved breeding lines of *C. annuum.* Interspecific hybridization, however, is accompanied by constraints such as the need to use embryo rescue to recover hybrids and the need to overcome sterility in hybrid progenies. On the other hand, resistance to Phytophthora blight has been reported in several *Capsicum* species.

The objective of this experiment is to evaluate and identify sources of resistance to anthracnose and Phytophthora in *Capsicum*. For evaluation of resistance to anthracnose, 23 accessions were sampled, using 5 fruits per accession at the intermediate stage between immature and mature stages. For Phytophthora blight, 58 accessions were screened among more than 200 accessions being regenerated. For each accession, 24 plants per accession 41 days after sowing were evaluated.

Phytophthora capsici isolate, Pc 17E, from the stock in AVRDC laboratories was multiplied on V-8 juice agar medium. The soil where the experimental plants were growing was drenched with inoculum of 1 $\times 10^5$ zoospores/ml. The Phytophthora blight resistance was scored on samples 14 days after inoculation.

A *Colletotrichum acutatum* isolate, Cg 153, was multiplied on potato dextrose agar (PDA) medium.

Inoculum of 5×10^5 spores/ml was introduced into the fruits by microinjection method. Inoculated fruits were kept at 25 ± 2°C in a room saturated with moisture. The disease symptoms were recorded 5 days after inoculation. The degree of disease incidence on fruits was judged by diameter of lesions formed.

Disease severity rating (DSR) was used for scoring reaction to *Phytophthora*. The DSR scale is as follows: 0 = no symptoms; 1 = 1–10% stem necrosis below the cotyledons; 2 = 11–50% stem necrosis below the cotyledons; 3 = 51–100% stem necrosis below the cotyledons; 4 = stem lesion extending above the cotyledons. Disease reaction categories were based on the percentage of surviving plants 21 days after inoculation. Data for anthracnose were subjected to analysis of variance and Duncan's multiple range test.

For anthracnose, three accessions were found to have similar lesion diameter as the resistant check KAR. Two of them were *C. annuum* (TC 6903, Apaseo Pasilla from Mexico and TC 6941, Pasilla from USA) carrying the chlorophyll retention gene and therefore have dark green fruits. The other accession was *C. baccatum* from Australia (TC 6842).

Resistance to anthracnose is common in *C. baccatum* and *C. chinense*. However, this is the first report of resistance to anthracnose in *C. annuum*. It is significant because it will make the transfer of the gene or genes for resistance to improved *C. annuum* breeding lines faster and easier. The two accessions showed within accession variation in morpho-agronomic traits. Screening for resistance to anthracnose using individual plants also showed variation in response. Highly resistant plants were identified and uniform inbred lines are being developed from them.

For Phytophthora blight, almost all materials were susceptible to the isolate of *Phytophthora capsici* used. Fortunately, one accession (C 3453) showed moderate resistance (2.4 DSR) to *Phytophthora capsici* isolate, Pc 17E. It showed 2.4 point of disease severity index. DSR ranged from 2.4 to 4. Resistant checks PI 201234 and PBC 602 had DSRs of 0.3 and 0.8, respectively. Susceptible checks PBC 137 and Early Calwonder had DSRs 3.8 and 4.0, respectively. Because pepper has high outcrossing rates, individual plants of C 3453 should be tested. C 3453 is a *C. annuum* (PI 368069) originating from Malaysia.

In conclusion, we found that vegetable germplasm regeneration plots can serve as sources of materials for both morpho-agronomic characterization and evaluation for resistance to diseases. For the first time, two sources of resistance to anthracnose were identified in *C. annuum*: TC 6903 (Apaseo Pasilla from Mexico) and TC 6941 (Pasilla from USA). A third source of resistance to anthracnose was identified in *C. baccatum*: TC 6842 from Australia. A new source of resistance to Phytophthora blight was identified in C 3453, a *C. annuum* from Malaysia. We also recommend that the existence of genetic heterogeneity within an accession be considered during evaluation. Individual plants should be tested and single plant selection done to produce genetically uniform inbred lines carrying the desired trait.

Diversity in antioxidant activity, ascorbic acid and total phenol contents of indigenous leafy vegetables

Accessions of indigenous leafy vegetables were analyzed for their antioxidant activity (AOA), ascorbic acid (AsA), and total phenol (T-phenol) contents (Table 21). Herbs and young shoots of fruit vegetables were included in the analysis. The activity was done in collaboration with the Japan International Research Center for Agricultural Sciences (JIRCAS). The following are descriptions of functional properties for all vegetables tested:

Amaranthus *spp. (Amaranth or Chinese spinach)*

The collection maintained and conserved at AVRDC includes 19 species. In South and Southeast Asia, *Amaranthus atropurpureus*, *A. caudatus*, *A. cruentus*, *A. hypochondriacus*, *A. dubius*, *A. spinosus*, *A. tricolor* and *A. viridis* are used as leafy vegetables just like spinach (*Spinacia oleracea*). In the Americas, *Amaranthus* spp. is mainly used as a grain crop. The collection maintained and conserved at AVRDC includes a wide genetic diversity not only in morpho-agronomic characteristics but also in response to environmental conditions.

Results of evaluation of AOA, AsA and T-Phenol contents from 2001 to 2002 are shown in Table 22. Averages of AOA and phenol contents in 2001 were lower than that of 2002. The differences might be due to the inclusion of different accessions and/or or exposure to different growth conditions. There is wide genetic diversity in terms of morpho-agronomic traits as well as AOA, AsA, and T-Phenol contents. Selection of functional *Amaranthus* accessions with high AOA in addition to high yield and good quality is possible.

Anredera cordiflolia *(Madeira vine)*

Madeira vine, which belongs to the family *Basellaceae*, is a wild or cultivated vegetable similar to Malabar spinach (*Basella alba*). Madeira vine is a native of Central and South America. The succulent, slightly mucilaginous leaves may be eaten raw in salads or used as potherb. Madeira vine is a common leafy vegetable in Taiwan. Tubers may be boiled and eaten like potatoes. Although it has higher AOA compared to Malabar spinach, Madeira vine has lower AsA and T-Phenol contents.

Basella alba *(Malabar spinach or Ceylon spinach)*

Apparent differences were observed in stem color (green, pale green, purplish green, pale purple and purple), leaf size, leaf thickness, width and length of stem, numbers of lateral shoots, and shape of flower clusters. Many of these traits, as well as response to environmental conditions such as heat tolerance and photosensitivity, have an effect on yield. As far as AOA is concerned, Malabar spinach belongs to the group with lower activity (Tables 21 and 22). Variations in AOA, AsA, and T-Phenol contents suggest it is possible to select superior accessions.

Brassica rapa *(Chinese leaves or Chinese green)*

The materials tested were Taiwanese and Japanese cultivars, belonging to groups Neep Greens (Komatsuna) and Pak Choi in *B. rapa*. Diversity was narrow in terms of AOA, AsA and T-Phenol contents. However, there are more local varieties or landraces of Chinese leaves (*B. rapa*) in Southeast Asia that are adopted to tropical regions. This vegetable has a short growth period to harvest time and can be used in multi-cropping systems. More local varieties should be analyzed for functional properties.

Cajanus cajan *(Pigeon pea or tree bean)*

Native to India, pigeon pea is mainly used as a pulse crop and is adapted to semiarid environments. For this reason, pigeon pea is a minor indigenous vegetable in Southeast Asia. However, the leaves and young shoots, having a protein content of about 9%, may be cooked as potherb. Also some accessions of pigeon pea were observed to be high in functional properties (Table 21). In the appropriate environment, pigeon pea fits well in small landholders' garden cropping systems and it can be planted along hedges and bunds of rice fields.

The data of pigeon pea in Table 21 were derived from accessions cultivated in the winter of 2001. The plants were grown in net cages. Usually, the value for AOA was stable, however AsA and T-Phenol contents fluctuated depending on growing conditions such as season and application of agricultural chemicals. Using highly functional pigeon pea varieties, cultivation in gardens or along hedges and bunds of rice fields is highly recommended.

A large diversity of AOA, AsA, and T-Phenol contents in young shoots and leaves of pigeon pea was observed in 51 accessions (Table 22). Morphological diversity in leaf traits was very narrow. However, diversity in flower color, seed color, plant height, and earliness were noted. AsA content in young shoots and leaves varied even in the same plant material. In some accessions, AsA contents differed at different sampling dates. This observation on AsA content was different from other vegetables. Special attention is necessary for the evaluation of AsA content in young shoots and leaves of pigeon pea using MERCK Fqflex plus. Overall, the large diversity detected among accessions indicates that superior accessions can be selected for functional properties and suitability for use as a leafy vegetable.

Capsicum annuum *and* C. frutescens *(Pepper)*

Capsicum peppers are one of the most important fruit vegetables in the world. Its young leaves and shoots may also be used as a herb in soups and soy dishes. Evaluation on AOA of young shoots and leaves of *C. annuum* including pungent and sweet pepper, *C. baccatum*, *C. chinense* and *C. frutescens*, was done using 22 accessions (Table 22). Table 21 shows that one accession of *C. annuum* with dark purple leaf, purple flower petals, and dark purple fruit was noted to have high AOA, AsA (226 mg/100 g FW), and T-Phenol content (1,158 mg chlorogenic acid equivalent/100 g FW). Young shoots and leaves of *Capsicum* pepper were observed to generally have high T-Phenol content (817 mg chlorogenic acid equivalent/100 g FW). In this study, young shoots and leaves of pungent *C. annuum* appeared to be promising leafy vegetables. The leaves are usually soft and thin narrow shaped and glabrous. *Capsicum* pepper is a very popular vegetable in gardens in Southeast Asia. Utilization of young shoots and leaves as vegetables will be useful in promoting good health.

Ideally speaking, utilization of both fruit and young

shoots is desirable. However, a sufficient amount of leaves is necessary for good yields of fruits. For utilization of both fruits and young shoots, small-fruited accessions of the pungent pepper type may be more suitable. Furthermore, *Capsicum* pepper accessions with more branches, soft and thin leaves, and also without pubescence are more acceptable for use as leafy vegetable. From a field observation of four species (*C. annuum*, *C. frutescens*, *C. chinense* and *C. baccatum*), young shoots and leaves of *C. annuum* were more suitable as leafy vegetable compared to *C. frutescens* and *C. chinense*, which have tougher leaves. Growing conditions in Southeast Asia are not favorable to *C. baccatum*. In addition to our selected accession with dark purple leaves, selection for green-leaved accessions will be important in the future.

Celosia argentea *(Feather cockscomb)*

Feather cockscomb belongs to the *Amaranthus* family and is found throughout much of Asia and Africa. Production of this ornamental plant is limited, but *Celosia* plants can be seen along roadsides or edges of fields. When used as a leafy vegetable, accumulated nitrates and oxalates in the plant must be removed by boiling for five minutes. The leaf color of *Celosia* is usually green to purplish green. One accession introduced from Thailand had dark purple leaves and red stems; this accession had very high AOA with high AsA and T-Phenol contents. Seeds and flower spikes have known medicinal properties.

Chrysanthemum coronarium *(Garland chrysanthemum)*

Garland chrysanthemum is native to the Mediterranean region and is distributed in Europe, Northern Africa, and Asia. It has been cultivated in Asia mostly in China and Japan as a vegetable. In Southeast Asia, the vegetable types were probably introduced from China recently. The aromatic leaves and young shoots of garland chrysanthemum have a spicy, slightly resinous, 'floral' taste. The Chinese and Japanese are especially fond of this vegetable. In Japan, garland chrysanthemum is recognized as a vegetable with strong AOA, but this was not evident in our study. Our evaluation of AOA, AsA and T-Phenol contents of 20 accessions introduced from different countries, showed similar values and diversity compared to one species of spider flower (Table 22). During morpho-agronomic characterization, variations of leaf size, degree of serration at leaf edge, number of leaves, and earliness were noted. One reason for the lower values and diversity of AOA, AsA, and T-Phenol contents is the hot growing conditions. Garland chrysanthemum, a typical winter vegetable in Japan, has been observed to have higher AOA during winter.

Cleome gynandra *(Spider flower or Cat's whiskers)*

Spider flower is considered native to Asia, and is cultivated in Asia and Africa, where it is only of local importance. The very bitter leaves are eaten as a vegetable. Cooking and fermentation both reduce the bitterness. Often the leaves are salted and pickled. Spider flower was observed to have relatively high AOA and AsA contents (Table 21).

All accessions of spider flower evaluated here were introduced from Thailand, and from the results of morphological characterization, plant types were relatively similar in appearance. As shown in Table 22, diversity in AOA, AsA, and T-phenol contents was relatively small. Introductions from other countries may be necessary to increase diversity in functional properties. At the moment the traits for high yield may be of more importance when selecting superior types for cultivation.

Coccinia grandis *(Ivy gourd or scarlet gourd)*

The genus *Coccinia* with about 30 species is confined to tropical Africa, with the exception of *C. grandis*, which occurs in the wild from Africa to the Indo-Malaysian region. Ivy gourd is cultivated mainly in India, Thailand, Malaysia and Indonesia. Young shoots and leaves are consumed as a fried, blanched or boiled vegetable and added to rice, noodles or soups. It is a very popular green in Thailand. The leaves are good sources of vitamins, in particular vitamin A (8,000–18,000 IU). Young fruits are used in soups and curries. As with regard to AOA, young shoots and leaves did not give high values, but T-Phenol content was relatively high (457 mg chlorogenic acid equivalent/100 g FW, Table 21). There were no clear differences in AOA and AsA content among male and female accessions observed in young shoots and leaves. Diversity in T-Phenol content was noted among accessions and T-Phenol content fluctuated depending on such environmental conditions as light intensity or temperature. Therefore, when screening for superior ivy gourd accessions, materials should be grown under similar conditions.

Corchorus *spp. (White jute, Jew's mallow or Nalta jute).*

The genus *Corchorus* contains at least two species used as leafy vegetables; one is *C. olitorious* and the other is *C. capsularis*. Many *C. olitorious* accessions possess large, wide leaves of green color and green or purplish-green stems. On the other hand, many *C. capsularis* accessions have small, narrow leaves with green to purplish green color and dark to pale purple stems. *Corchorus* accessions used for leafy vegetables are shorter and have more lateral shoots than accessions used for fiber production.

Corchorus has recently become popular as a leafy vegetable in Taiwan and Japan. *Corchorus olitorious* var. 'Moroheiya' is well known for its high AOA in Japan, where it is used for noodles, cookies, and cakes.

The jute collection at AVRDC showed wide diversity in morphological characteristics as well as AOA, AsA, and T-Phenol contents. AOA did not vary during different years (Table 22), but AsA did. Varietal differences might account for the lower AsA contents in 2002 since that year's testing included some fiber type accessions.

Corchorus grow well under hot-wet summer conditions and are therefore suitable for cultivation in Southeast Asia. It is one of the indigenous leafy vegetables recognized to be highly nutritious. However, eating acceptability differs in different regions. For this reason, it is suggested that promoting utilization of *Corchorus* through the introduction of improved cooking methods and recipes is necessary.

Coriandrum sativum *(Coriander or Chinese parsley)*

Coriander is grown as a culinary herb and vegetable, and used for chutneys or in soups throughout Southeast Asia. Coriander fruits are commonly used as a spice and added to numerous dishes. Coriander leaves did not possess strong AOA, but had relatively high T-Phenol content (580 mg chlorogenic acid equivalent/ 100 g FW, Table 21). Coriander is a very diverse species, and it is mainly classified by its fruit characteristics. The coriander collection at GRSU is small and future additions may include populations with higher T-Phenol contents.

Gynura bicolor *(Gynura or Purple gynura)*

Gynura belongs to the *Compositae* family and is cultivated from tropical East Asia to Taiwan and Japan. Young shoots and leaves are the main edible part. Gynura is mainly propagated by cutting because of difficulties in seed setting. Table 21 shows relatively low levels of AOA, AsA, and T-Phenols.

Ipomoea aquatica *(Kangkong or Water convolvulus)*

Kangkong is a leafy vegetable suitable for cultivation during the hot-wet summer season in Southeast Asia. Kangkong is heat-tolerant and has a short growing period from seeding to harvest. Kangkong showed a relatively high AOA and high T-phenol content, but the AsA content of most of accessions was low (Table 22).

Our kangkong accessions were divided into two groups: 1) accessions with large, green-colored leaves and green or purplish-green stems; and 2) accessions with small, purplish-green leaves with purple-colored stems. The latter were observed to have higher AOA compared to the green-leaved types. These purple-leaved accessions with high AOA were late maturing and more suited to regions with hot-wet growing conditions. It is suggested that in addition to yield properties, AOA and high T-Phenol contents may be considered in selecting superior kangkong accessions.

Ipomoea batatas *(Sweet potato vine)*

Sweet potato is one of the important food crops in the world. Although mostly grown for its edible roots, its young shoots and leaves may be eaten as leafy vegetables. AOA, AsA, and T-Phenol contents were similar to that of kangkong (Table 21). The number of accessions in this study was small considering the vast genetic diversity of this crop.

Lycium chinense *(Chinese wolfberry or Chinese boxthorn)*

Chinese wolfberry is a native of China and Japan. It is occasionally cultivated and locally naturalized in other areas, e.g. East and Southeast Asia, and West, Central and South Europe. Chinese wolfberry is mainly grown for the young shoots and leaves that are used as vegetable, medicine, and food flavoring (peppermint-like flavor). Its fresh and dried fruits are used as flavoring in specialty Chinese dishes. After roasting, the seeds are made into a coffee-like beverage. The fruits have a sweet, licorice-like flavor and are eaten raw, dried, added to soups and braised dishes, or used in the preparation of a liqueur. AOA, AsA, and T-Phenol contents were very similar to those observed in African eggplant.

Table 21. *Evaluation of functional properties of indigenous leafy vegetables, young shoots of fruit vegetables and herbs.*

No.	Indigenous vegetable	Botanical name	Antioxidant activity[1]	Ascorbic acid[2]	Total phenol[2]
1	Chinese mahogany	*Toona sinensis*	128	125	(3,784)
2	Sage	*Salvia officinalis*	122	89	(1,009)
3	Rosemary	*Rosmarinus officinalis*	117	93	(1,241)
4	Horseradish tree (Mo13)	*Moringa oleifera*	115	(287)	691
5	Feather cockscomb (purple)	*Celosia argentea*	114	(134)	(947)
6	Perilla	*Perilla frutescens*	114	84	727
7	Pigeon pea	*Cajanus cajan*	113	(259)	833
8	Horseradish tree	*Moringa* spp.	113	(245)	713
9	Black nightshade	*Solanum nigrum*	112	(146)	432
10	Oregano	*Origanum vulgare*	112	75	(776)
11	Ailanthus	*Zanthoxylum ailanthoides*	111	82	(2,134)
12	Mint	*Mentha* spp.	111	92	(746)
13	Rue	*Ruta graveolens*	110	196	415
14	Salad burnet	*Sanguisorba minor*	109	125	456
15	Lemon balm	*Melissa officinalis*	109	46	545
16	Pepper (purple)	*Capsicum annuum*	108	(226)	(1,158)
17	White jute	*Corchorus* spp.	107	(153)	503
18	Thyme	*Thymus vulgaris*	106	58	475
19	African eggplant	*Solanum macrocarpon*	105	120	537
20	Chinese wolfberry	*Lycium chinense*	105	116	597
21	Peppermint	*Mentha x Piperita*	104	72	654
22	Parsley	*Petroselinum crispum*	104	(132)	271
23	Tarragon	*Artemisia dracunculus*	101	30	278
24	Pepper	*Capsicum* spp.	99	(128)	(817)
25	Basil	*Ocimum basilicum*	99	28	302
26	Kangkong	*Ipomoea aquatica*	99	45	726
27	Gynura	*Gynura bicolor*	97	35	313
28	Madeira vine	*Anredera cordifolia*	97	59	232
29	Hyssop	*Hyssopus officinalis*	96	99	761
30	Dandelion	*Taraxacum officinale*	96	27	137
31	Sweet potato vine	*Ipomoea batatas*	96	35	684
32	Spider flower	*Cleome gynandra*	95	(127)	274
33	Whorlend mallow	*Malva verticillata*	94	75	170
34	Endive	*Cichorium endivia*	94	41	360
35	Coriander	*Coriandrum sativum*	93	72	580
36	New Zealand spinach	*Tetragonia tetragonioides*	93	32	123
37	Garland chrysanthemum	*Chrysanthemum coronarium*	92	45	281
38	Kale	*Brassica oleracea*	91	68	187
39	Swiss chard	*Beta vulgaris*	90	33	145
40	Ivy gourd	*Coccinia grandis*	89	73	457
41	Komatsuna	*Brassica rapa*	87	60	143
42	Chamomile	*Matricaria chamomilla*	86	54	390
43	Chive	*Allium schoenoprasum*	85	51	133
44	Purslane	*Portulaca oleracea*	84	27	131
45	Leafy radish	*Raphanus sativus*	83	54	99
46	Celery	*Apium graveolens*	79	30	91
47	Rocket salad	*Eruca sativa*	77	105	235
48	Amaranth	*Amaranthus* spp.	73	59	247
49	Bunching onion	*Allium fistulosum*	73	49	94
50	Bird-nest fern	*Neottopteris nidus*	64	44	133
51	Malabar spinach	*Basella alba*	61	95	315
52	Pea seedling	*Pisum sativum*	54	-	66

Data in parentheses were among the top ten values in ascorbic acid and total phenol content.

[1]Relative value against 10mM BHA positive control (%). A final concentration of BHA was 40 mM and one of sample was 2 mg (FW)/ml.

[2]Ascorbic acid content (mg/100 g FW); total phenol content (mg chlorogenic acid equivalent/100 g FW)

Table 22. *Evaluation of functional properties of young shoots and leaves in indigenous vegetables in 2001 and 2002.*

Indigenous vegetables	Acc. tested	Antioxidant activity[1] Avg	Antioxidant activity[1] Range	Ascorbic acid[2] Avg	Ascorbic acid[2] Range	Total phenol[2] Avg	Total phenol[2] Range
1 Amaranth (2001)	75	73	99–37	59	110–28	247	405–124
Amaranth (2002)	25	96	103–84	84	135–52	289	452–172
2 Malabar spinach (2001)	43	61	93–35	95	143–53	315	399–211
Malabar spinach (2002)	35	89	94–82	98	154–71	402	547–312
3 White jute (2001)	34	107	110–104	153	216–108	503	666–318
White jute (2002)	15	103	106–100	93	111–70	422	495–326
4 Kangkong (2001)	41	99	116–80	45	68–31	726	1,324–478
Kangkong (2002)	31	100	110–94	46	67–31	497	672–275
5 Perilla (2002)	7	114	118–110	84	98–67	727	1,039–479
6 Spider flower (2002)	17	95	97–91	127	160–113	274	322–243
7 Garland chrysanthemum (2002)	20	92	96–89	45	57–35	281	343–210
8 Basil (2002)	11	99	107–87	28	31–23	302	481–182
9 Chinese leaves (2001)	15	88	99–79	61	98–38	139	234–101
Chinese leaves (2003)	19	83	90–73	50	60–43	123	136–93
10 Pigeon pea (2002)	51	100	116–86	143	198–78	975	1,348 -757
11 *Capsicum* pepper (2002)	22	99	108–93	132	226–82	817	1,158–428
12 Horseradish tree (2002)	26	113	118–92	245	323–158	713	983–566
13 Black nightshade (2002)	18	112	116–108	146	178–128	432	570–357
14 Ivy gourd (Male, 2002)	31	94	101–88	57	86–44	404	530–286
15 Ivy gourd (Female, 2002)	39	90	96–81	51	75–37	386	510–292

[1]Relative value against 10mM BHA positive control (%). A final concentration of BHA was 40 mM and one of sample was 2 mg (FW)/ml.
[2]Ascorbic acid content (mg/100 g FW); total phenol content (mg chlorogenic acid equivalent/100 g FW)

Moringa *spp. (Horseradish tree or Drumstick tree)*

Horseradish tree is indigenous to northern India and Pakistan and was introduced into Southeast Asia at an early date. Now, horseradish tree is cultivated for multiple uses throughout sub-tropical and tropical regions. It is used not only for vegetable but also medicinal and other uses. Almost all parts, including the leaves, flowers, young fruits, seeds, and bark, are used.

In this experiment, 26 *Moringa* spp. accessions were evaluated, most of which were *M. oleifera* but also included accessions of *M. peregrina*, *M. stenopetala* and one unknown species. Young shoots and leaves were observed to be highly functional. AsA and T-phenol contents were very high with the exception of one accession of *M. peregrina* (data not shown).

Among the *M. oleifera* accessions tested, AOA was almost at the same level but some diversity was observed in AsA and T-Phenol contents. Most of *M. oleifera* accessions introduced from Thailand showed relatively similar values in AOA, AsA, and T-Phenol contents. These accessions from Thailand were observed to have a high degree of genetic similarity at the DNA level as reflected in cluster analysis studies based on RAPD-PCR. However, because of the diversity observed in AOA, AsA, and T-Phenol contents among *M. oleifera* accessions introduced from other countries, selection of superior accessions will be possible and useful.

Moringa spp. seems to be an outcrossing species, since some segregation in morphological characteristics was observed in seedlings derived from open-pollinated seeds. This means that propagation of superior accessions by seeds may result in segregating populations. Using asexual propagation by cuttings will lead to quarantine problems unless germplasm movement is done through virus-cleaned and indexed materials.

Ocimum basilicum *(Basil or Sweet basil)*

Basil is one of the most popular herbs in Southeast Asia and is commonly grown in gardens. Using 11 accessions, diversity of AOA and T-Phenol contents were noted (Table 22). AOA was relatively high, but AsA was low (28 mg/100 g FW). Major differences in morphological characteristics were noted for leaf color and leaf size. There are many local varieties and

landraces of basil in Southeast Asia and more functional accessions can be expected to be found with further research.

Perilla frutescens *(Perilla)*

Perilla may be used as vegetable or potherb in temperate regions. The leaves, inflorescences, fruits, seeds, and seedlings (sprouts) are used as a flavoring or garnishing in a number of foods, particularly in Japanese, Korean and Vietnamese cooking. Perilla, as an oilseed crop and spice, is an important economic crop in some countries. It is also used for natural food coloring (a red pigment). In Japan, a healthy salad dressing is made using perilla.

Seven perilla accessions tested here were noted to have very strong AOA (Tables 21 and 22). The same trend was observed by Japanese researchers. However, the diversity in T-Phenol content (478–1,039 mg chlorogenic acid equivalent/100 g FW) was large enough to enable us to select for superior perilla accessions. Diversity was noted in leaf color (green and purple) and other leaf characteristics (smooth or curly). Heat tolerance and photoperiodism are also important criteria in selecting for adaptability to the tropics since perilla prefers cooler growth conditions and is a short-day plant.

Petroselium crispum *(Parsley)*

Parsley is usually classified as a spice; however, in the temperate regions it is also used as a vegetable. It is usually consumed in both dried and fresh forms. In Japan, parsley is considered as a vegetable with very high AOA. Our results showed it also has high AsA content (132 mg/100 g FW). In spite of parsley being a highly nutritious vegetable, it is not suitable for gardens in tropical areas. Parsley prefers a cooler climate and therefore is limited only to higher elevations.

Solanum americanum *or* S. nigrum *(Black nightshade)*

Black or glossy nightshade is now found throughout tropical and warm temperate regions, as both a weed and a cultivated crop. The tender shoots, young leaves and unripe green fruits are eaten raw, cooked or steamed for 5–10 minutes, alone or in combination with other vegetables. Black nightshade is a sturdy plant that can grow under adverse conditions. It is suitable for gardens, but is rarely commercially grown.

Eighteen accessions of black nightshade were evaluated for functional properties using young shoots and leaves (Table 22). A range of diversity was observed among the samples (Table 22). They exhibited relatively higher AOA, AsA, and T-Phenol contents compared to other crop species. Field observation showed diversity in morphological characteristics such as leaf shape, leaf size, leaf color, leaf thickness, leaf softness, leaf pubescence, and number of branches. All of these traits can affect its suitability for use as a leafy vegetable and should be considered in the selection of superior varieties.

Solanum macrocarpon *(African eggplant or Gboma eggplant)*

African eggplant is not a common vegetable in Southeast Asia; however, its fruits and leaves are used as vegetables in tropical Africa. The leaves of African eggplant are soft and juicy, glossy, and spineless. Young shoots and leaves showed high AOA with also relatively high AsA (120 mg/100 g FW) and T-phenol contents (537 mg chlorogenic acid equivalent/100 g FW). Based on our results, African eggplant should be considered as a highly functional leafy vegetable. However, more accessions need to be evaluated to understand the range of diversity in its functional properties.

Taraxacum officinale *(Dandelion)*

Dandelion is native to Europe and temperate Asia, where its leaves are eaten either raw or cooked, preferably blanched. Roots and flowers are edible as well. It is rarely found in the tropics below altitudes of 1200 m. In our study, both AsA and T-phenol contents were low but AOA was relatively high.

Toona sinensis *(Chinese mahogany or cedrus)*

Chinese mahogany is native to China and grows mainly in the temperate zones of East Asia. There is very little information on this crop in tropical and subtropical areas; however, this plant is flavorful and has the potential to be utilized as an indigenous leafy vegetable with high functional properties. The high AOA in Chinese mahogany may be due to its high AsA (128 mg/100 g FW) and high T-Phenol contents.

Zanthoxylum ailanthoides *(Ailanthus or Ailanthus prickly ash)*

Ailanthus or Ailanthus prickly ash is native to China, Korea, Japan and Taiwan. There is no cultivation of Ailanthus and usually wild materials are harvested from the lower slopes of mountains. Young seedling and

young leaves with a particular sweet smell are used as vegetable. Ailanthus contains high T-Phenol content (2,134 mg chlorogenic acid equivalent/100 g FW), which is one of the reasons for its high AOA (Table 21).

Miscellaneous herbs

Most of the herbs sampled exhibited high AOA (Table 22) and are recommended for use as seasonings in a healthy diet. Sage (*Salvia officinalis*) and rosemary (*Rosmarinus officinalis*) have very high T-Phenol contents (1,009 and 1,241 mg chlorogenic acid equivalent/100 g FW, respectively). Rue (*Ruta graveolens*) had high AsA content (194 mg/100 g FW). Oregano (*Origanum vulgar*e), mint (*Mentha* spp.), peppermint (*Mentha* × *Piperita*) and hyssop (*Hyssopus officinalis*) showed high total phenol content (from 654 to 776 mg chlorogenic acid equivalent/100 g FW). Rue, salad burnet (*Sanguisorba minor*), lemon balm (*Melissa officinalis*) and thyme (*Thymus vulgaris*) also exhibited relatively high T-Phenol contents (ranging from 415 to 545 mg chlorogenic acid equivalent/100 g FW). Tarragon (*Artemisia dracunculus*) was high in AOA, but low in AsA and T-Phenol contents.

Seed production and processing in indigenous vegetables

Selection for accessions of indigenous leafy vegetables that possess high yield capacities, desirable and unique morphological and ecological characteristics, high nutrients and functional properties, and also good eating quality, must be accompanied by suitable seed reproduction systems. Otherwise, the desirable traits can be lost or contaminated with undesirable accessions through mere carelessness or ignorance. For many indigenous vegetables there is little information about seed reproduction systems, processing, and storage. Indigenous vegetables include a lot of different types of vegetables that require different protocols for seed production. Major traits that should be considered during seed production of vegetables are the breeding system (e.g. cross-pollinated or self-pollinated) and any incompatibility system that may exist (e.g. self-incompatibility or self-compatibility).

In the case of highly self-pollinating species such as some legume crops, seed production may be carried out in the open field. However, in the case of cross-pollinating species, plant materials must be grown and allowed to flower inside net cages covered with nylon nets with fine mesh (32-mesh) to prevent pollination by insect vectors. If necessary, pollinators such as honeybees and houseflies may be used to promote cross-pollination inside the net cage. Otherwise supplementary pollination by hand may be necessary in some kinds of vegetables. Special attention is required to avoid contamination whenever seeds of different accessions of the same species are produced at the same time.

The following seed production and processing recommendations are based on AVRDC experience through the collaborative efforts with a visiting scientist from the Japan International Research Center for Agricultural Sciences (JIRCAS).

Amaranthus *spp. (Amaranth or Chinese spinach)*

Amaranth consists of outcrossing species and pollination is mainly by wind. Some accessions are commonly cultivated in home gardens. It also includes weedy species such as *A. spinosus*. Amaranth accessions are relatively early maturing and sometimes off-season flowering occurs due to undesirable growth conditions. One important thing to consider is the presence of many *Amaranthus* spp. growing as weeds around the fields. For these reasons, local varieties or landraces are usually heterogeneous populations.

In order to get pure amaranth seeds, several hundred seeds of one amaranth accession are seeded in seedling pans. The population is checked for degree of segregation in hypocotyl color, cotyledon color, size and shape, and true leaf shape, color, pattern and size. For accessions containing few off-types, around 10 plants from desirable and uniform plants are transplanted to a 30-cm-diameter pot, in a greenhouse or a plastic film greenhouse (Fig. 6). In case of apparent segregations in several characteristics, similar types are selected. Observations on morphological characteristics, earliness, and other traits, are carried out until flowering. Just before flowering, the plants in individual pots are covered with a nylon net bag.

In order to check for segregation, seeds from uniform seedlings are harvested and planted. The succeeding generation is checked for segregation.

Since one plant of amaranth produces many seeds, a large quantity of seeds may be produced using a small-scale seed reproduction system using a small space like the one mentioned. Depending on demand, a large-scale seed reproduction system in a field (for

a single accession or variety) or in net cages covered with nylon mesh cloth (for more than two accessions) may be carried out. Plant size at flowering differs according to the growing season. In order to prevent cross-pollination among accessions, enough spaces between accessions should be provided if the more than one accession is planted inside the same net cage.

Flower trusses are harvested before drying completely on the plant, put into very fine nylon mesh bags, and then dried under shade. After drying, the seeds can be recovered easily from flower trusses by crumpling or shaking the bags. Seeds of some weedy types of amaranth (e.g., *A. viridis*) are black and covered with beige-brown colored seed coats. Removal of such weed seeds from seed lots is laborious. If there is no bad effect on germination after storage, the removal of seed coat may be omitted for convenience.

Basella alba *(Malabar spinach or Ceylon spinach)*

Malabar spinach is a short-day plant, flowering being precluded at a daylength of more than 13 hours. Water stress promotes early flowering. Malabar spinach appears to be a self-pollinated species judging from the characteristics of its inflorescence. In fact, there is no apparent segregation in plants coming from seeds from open-pollinated fruits.

Fig. 6. *Small-scale seed reproduction of amaranth accessions in a nethouse. Before flowering, each pot is covered with nylon net bags to prevent outcrossing.*

Considering seed production of Malabar spinach, cultivation with trellis training (about 1 m high) is more useful and practical than training over the ground from the point of view of flower induction, fruit harvesting, and crop management (Fig. 7). Mature fruits with dark purple color are harvested singly or by fruit clusters. There are two seed processing methods: one is removing the seed coat by washing with tap water and the other is drying with the seed coat attached. The number of accessions and amount of fruit per accession are the key factors in choosing the suitable processing method. Wet processing is time consuming and laborious while the drying method requires space or the use of a drying oven. The fruits of *Basella* are juicy, and if drying is incomplete, the seeds turn bad. The choice of a good seed processing method is one of the most important steps in the proper preservation of *Basella* seeds.

Corchorus olitorius *(Nalta jute) and* C. capsularis *(White jute)*

Corchorus spp. is a nutritious vegetable that grows well during the hot-wet summer. Flowering of *Corchorus* spp. is usually induced by short-day conditions. However, it was observed that there is some diversity in daylength requirements for flower induction among *Corchorus*. Plants of *Corchorus* spp. become taller and wider during the summer. *Corchorus* accessions are easy to cross contaminate through outcrossing in an open field. In order to protect from outcrossing, a net cage must be prepared for each accession. Insect vector is not necessary for seed reproduction inside the net cage (Fig. 8). *C. olitorius* produces long capsules and *C. capsularis* produces round capsules. Both types of capsules are dried under shade. Seeds can then be separated from capsules easily.

Fig. 7. *Seed production in* Basella alba *using trellises made from iron pipes.*

Observations on morphological characteristics showed segregation in some traits such as stem color in some accessions. Contamination by outcrossing is one of the most important but common problems in producing good quality seeds.

Ipomoea aquatica *(Kangkong or Water convolvulus)*

Kangkong is a short-day plant that begins to flower 48–63 days after sowing. Kangkong prefers high temperature for growth, flowering, and fruit setting.

Kangkong is an outcrossing plant and large quantities of seeds can be produced in open fields. However some degree of segregations in morphological characteristics can be detected even in some commercial varieties because of the heterogeneity caused by open-pollination. Kangkong has self-incompatibility, and therefore requires supplementary hand pollination among plants of the same accession to produce sufficient quantities of seeds.

Several references mention that there are two or three types of kangkong in South and Southeast Asia based on morphological characteristics such as leaf size, leaf and stem color, and flower color. So far, accessions maintained and conserved at AVRDC are of two groups. One group consists of accessions with green and large leaves. These accessions usually grow faster, start flowering earlier, and produce large quantities of seeds. In contrast, the other group of accessions have small purplish-green leaves, purple stems, and white flowers with a magenta or purple throats. These accessions mature later and usually produce a smaller number of flowers and a smaller number of seeds. Especially for this latter group, training using trellis with frames at around 1 m high is recommended to promote early flowering (Fig. 9).

Fig. 8. *Iron pipe frames and nylon mesh cloth covers are used in seed production of* Corchorus *spp.*

Because of self-incompatibility, several plants with different self-incompatibility genes (*S*-gene) must be necessary for successful cross-pollination among plants belonging to the same accession. The number of seeds in one fruit is three to four only. An intensive and effective supplementary pollination is necessary to get good seed yield. To distinguish between pollinated and unpollinated flowers, the flower petals must be cleaved after pollination.

Processing of kangkong seeds is time consuming and laborious because the seed coat is difficult to separate from the fruits. Usually harvested fruits are dried under the shade for several days and then the seeds are taken out of the fruits. One of the constraints in threshing is incomplete drying. If fruits are still soft, dry the fruits further for about a day in an oven at around 35 to 40°C and with air circulation. It is easier to crush the fruits and separate the seeds from the fruits when the fruits are completely dry.

Fig. 9. *Seed production in kangkong inside net cages made with iron pipe frames and covered with nylon mesh cloth. One-meter-high frames are convenient for cross-pollination work by hand.*

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Legume Unit

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

Introduction

Under the umbrella of South Asia Vegetable Research Network (SAVERNET), the mungbean subnetwork initiated a project, "Improving the income and nutrition by incorporating mungbean in cereal fallows in the Indo-Gangetic Plains of South Asia, specifically Bangladesh, India and Nepal". The project was supported by the Department for International Development (DFID) of the United Kingdom. As in 2002, a number of agronomic trials evaluating cultural practices involving sowing dates, seed rates, seed priming, plant population density, tillage versus no tillage, irrigation and mulching were conducted at AVRDC and in India.

Trials at AVRDC

Plant density

Four varieties (SML 668, Pusa Vishal, VC 3890A and SML 134) were planted in four plant population densities (200,000, 300,000, 400,000 and 500,000 plants/ha). The experiment was conducted using a factorial design with three replications at AVRDC. The seeds were sown on 17 July 2003 in 5-m-long, 2-m-wide plots each having two rows on a raised bed with rows spaced 50 cm apart. Plant spacings were 2.5, 5, 7.5 and 10 cm, thereby creating population densities of 500,000, 400,000, 300,000 and 200,000 plants/ha, respectively. Observations were made on days to flower, days to first mature pod, days to all pod maturity, plant height at maturity, pods/plant, seeds/pod, 100-seed weight, grain yield, lodging score, and powdery mildew score.

The differences in yield between varieties were significant. Pusa Vishal and VC 3890A were significantly higher yielding than SML 668 and SML 134, and SML 668 was significantly higher yielding than SML 134 (Table 23). All four varieties matured in 61 to 62 days. SML 134 had a significantly higher number of pods/plant compared to all the other varieties and had significantly smaller seed size. However, the differences in yield between different plant population densities were nonsignificant. The interaction between varieties and plant population density was significant (Table 24). The results confirmed the findings of 2002 that a plant population density of 200,000 plants/ha gives the maximum yield under AVRDC conditions.

Table 23. *Effect of plant density on the growth and yield of mungbean genotypes.*[1]

Treatment	Days to first flower	Days to first mature pod	Days to maturity	Plant height (cm)	Pods/ plant	Seeds/ pod	100-seed wt (g)	Grain yield (kg/ha)	Lodging score[2]	Powdery mildew score[3]
Genotype										
Pusa Vishal	33.1	49.0	60.4	84.8	23.6	12.09	4.74	2037	1.00	3.83
SML 668	32.6	48.0	61.0	76.1	19.5	12.22	4.27	1837	3.66	4.75
SML 134	34.2	50.4	62.5	98.1	28.6	12.40	2.99	1494	2.75	3.66
VC 3890 A	36.5	52.4	61.3	91.7	21.6	12.60	5.17	2059	1.50	1.08
CD (5%)	0.58	0.57	0.49	3.78	5.35	0.35	0.61	175	0.40	1.11
Plant density (000/ha)										
200	34.0	49.9	61.2	85.6	25.8	12.37	4.06	1857	1.66	3.16
300	34.0	50.0	61.4	88.0	24.7	12.53	4.45	1860	1.91	3.08
400	34.2	49.9	61.3	89.9	22.6	12.15	4.34	1925	2.50	3.25
500	34.2	50.0	61.2	87.2	20.2	12.25	4.32	1785	2.83	3.83
CD (5%)	NS	NS	NS	NS	2.85	NS	NS	NS	0.36	NS

[1]Sown 17 July 2003 at AVRDC.

[2]Rated on scale of 1 to 9 with 1 = no lodging and 9 = severe lodging.

[3]Rated on a scale of 1 to 9 with 1 = no mildew or immune and 9 = severe mildew.

Table 24. *Interaction effect of genotypes and plant density on the grain yield of mungbean.*[1]

Genotype	Plant density (000/ha)			
	200	300	400	500
	Grain yield (kg/ha)			
Pusa Vishal	2106	2066	2035	1940
SML 668	1678	1694	2035	1940
SML 134	1498	1662	1580	1236
VC 3890A	2145	2017	2053	2022

[1]Sown 17 July 2003 at AVRDC. CD (5%) = 200.

Tillage and crop residue

Time, labor, and cost savings are some of the criteria in opting for tillage or no tillage practice in mungbean cultivation. A factorial experiment was conducted using two varieties (SML 668 and Pusa Vishal) and four treatments (no tillage, tillage, no-tillage-rice straw incorporation, and tillage + straw mulch), using three replications. The plot size was 4 m × 2 m. Each plot had four rows spaced 50 cm apart. The seeds were sown on 21 July 2003. A plant population density of 200,000 plants/ha was used.

The differences in yield between varieties, between tillage treatments, and the interaction between varieties and tillage were nonsignificant (Table 25). The results of this two-year study confirm that no-tillage is as good as the tillage treatment and it saves time, labor, costs, and soil moisture.

Irrigation

Mungbeans are usually indeterminate in growth habit and require several harvests. However, the improved variety SML 668 has a determinate growth habit and synchronous maturity, and therefore, requires only a single harvest. Farmers have observed that continued irrigation at maturity produces a second flush of flowers and pods in SML 668. Therefore, the effect of irrigation at maturity in two varieties (Pusa Vishal and SML 134) were studied using two irrigation treatments [stopping irrigation at 45 days after sowing (DAS) and continuing irrigation as needed up to 60 DAS].

The experiment was conducted using a split plot design with irrigation as the main plot and varieties as the subplots, using six replications. The plot size was 5 m × 2 m and each plot had four rows spaced 50 cm apart between rows. Plots were sown on 21 July 2003.

The differences in yield between varieties and between treatments were significant. SML 668 was significantly higher yielding than SML 134 (Table 26). Providing irrigation until 60 DAS produced significantly higher yields than terminating irrigation at 45 DAS.

Seed priming

Seed priming has been suggested as an economical, simple and safe technique for improving germination, seedling growth and crop production. On-farm seed priming studies conducted in India and Pakistan reported that under rainfed conditions, seed priming ensures faster emergence, improved plant stand, more

Table 25. *Effect of tillage and crop residues management on the growth and yield of mungbean.*[1]

Treatment	Days to			Plant height (cm)	Pods/ plant	Seeds/ pod	100-seed wt (g)	Grain yield (kg/ha)	Lodging score[2]	Powdery mildew score[3]
	first flower	first mature pod	maturity							
Genotype										
Pusa Vishal	33.1	49.0	60.4	84.8	23.6	12.09	4.74	2037	1.00	3.83
NM 92	30.5	45.4	60.7	81.2	17.02	11.89	4.51	2446	1.50	1.91
NM 94	30.3	44.5	61.2	76.8	18.00	12.69	4.97	2430	2.41	2.83
CD (5%)	NS	0.42	NS	NS	NS	0.55	0.11	NS	0.64	0.74
Tillage practices										
No-tillage	30.1	44.6	59.5	80.2	17.5	12.15	4.76	2567	1.00	2.00
Tillage	30.1	44.8	60.3	79.3	16.2	12.66	4.80	2487	2.00	2.00
Tillage + mulch	31.0	45.6	62.5	80.2	18.4	11.98	4.63	2466	2.66	2.83
Tillage + residue incorp.	30.3	44.6	61.6	76.4	17.8	12.36	4.78	2452	2.16	2.66
CD (5%)	0.53	0.59	0.93	NS	NS	NS	NS	NS	0.89	NS

[1]Sown 21 July 2003 at AVRDC.
[2]Rated on scale of 1 to 9 with 1 = no lodging and 9 = severe lodging.
[3]Rated on a scale of 1 to 9 with 1 = no mildew or immune and 9 = severe mildew.

Table 26. *Influence of termination of last irrigation on the growth and yield of mungbean.*[1]

Treatment	Days to first flower	Days to first mature pod	Plant height (cm)	Pods/ plant	Seeds/ pod	100-seed wt (g)	Grain yield (kg/ha)	Lodging score[2]	Powdery mildew score[3]
Genotype									
SML 668	29.25	45.8	63.3	18.71	11.25	4.85	1782	3.6	3.3
SML 134	30.75	48.1	74.3	19.86	11.00	2.89	1557	3.5	2.8
CD (5%)	0.30	0.35	2.64	NS	NS	0.08	78	NS	NS
Termination of last irrigation (DAS)									
45	29.16	46.9	67.8	18.36	11.15	3.90	1629	3.6	3.1
60	30.08	47.0	69.8	20.23	11.10	3.85	1709	3.5	3.0
CD (5%)	NS	NS	NS	1.55	NS	NS	78	NS	NS

[1]Sown 21 July 2003 at AVRDC.
[2]Rated on scale of 1 to 9 with 1 = no lodging and 9 = severe lodging.
[3]Rated on a scale of 1 to 9 with 1 = no mildew or immune and 9 = severe mildew.

vigorous plants, better drought tolerance, earlier flowering and higher grain yield in wheat, mungbean and other crops.

A randomized complete block design (RCBD) with three replications was used with three varieties (Pusa Vishal, SML 668, and SML 134) and four seed priming treatments (no seed soaking in water [control], and soaking 100 seeds for each replication in water for 4 h, 6 h, and 8 h). After the prescribed treatment, five seeds were sown in each pot in the greenhouse. The differences in yield between different seed priming were nonsignificant (Table 27). Similar results were obtained from studies conducted in 2002. The moisture status of the soil was good; therefore, the germination of seeds regardless of seed priming was good. It is likely that seed priming may be helpful in situations where soil moisture is a limiting factor at the time of germination.

Table 27. *Germination rates (%) of mungbean genotypes as influenced by seed priming.*

Soaking period	Genotype			Mean
	SML 134	Pusa Vishal	SML 668	
0 h	88.9	100.0	94.4	94.4
4 h	94.4	100.0	94.4	96.3
6 h	83.3	83.3	83.3	83.3
8 h	77.7	77.7	77.7	77.7
Mean	86.1	90.2	87.4	

Trials in India

Date of sowing and seeding rate

At Punjab Agricultural University (PAU), an experiment evaluating date of sowing and seeding rate was repeated for the second year. Variety SML 668 was planted on 30 March and 20 April 2003. Seed rates of 25, 30, 35, 37.5 and 40 kg/ha were used. A split plot design with date of sowing as the main plot and seed rates as the subplot with four replications was used.

The differences in yield between sowing dates and between seed rates were significant (Table 28). But the interaction between sowing dates and seed rates were non-significant. The results showed that the yield will decrease (16.5%) significantly as the planting date is delayed. The percent decrease in yield was less than

Table 28. *The response of SML 668 to different dates and rates of sowing in a split-plot experiment.*[1]

Treatment	Yield (kg/ha)
Sowing date	
30 March	1760
20 April	1470
CD (5%)	190
Seed rate (kg/ha)	
25	1450
30	1530
37.5	1610
40.0	1720
CD (5%)	53

[1]Sown at Punjab Agricultural University, India.

that observed in 2002. The yield of 30 March planting in 2002 was 2069 kg/ha compared to 26 March planting in 2003 (1760 kg/ha). Our recommended seeding rate for seed production of SML 668 is 40 kg/ha.

Irrigation and mulching

A split plot trial was repeated in 2003 to determine the effects of irrigation and mulching on productivity of SML 668. As in 2002, three levels of irrigation (2, 3 and 4 irrigations) were used as the main plot and three mulching treatments (4 t/ha wheat straw mulch at sowing, mulch at 25 DAS and no mulch) were the subplots. Three replications were used. The trial was sown on 28 March 2003 at PAU farm in India. The differences in yield between irrigation and mulching treatments were significant. Three irrigations produced similar yield as four irrigations, but two irrigations produced significantly lower yield. Mulching at 25 DAS produced significantly higher yield than no mulching; however, mulching at sowing was not helpful in increasing yield (Table 29).

Table 29. *The response of SML 668 to different irrigation and mulching practices.*[1]

Treatment	Yield (kg/ha)
Irrigation number	
2	929
3	1362
4	1575
CD (5%)	279
Mulching	
No mulching	1194
Mulching at sowing	1265
Mulching at 25 DAS	1407
CD (5%)	207

[1]Sown on 28 March 2003 at Punjab Agricultural University in India.

Irrigation

In a related study, irrigation was terminated at different times after sowing to determine the yield of variety SML 668. The crop was sown at the PAU farm on 29 March 2003. Treatments consisted of termination of irrigation at 47, 54, 61, 68, 75 and 82 DAS. The experiment used a RCBD with three replications.

The differences in yield between treatments were significant. The yield increased significantly where the termination of irrigation date had been postponed to 75 and 82 DAS compared to termination of irrigation at 47 DAS. Compared to 47 DAS termination of irrigation, the increase in yield at 75 DAS and 82 DAS were 25% and 38%, respectively. However, the yield differences between termination of irrigation at 47 DAS and up to 68 DAS were nonsignificant (Table 30).

The correlation between termination date of last irrigation and the yield was highly significant (0.95**) suggesting that a progressive increase in the days to termination of the last irrigation will increase yields proportionately. Farmers may elect to continue irrigation to obtain higher yields, depending on available time and soil moisture conditions.

Table 30. *Response of termination of last irrigation on grain yield of summer mungbean.*[1]

Termination of last irrigation (DAS)	Grain yield (kg/ha)
47	1506
54	1604
61	1642
68	1691
75	1888
82	2074
CD (5%)	242

[1]Sown 29 March 2003 at Punjab Agricultural University in India.

Date of sowing

As an alternative to rice, mungbean can be cultivated after the harvest of the summer mungbean or other summer crops. A trial was conducted in 2002 to determine the optimum time of sowing mungbean in the rainy season (kharif). Three varieties (SML 668, ML 818 and ML 613) were used. Four planting dates (8 July, 16 July, 24 July and 1 August) were used. The experiment was conducted at the PAU farm in India. A split plot design with three replications was used. Planting dates were the main plots and the varieties were used as subplots.

The results showed that the differences in yield between different sowing dates and different varieties were significant. However, the interaction between sowing dates and varieties were nonsignificant (Table 31). Earlier planting in July gave the highest yield and yields decreased steadily as the time of planting was delayed. SML 668 and ML 818 were significantly higher yielding than ML 613. Therefore, farmers should try to plant their mungbean crop in July to obtain high yield.

Seed production

A seed village program was instituted in Ludhiana, Punjab, India during 2003. A total of 270 farmers in 30 villages were selected. Each farmer planted 0.4 ha. A total of 4500 kg of seeds of SML 668 were distributed to the farmers. Additional seed producers included private seed companies, progressive farmers, Punjab Agricultural University (PAU), National Seeds Corporation, Punjab State Seed Corporation, State Farms Corporation of India, and the Department of Agriculture in Punjab. At the end of 2003, the total quantity of SML 668 seed produced by the team was 51,066 tons, sufficient to plant 1.37 million ha.

Table 31. *Grain yield of kharif mungbean as influenced by date of sowing in kharif at Ludhiana, India in 2002.*

Treatment	Grain yield (kg/ha)
Date of sowing	
July 8	1780
July 16	1650
July 24	1426
August 1	1426
CD (5%)	123
Genotype	
SML 668	1704
ML 818	1529
ML 613	1368
CD (5%)	161

Effect of storage conditions on viability of soybean seed

The developing soybean seed attains maximum quality at physiological maturity. At the end of the seed filling period, the seed viability and seedling vigor begins to decline immediately thereafter. Storage conditions such as temperature, relative humidity, the container in which the seeds are stored, the initial moisture content of the seed, and the seed quality at the time of storage all have an effect on the rate of deterioration in quality of the seed. The seed size and seed color have also been reported to have an effect on seed quality. The soybean seeds stored under ambient conditions in the tropics lose viability very rapidly. Therefore, the purpose of this investigation was to determine the effect of storage temperature, relative humidity, and seed size on the viability of soybean seed.

Table 32. *Seed weights of entries in this study.*

Entry	Code	Pedigree or name	100-seed wt (g)
KS 5	V1	-	31.3
AGS 190	V2	Vesoy 4	30.1
AGS 375	V3	IAC 100 / OCB	19.0
AGS 370	V4	IA 78-2318/ 269	15.2
AGS 372	V5	IAC 100/ AGS 313	8.6
AGS 373	V6	IAC 100/ AGS 313	7.4

Two genotypes in each of large (>30 g/100 seeds), medium (15–20 g/100 seeds) and small (7–9 g/100 seeds) seed weight classes were selected for this study (Table 32). All six genotypes were sown on 15 October 1999 and harvested in early January 2000. The seeds were dried to a constant moisture content of 8.5% prior to storage. A total of 5 kg of seeds of each genotype were packed in 0.08-mm-thick plastic bags and tightly tied with a plastic rope. Since farmers store the seeds in such a manner we kept them the same way. Seeds were stored under two different storage conditions, namely cold storage (16–19°C and 40–50% RH) and ambient storage (16–28°C and 49–96% RH). The experiment was conducted using a split plot design with storage conditions as main plot and the genotypes as the sub-plots. The treatments were replicated twice. The seed viability was determined by taking samples at three-month intervals and testing the germination rate. The germination rate was determined by placing 50 seeds each in two petri dishes with moistened filter paper in the ambient room condition. The seeds were examined 15 times over a period of 42 months after harvest. Seed moisture contents were also evaluated in germination tests conducted 18 months or more after harvest.

An experiment with data collected at several points in time on the same sampling unit is called an experiment with repeated measurements. Using the REPEATED statement in PROGRAM in SAS, a repeated measure ANOVA was performed. The differences between genotypes (G) and the interaction between genotypes and the storage treatments (S) were significant (Table 33). Storage time (T) and T × S, T × G, and T × G × S were all highly significant. Therefore, ANOVA were conducted at individual storage durations. Results showed significant interactions between genotypes with storage treatments at 21, 30, 33, 36 and 39 months of storage duration. Data for germination rates of genotypes at different storage times and treatments are presented in Tables 34 and 35. The

Table 33. *ANOVA for storage trial by repeated measure analysis.*

Source	df	SS	Univariate analysis		Adjusted univariate (P>F)	
			F value	P>F	G-G	H-F1
Rep.	1	78	0.49	0.61		
Storage (S)	1	10070	62.9	0.08		
R x S	1	160	3.7	0.08		
Genotypes (G)	5	6535	29.9	0.0001		
G x S	5	1759	8.0	0.003		
Error a	10	437				
Time (T)	14	51202	354.7	0.0001	0.0001	0.0001
T x R	14	339	1.13	0.4	0.10	0.026
T x S	14	30120	100.1	0.0001	0.0001	0.0001
T x R x S	14	301	2.1	0.02	0.13	0.05
T x G	70	7559	10.5	0.0001	0.0001	0.0001
T x G x S	70	3445	4.8	0.0001	0.0004	0.0001
Error b	140	1444				

Table 34. *Comparisons among genotypes on germination rate for different storage time.*

Genotype		Months after harvest							
		0	3	6	9	12	15	18	21[1]
AGS 190	V2	98.5 b	98.8 ab	99.0 b	97.3 ab	98.3	97.0 ab	97.5 ab	96.3
AGS 370	V4	100.0 a	100.0 a	100.0 a	97.5 ab	100.0	98.0 ab	95.8 b	97.0
AGS 372	V5	100.0 a	100.0 a	100.0 a	99.3 a	100.0	100.0 a	99.8 a	99.3
AGS 373	V6	100.0 a	99.8 a	100.0 a	99.3 a	100.0	98.0 ab	96.5 ab	96.0
AGS 375	V3	99.8 a	99.0 ab	100.0 a	97.3 ab	98.8	97.0 b	94.8 b	95.3
KS 5	V1	98.8 ab	98.0 b	98.8 b	95.8 b	98.3	97.0 b	95.3 b	93.0

Genotype		Months after harvest						
		24	27	30[1]	33[1]	36[1]	39[1]	42
AGS 190	V2	96.8 c	82.5 c	82.8	89.0	76.8	77.3	61.8 ab
AGS 370	V4	85.3 c	87.5 bc	95.0	83.3	80.8	53.5	95.8 b
AGS 372	V5	99.0 a	98.5 a	98.5	93.3	94.8	69.8	99.8 a
AGS 373	V6	99.3 ab	92.0 b	91.8	91.8	81.8	82.8	50.3 bc
AGS 375	V3	96.5 c	87.5 bc	82.5	91.8	84.0	83.8	53.5 b
KS 5	V1	94.0 d	73.8 d	71.3	70.3	62.3	52.3	37.0 c

[1]Data for 21, 30, 33, 36 and 39 months of storage cannot be compared since there were significant interaction between treatments and genotypes.

differences in germination rates between cold and ambient storage were significant only at 27 months after storage (MAS), when rates for ambient storage declined sharply (Table 35).

The moisture content of the seeds in the ambient storage sharply increased over time whereas the relative increase under cold storage condition fluctuated and varied with cultivars (Figs. 10 and 11). The regression fits well with for the quadratic component.

Significant differences in germination rate among genotypes could be observed from 27 months and 18 MAS for cold storage and ambient storage respectively (Table 36). KS 5 had the largest 100-seed weight and the lowest germination rates beginning 27 months after cold storage (MACS) and 18 months after ambient storage (MAAS). Small-seeded AGS 372 had the highest germination rate among genotypes regardless of storage conditions and duration. Excluding KS 5, the germination rates of the other five genotypes exceeded 80% at 42 MACS. The germination rate of KS 5 started to decline 27 MAAS and reached 0% at 42 MAAS. The results showed that all genotypes maintained more than 90% germination rate for up to 24 months regardless of storage conditions.

Table 35. *Mean germination rates of six soybean genotypes at 3-month intervals between two storage conditions.*

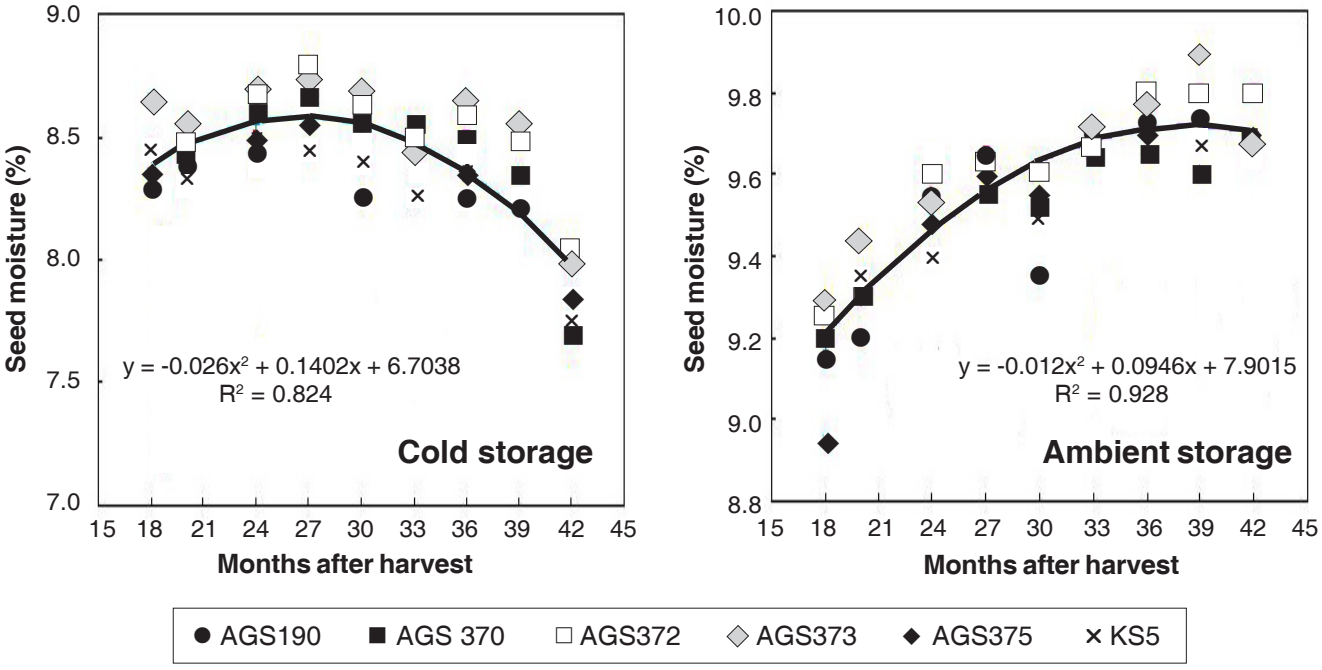
Storage condition	Germination rates (%) at respective months after harvest														
	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42
Ambient	99.3	99.2	99.7	97.6	99.2	97.9	96.8	96.6	97.8	91.8	91.6	92.9	94.8	93.7	88.3
Cold	99.7	99.3	99.6	97.8	99.3	97.6	96.3	95.7	96.8	81.5	79.8	85.8	65.6	63.5	20.3
Significance	NS	NS	NS	NS	NS	NS	NS	-	NS	*	-	-	-	-	NS

NS,*Nonsignificant and significant at $P \leq 0.05$, respectively. Data for 21, 30, 33, 36, and 39 months of storage cannot be compared since there were significant interaction between treatments and genotypes.

Table 36. *Germination rates of six soybean lines under cold and ambent storage conditions.*

Lines	Germination rates (%) at respective months after harvest														
	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42
Cold conditions															
AGS 190	98	99	99	96	98	98	97	96	96	89 cd[1]	88 cd	91 b	90 b	92 b	87 a
AGS 370	100	100	100	98	100	98	96	97	99	92 bc	92 bc	97 a	96 ab	95 ab	92 a
AGS 372	100	100	100	99	100	100	100	99	100	100 a	99 a	98 a	99 a	99 a	97 a
AGS 373	100	100	100	99	100	98	97	96	100	94 b	94 b	95 ab	98 a	95 ab	89 a
AGS 375	100	99	100	99	99	96	94	97	98	92 bc	91 bc	92 b	98 a	96 ab	92 a
KS 5	99	98	100	96	99	98	97	96	96	85 d	86 d	86 c	90 b	86 c	74 b
Ambient conditions															
AGS 190	99	99	100	99	99	98	97 b	97 bc	98 ab	77 b	78 b	87 b	64 b	63 b	37 a
AGS 370	100	100	100	98	100	98	96 bc	97 ab	97 ab	79 b	83 ab	93 ab	71 ab	67 b	16 ab
AGS 372	100	100	100	100	100	100	100 a	100 a	100 a	98 a	98 a	100 a	88 a	91 a	43 a
AGS 373	100	100	100	100	100	98	97 b	97 bc	99 a	90 ab	90 ab	89 ab	66 b	71 b	12 ab
AGS 375	100	99	100	96	99	98	96 bc	94 c	96 b	83 b	74 b	92 ab	71 ab	72 b	15 ab
KS 5	99	98	98	96	98	96	94 c	91 d	93 c	63 c	57 c	55 c	35 c	19 c	0 b

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



Figs. 10 and 11. *Seed moisture percentages of six soybean lines under cold and ambient storage conditions.*

Heritability of quality traits in vegetable soybean

Vegetable soybean breeding efforts continue to focus on increased graded pod yield, pod color, 100-green bean weight, sugar content and shorter growth duration. A total of 50 cultivars originating from AVRDC, China, Japan, Korea, Philippines, Taiwan and USA (Table 37) were sown on 14 February, 12 March and 12 February (spring season), 8 August, 19 August and 8 July (summer season) and 16 October, 23 September and 9 September (autumn season) in 2001, 2002 and 2003 respectively. AGS 359, AGS 364, and KS 2 were severely infected by necrotic-soybean mosaic virus from spring season 2002 until 2003 and therefore the above three cultivars were excluded from the analysis. Trials were conducted using a RCBD with three replications. Two-meter-long single row plots were used. Rows were spaced 0.5 m apart and the plant population density was 400,000 plants/ha. Harvest plot size for data collection was 0.5 m^2.

Observations were recorded on days to R_1, days to $R_{6.5}$, total biomass, total pod yield, graded pod yield, length and width of 2-seed pods, 100-fresh green bean weight, harvest index, and graded pod harvest index. A sample of 250 g of graded pods were sent to the Nutrition and Analytical Lab at AVRDC to analyze the dry matter, protein, oil and sugar content of beans and determination of pod color for each sample. Agronomic traits and yield data from nine seasons in three years were combined and analyzed. Data for dry matter, protein, oil, sugar, and pod color for seven trials were combined and analyzed (spring, summer and autumn in 2001 and 2002, and spring of 2003). The total variance among the cultivar means (σ^2A) representing additive, dominance and epistatic variance was estimated using the formula, $\sigma^2(G) + \sigma^2(GxS)/S + \sigma^2(error)/RS$. Broad sense heritability, H^2, was estimated by $\sigma^2(G)/\sigma^2A$. Test of homogeneity of variance was conducted and only those trials with homogeneous mean square for error were used for combined ANOVA.

The mean squares for various agronomic traits are given in Tables 38 and 39. For most of the agronomic traits, with the exceptions of 100-green bean weight and harvest index, most of the variation was environmental. Variation due to genotypes and cultivar × environmental interaction were relatively small. These results suggest there are greater opportunities for improving the traits by selecting suitable cropping season and crop management. However, for 100-green bean weight and harvest index, specific cultivars need

Table 37. *Soybean genotypes used in heritability study.*

No.	Genotype	Seed coat color	Origin	Name
1	AGS 184	Yellow	Korea	203
2	AGS 185	Yellow	Japan	Houjaku
3	AGS 186	Yellow	Japan	Yoshida-1
4	AGS 187	Yellow	Korea	PI 85590
5	AGS 188	Yellow	Korea	PI 157424
6	AGS 189	Yellow	USA	Disoy
7	AGS 190	Yellow	Philipp.	Vesoy 4
8	AGS 191	Lt grn	Philipp.	BPI 4
9	AGS 291	Lt grn	Japan	Kinshu
10	AGS 292	Yellow	Japan	Taisho Shiroge
11	AGS 293	Lt grn	Japan	Nakate Kaori
12	AGS 294	Yellow	Japan	Imperial
13	AGS 295	Yellow	Korea	PI 157469
14	AGS 328	Green	Japan	Blue Side
15	AGS 329	Yellow	Japan	Shironomai
16	AGS 334	Yellow	AVRDC	GC 94128-9-2-1
17	AGS 337	Yellow	AVRDC	GC 87012-20-B-2-2
18	AGS 339	Yellow	AVRDC	GC 87008-15-1-11
19	AGS 340	Lt grn	Japan	Shirofumi
20	AGS 346	Lt grn	AVRDC	GC 88044-2
21	AGS 357	Yellow	AVRDC	GC 92001-P-25-1
22	AGS 359[1]	Lt grn	AVRDC	GC 92016-12-11
23	AGS 360	Dk grn	AVRDC	GC 91023-23-1
24	AGS 364[1]	Lt grn	AVRDC	GC 92014-P-12-1
25	Dadacha 2000	BR	Japan	
26	Hiden	Green	Japan	
27	Kocha	Brown	Japan	
28	KS 2[1]	Lt grn	Taiwan	
29	KVS 844	Lt grn	Taiwan	KS 6
30	KVS 862	Black	Taiwan	KS 7
31	KY 3	BR	Korea	
32	KY 6	Black	Korea	
33	KY 7	Yellow	Korea	
34	KY 8	Black	Korea	
35	Mika. Edamame	Yellow	Japan	
36	NTP 1	Green	China	
37	NTP 2	Green	China	
38	Onachugi Dada Cha	Brown	Japan	
39	Ryokkoh 75	Lt grn	Japan	
40	Sakata Kairyo Mika.	Yellow	Japan	
41	Sapp.-Midi.-Edam.	Lt grn	Japan	
42	Setuzu	Lt grn	Japan	
43	Shiu Nai No. 2	Brown	Japan	
44	Tanba	Black	Japan	
45	Tengamine	Lt grn	Japan	
46	TS 85-21V	Brown	Taiwan	
47	Tzuzunoko Edam.	Yellow	Japan	
48	Wuyehedou	Black	China?	
49	YS 1057	Yellow	Korea	
50	Yukinoshita	Lt grn	Japan	

[1]Highly susceptible to SMV-N and therefore dropped from analysis.

to be selected. For pod color, width of pod, and dry matter traits, improvement can be made through cultivar selection. The sugar, protein, and oil contents are influenced more by season and cultural management. The small cultivar × environment interaction suggested the trend towards greater stability of performance of the cultivars.

The broad sense heritability estimates for agronomic traits were high. For graded pod yield, 100-green bean weight, days to maturity, days to flowering, total biomass yield, total pod yield, harvest index and standard harvest index, estimates were 71, 94, 89, 95, 86, 80, 72 and 64%, respectively. Broad sense heritability estimates were similarly high for pod quality traits. For sugar, pod color, pod length, pod width, dry matter, protein and oil contents, estimates were 87, 75, 91, 96, 84, 95, and 91%, respectively. Estimates for traits with heritabilities over 80% imply that genotypic selection will be effective. However, genotypic selection for graded pod yield, harvest index and pod color will be difficult since their heritability estimates are low.

The current findings confirm our previous heritability estimates determined in 2000 using selected breeding lines. Highly significant correlations among the different agronomic traits suggested that pod length and pod width could be used to select for 100-green bean weight (r = 0.73*** and 0.79***, respectively). The correlation between pod length and pod width are also highly significant (r = 0.85***). Correlation between oil and sugar in the spring season was highly significant and negative (r = –0.79***). Since determination of sugar is time consuming, selection for low oil content in spring season should result in selection for high sugar content.

Table 38. *Pooled ANOVA of agronomic traits of vegetable soybean over seasons.*

	Graded pod yield			100-green bean wt			Days to maturity			Days to flower			Total biomass yield			Total pod yield			Harvest index			Std harv. index		
Source	df	MS (10^6)	(%)	df	MS	(%)	df	MS	(%)	df	MS	(%)	df	MS (10^6)	(%)	df	MS (10^6)	(%)	df	(MS	(%)		MS	(%)
Season (S)	5	1197	(96)	5	1454	(43)	3	1506	(86)	5	2282	(97)	5	10090	(96)	5	734	(81)	4	306	(46)	6	809	
Rep (S)	12	7	(1)	12	47	(1)	8	1	(0)	12	0	(0)	12	19	(0)	12	7	(0)	10	7	(1)	14	45	
Genotype (G)	46	28	(2)	46	1736	(52)	46	223	(13)	46	72	(3)	46	343	(3)	46	129	(14)	46	269	(40)	46	224	
S x G	230	8	(1)	230	104	(3)	138	24	(1)	230	3	(0)	230	49	(1)	184	46	(5)	184	75	(11)	276	81	
Error	552	2	(0)	552	23	(1)	368	1	(0)	552	0	(0)	552	13	(0)	552	5	(0)	460	15	(2)	644	15	

Table 39. *Pooled ANOVA of quality traits of vegetable soybean over seasons.*

	Sugar			Pod color			Pod length			Pod width			Dry matter			Protein			Oil		
Source	df	MS	(%)	df	MS	(%)	df	MS	(%)	df	MS	(%)	df	MS	(%)	df	MS	(%)	df	MS	(%)
Season (S)	2	792	(99)	4	11	(67)	6	450	(100)	7	0	(66)	4	105	(70)	6	490	(86)	5	291	(92)
Rep (S)	6	0	(0)	10	0	(1)	14	0	(0)	16	0	(0)	10	2	(2)	14	1	(0)	12	0	(0)
Genotype (G)	46	9	(1)	46	4	(25)	46	2	(0)	46	0	(32)	46	36	(24)	46	74	(13)	46	22	(7)
S x G	92	1	(0)	184	1	(6)	276	0	(0)	322	0	(1)	184	6	(4)	276	4	(1)	230	2	(1)
Error	276	0	(0)	460	0	(1)	644	0	(0)	736	0	(0)	460	1	(1)	644	1	(0)	552	0	(0)

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Pepper Unit

Development of high yielding, disease-resistant chili peppers

The AVRDC pepper breeding program's long-term priority is the development of improved inbred lines of chili pepper that provide higher and more stable yields under a broad array of environmental conditions. We approach this goal by incorporating resistances to multiple diseases and tolerances to high temperatures and humidity into pepper types that are acceptable to growers.

2003 Hot Pepper Preliminary Yield Trials

Each year, numerous individual plants selected in the F_6 and F_7 generation are evaluated in replicated trial conditions to identify those that excel across a wide array of plant and crop characteristics. Out of these trials, candidates for release and distribution through the ICPN are identified. In 2003, only 24 entries were found suitable for this testing. Two variety trials were conducted, using a randomized complete block design (RCBD) with 3 replications, 24 plants per plot, and a stand equivalent to 29,630 plants per hectare. Each plant was tied to a bamboo stake for support. The spring planting was sown on 14 February, transplanted on 25 March, and harvested four times from 17 June to 22 July. The summer planting was sown on 22 April, transplanted on 2 May, and harvested four times between 30 July and 3 September. Results of these trials are presented in Tables 40 and 41. Assays were conducted for resistance to bacterial wilt (BW), Phytophthora blight race 3 (PC3), chilli veinal mosaic virus (ChiVMV), and fruit flavor traits (Table 42). More than half of the entries displayed high levels of resistance to BW, and three entries showed moderate resistance (less than 30% incidence among 24 inoculated plants) to PC3.

Comparing the spring preliminary yield trial (PYT) results to the summer trial data confirms trends found in previous trials. Developmental rate was increased, but fruit size and set were reduced. Time to flowering averaged 8% earlier and time to maturity averaged 9% earlier. Fruit were typically 8% shorter, 14% narrower, and 40% lighter, while marketable and total yields declined by 65% and 63%, respectively. Summer yields were suppressed substantially by heavy rains, high temperatures and high humidity during the period, resulting in losses of plants to soil-borne diseases, and fruit to transient insect infestations, despite periodic protective pesticide sprays. Some lines, however, performed atypically.

Three entries in this trial are of particular interest (0038-9155-5-1, 0038-9250-4, and 0238-8507-bk), as they are products of our ongoing program to transfer anthracnose resistance from a *Capsicum chinense* accession (PBC932) into *C. annuum*. Two recurrent parents were used, Kulai and IR. These lines still display some defects in fruit size and yield potential, but they display high levels of resistance at the green fruit stage under our laboratory assay methodology (see p. 52 on breeding for anthracnose resistance). One of these advanced lines (0238-8507-bk) displayed the greatest stability across growing seasons, with summer fruit size remaining approximately constant (actually significantly longer), and marketable and total yields increasing by 24–34% over the spring. This resulted in the unusual observation that the line was among the lowest yielders during the spring and among the highest yielders in the summer. Two other lines (0038-9155-1, and 0038-9261), including the recurrent parent IR, displayed the highest levels of yield stability across these two trials, but largely as a result of performing very poorly in the spring trials. IR has been noted as displaying good adaptation and yield in trials in India and China.

One of our check varieties, 9950-5197, delivered relatively high marketable yields in both the spring and summer trials. However, because of the severe reduction of productivity in the summer trial, the production in late July to early September was only 30% of productivity during the period of mid June through mid July. Another line, 0207-7516, received high scores in the summer trial for yield potential, bacterial wilt resistance, high pungency, and for fruit quality traits, including total solids and sugars contents.

Thirteenth International Chili Pepper Nursery (ICPN13)

AVRDC's pepper breeding program sustains a long-term development program to combine superior traits into desirable genetic backgrounds of hot peppers that may be of use in chili production areas around the world.

We have focused on disease resistance and adaptation to warm and humid growing conditions, but maintain priority in selecting for acceptable fruit shapes, sizes, pungencies and flavors, as well as high yield potential. Eight or more generations may be required from the initial cross to the advanced line selected for evaluation by ICPN cooperators. During 2003, 27 sets of ICPN seed were distributed to collaborators around the world.

ICPN13 was grown at AVRDC during the summer and fall nurseries of 2003. The summer nursery was sown on 2 April 2003 and transplanted into the field on 23 May, using a RCBD with 24 plants per plot and 3 replications. Harvests were conducted on all plants in the plot excepting the border plants, which were left for observation of fruit development. The plots were harvested four times, at approximately two-week intervals, beginning July 30 and continuing until 3 September. Heavy rains occurred in late July and early August, causing widespread deterioration of the crop. Fruit rots, root diseases, and other disorders caused many plants to be lost, and many fruit were judged unmarketable; consequently, cumulative yields are unusually low. This, however, is typical of the hazards faced by the pepper grower during this season, so they are presented to identify those lines that tolerated these poor conditions best.

Table 40. *Field performance of entries in the spring planting of the 2003 Hot Pepper Preliminary Yield trial.*[1]

Code	Pedigree	Days to 50% flower	Days to 50% maturity	Market. yield (t/ha)	Total yield (t/ha)	Plant height (cm)	Fruit length (cm)	Fruit width (cm)	Fruit fresh wt (g)	Overall score[2]
0207-7504	HDA248/PBC385//Tit-Paris/HDA 295	64	111	28.04	28.88	69.58	8.57	1.45	6.80	4.33
0207-7505	HDA248/PBC385//PS 1	66	113	26.60	27.84	73.33	8.00	2.00	9.07	4.17
0207-7510	Szechwan9/PerennialHDV// Jin's Curlicue///F1 Hy Hot 3 F3 sel.	63	121	27.62	30.88	70.00	10.53	1.07	6.07	4.50
0207-7512	HP1-BW	71	121	16.73	18.32	95.00	9.90	1.63	8.13	3.33
0207-7516	HDA248/PBC385//Tit-Paris/HDA 295	67	123	21.21	24.19	94.58	10.10	1.32	6.93	3.83
0207-7517	F1 Red Chili sel.	68	120	23.70	24.85	86.67	8.53	1.82	9.47	3.83
0207-7521	PuliBeauty/Szechwan9//PerennialHDV	65	115	28.19	29.37	79.17	11.40	1.22	7.60	4.50
0207-7527	PBC 638/PBC 473 selex//HyHot3	71	117	23.21	26.91	77.92	9.70	1.42	8.13	3.83
0207-7528	BangChang//Szechwan9/ PerennialHDV///Galron	67	116	22.72	23.72	101.25	11.20	2.03	12.93	3.67
0207-7532	BSS-269/HyHot3	66	119	31.87	35.25	89.58	12.67	1.70	13.20	4.67
0207-7534	HyHot3/LongFruit	67	120	19.74	20.58	100.00	10.83	1.47	7.73	3.50
0237-7502	(IR/PBC932-2//IR)-58///IR	71	118	21.19	21.79	68.33	10.83	1.48	8.20	3.33
0237-7507	Szechwan9/Perennial//HDA273/ 2*PBC385	61	113	26.29	27.11	80.00	11.90	1.53	9.20	4.33
0237-7508	Bangchang selex///HDA210/ Szechwan10//MC4	70	112	31.92	32.58	77.08	10.03	1.27	6.47	4.83
0237-7510	Hot_Beauty/MC-12	68	115	20.96	22.59	92.92	10.67	1.45	7.13	4.67
0237-7511	HyHot3//PerennialHDA/2*TitParis	66	116	15.34	19.25	73.75	9.57	1.58	7.87	3.50
0237-7516	PBC385/HyHot 3	69	118	25.35	27.23	97.50	12.87	1.77	11.73	3.67
0237-7517	HDA249/HyHot3	62	113	19.72	20.08	81.25	10.33	0.98	5.20	4.17
9950-5197	Kulim/HDA248	67	113	33.86	34.91	95.83	10.43	1.60	8.47	5.00
F1 Hy Hot 26	Hy Hot 26 (hybrid check)	67	120	22.61	29.84	95.83	12.90	1.42	11.13	5.00
0038-9155-5-1	IR/PBC932//3*IR BC3F7	73	125	5.33	5.64	75.00	8.63	1.77	6.60	2.67
0038-9250-4	Kulai/PBC932/3*Kulai BC3 F4	81	128	8.68	9.04	90.00	10.07	2.00	11.00	2.17
0038-9261	IR	76	125	10.73	11.08	70.67	8.40	1.40	5.00	2.33
0238-8507-BK	IR/PBC932/IR BC1F6	81	132	8.85	9.06	60.42	5.77	1.57	4.27	1.67
Mean		69	118	21.69	23.38	83.15	10.16	1.54	8.26	3.81
LSD (5%)		2.84	7.60	4.95	4.93	12.68	1.05	0.18	1.42	0.78
CV (%)		2.52	3.90	13.88	12.84	9.28	6.32	6.93	10.49	12.44

[1]Transplanted 25 March 2003 at AVRDC.

[2]Subjective quality rated on scale of 1 to 5, with 1 = poor and 5 = excellent.

Yield and fruit quality results are presented in Table 43, and disease resistance data are presented in Table 44. Four inbred entries are equivalent to our hybrid checks in marketable yield, and display resistance to at least one of the pathogens evaluated. Entry ICPN13#10 (0137-7538) is particularly interesting, in that it carries resistance to potato virus Y (PVY), cucumber mosaic virus (CMV) and BW, and its fruit contain 5.1% sugars, higher than any other entry in the trial, combined with a medium level of pungency. Its fruit tend to be larger in diameter than the typical Asian chili, but its flavorfulness may compensate for that defect. ICPN13#8 (Kulim/HDA248) also shows promise, combining high yield potential, high solids, very high pungency, and resistance to ChiVMV and PVY (and moderate resistance to CMV). This line happens

Table 41. *Field performance of entries in the summer planting of the 2003 Hot Pepper Preliminary Yield trial.*[1]

Code	Name	Days to 50% flower	Days to 50% maturity	Fruit length (cm)	Fruit width (cm)	Fruit fresh wt (g)	Market. yield (t/ha)	Total yield (t/ha)	Plant vigor	Uniform maturity	Plant health
									— (scores 1–5)[2]		—
0207-7504	HDA248/PBC385// Tit-Paris/HAD 295	58	108	6.67	1.10	4.40	4.03	4.43	3.33	3.83	2.67
0207-7505	HDA248/PBC385//PS 1	60	109	7.13	1.18	4.67	4.82	5.42	4.00	3.67	3.17
0207-7510	Szechwan9/PerennialHDV// Jin's Curlicue///Hy Hot 3 F3 sel.	62	109	9.00	1.22	4.13	6.49	7.18	4.33	3.67	3.67
0207-7512	HP1-BW	63	108	9.03	1.38	5.53	8.64	9.33	4.83	3.83	4.33
0207-7516	HDA248/PBC385// Tit-Paris/HDA295	62	106	9.83	1.27	5.33	9.44	10.16	4.83	4.17	4.50
0207-7517	F1 Red Chili sel.	61	106	9.80	1.30	5.47	10.07	11.09	4.83	4.17	4.50
0207-7521	PuliBeauty/Szechwan9// PerennialHDV	61	104	9.00	1.27	3.67	6.81	7.82	3.50	4.50	3.33
0207-7527	PBC638/PBC473_selex// HyHot3	61	106	9.23	1.37	4.53	6.70	7.63	3.33	4.17	3.00
0207-7528	BangChang//Szechwan9/ PerennialHDV///Galron	62	108	9.07	1.33	4.20	3.99	4.38	3.00	3.83	2.67
0207-7532	BSS-269/HyHot3	63	110	9.40	1.20	4.47	3.92	4.25	3.33	3.50	3.00
0207-7534	HyHot3/LongFruit	62	107	9.10	1.17	3.87	1.65	1.79	2.67	4.00	2.17
0237-7502	(IR/PBC932-2//IR)-58///IR	62	103	8.70	1.10	3.80	2.04	2.32	2.50	4.67	2.17
0237-7507	Szechwan9/Perennial// HDA273/2*PBC385	62	103	9.23	1.20	4.53	3.26	3.99	3.50	4.67	3.00
0237-7508	Bangchang selex/// HDA210/Szechwan10//MC4	62	105	8.33	1.23	3.87	3.21	4.03	4.00	4.33	3.50
0237-7510	Hot Beauty/MC-12	63	108	9.73	1.40	5.47	3.86	5.15	4.50	3.83	4.17
0237-7511	HyHot3//PerennialHDA/ 2*TitParis	62	108	9.57	1.28	4.67	3.94	4.88	4.33	3.83	4.00
0237-7516	PBC385/HyHot 3	63	108	10.20	1.32	5.60	9.27	10.46	4.50	3.83	4.33
0237-7517	HDA249/HyHot3	63	107	10.10	1.22	5.07	10.81	12.57	4.67	4.00	4.17
9950-5197	Kulim/HDA248	65	108	10.37	1.37	5.13	9.82	11.54	4.50	3.83	4.00
F1 Hy Hot 26	HyHot 26 (hybrid check)	69	109	10.50	1.28	6.13	4.71	6.22	4.50	3.67	4.00
0038-9155-5-1	IR/PBC932//3*IR BC3F7	69	108	11.03	1.35	5.60	4.06	4.63	4.00	3.83	3.50
0038-9250-4	Kulai/PBC932// 3*Kulai BC3 F4	69	107	9.80	1.38	5.47	4.90	5.51	4.00	4.00	3.83
0038-9261	IR	65	104	9.10	1.38	4.07	8.99	9.74	3.83	4.50	3.67
0238-8507-BK	IR/PBC932//IR BC1F6	63	103	7.03	1.48	4.33	10.93	12.12	4.00	4.67	3.83
Mean		63	107	9.21	1.28	4.75	6.10	6.94	3.95	4.04	3.55
LSD (5%)		3.47	3.42	1.37	0.20	1.72	5.26	5.55	1.13	0.61	1.06
CV (%)		3.39	1.95	8.72	8.96	18.38	40.68	36.79	15.73	9.13	17.20

[1]Transplanted 2 May 2003 at AVRDC.

[2]Plant vigor, uniform maturity and plant health rated on scales of 1 to 5 where 1 = poor vigor and 5 = outstanding vigor, 1 = diverse maturity and 5 = concentrated maturity, and 1 = poor health and 5 = outstanding health, respectively.

Table 42. *Fruit constituents and disease resistance qualities of entries in the 2003 Hot Pepper Preliminary Yield Trial.*[1]

CCA	Name	Solids (%)	Sugar (%)	Capsaicin (mg/100g)	BW (% res.)	PC3 (% res.)	ChiVMV (% res.)
CCA 4125	HDA248/PBC385//Tit-Paris/HDA295	20.4	4.4	7.9	95.8	37.5	0
CCA 4126	HDA248/PBC385//PS 1	16.9	5.0	1.2	55.0	0	0
CCA 4283	Szech.9/Per.HDV//Jin'sCurl.///F1HyHot 3F3 sel.	16.2	3.8	5.2	100.0	0	4
HP1-BW	HP1-BW	14.6	4.9	60.4	59.2	62.5	58
CCA 4125	HDA248/PBC385//Tit-Paris/HDA 295	18.4	4.7	35.3	99.2	4.2	0
F_1 Red Chili sel.	F_1 Red Chili sel.	12.6	3.4	32.2	83.3	4.2	0
CCA 3935	PuliBeauty/Szechwan9//PerennialHDV	18.9	5.1	49.5	14.2	48.0	0
CCA 4074	PBC638/PBC473_selex//HyHot3	16.1	4.1	12.7	95.0	0	0
CCA 4079	BangChang//Szechwan9/PerennialHDV///Galron	14.0	3.8	1.4	4.2	0	0
CCA 4104	BSS-269/HyHot3	13.6	4.2	10.8	66.7	16.7	0
CCA 3608	HyHot3/LongFruit	11.9	3.2	10.2	83.8	75.0	0
CCA 4431	(IR/PBC 932-2//IR)-58///IR	16.3	3.3	35.4	100.0	70.8	0
CCA 4203	Szechwan9/Perennial//HDA273/2*PBC385	15.5	3.8	16.1	82.5	0	21
CCA 4205	Bangchang selex///HDA210/Szechwan10//MC4	14.8	3.4	22.4	94.2	66.7	0
CCA 4512	Hot Beauty/MC-12	15.9	4.1	36.7	97.5	4.2	0
CCA 4516	HyHot3//PerennialHDA/2*Tit-Paris	15.6	3.6	17.2	100.0	62.5	0
CCA 4541	PBC385/HyHot 3	12.5	3.2	34.2	100.0	54.2	0
CCA 4557	HDA249/HyHot3	14.8	3.0	18.1	91.7	0	0
CCA 321	Kulim/HDA248	11.3	3.4	20.7	90.8	0	92
F1 Hy Hot 26	HyHot 26 (hybrid check)	14.3	3.6	15.1	95.8	25.0	0
0038-9155-5-1	IR/PBC932//3*IR BC3F7	18.5	5.5	43.2	100.0	29.2	0
CCA 3862-47-4	Kulai/PBC932//3*Kulai BC3 F4	13.6	3.9	25.5	100.0	0	0
PBC535	IR	17.1	3.6	5.3	91.7	88.0	21
9956-5861	IR/PBC932//IR BC1F6	16.4	3.7	45.5	97.5	50.0	0
Mean		15.4	3.9	23.4	83.2	29.1	8

[1]Transplanted 2 May 2003 at AVRDC; BW = bacterial wilt, PC3 - Phytophthora blight race 3, and ChiVMV = chilli veinal mosaic virus.

Table 43. *Performance for yield and fruit quality traits of entries in the summer planting of ICPN13.*[1]

ICPN13 Index	Entry	Name or Pedigree	Marketable yield (t/ha)	Total yield (t/ha)	Days to 50% maturity	Fruit length (cm)	Fruit width (cm)	Fruit fresh wt (g)	Solids (%)	Sugar (%)	Capsaicin (mg/ 100 g)
#1	PBC 142	PantC-1 (long-term ck)	7.64	7.83	105	6.47	0.83	1.73	14.73	3.84	19.15
#2	0107-7006	FriesdorferSelex/LongFruit	6.12	7.34	102	7.33	1.33	4.73	24.43	3.76	67.67
#3	0107-7011	IR/LongFruit	6.11	6.53	102	11.43	1.40	7.73	14.75	3.73	4.87
#4	9852-173	Kulim/HDA295	11.60	12.50	101	8.66	1.40	5.53	11.60	3.31	20.66
#5	0107-7047	Szechwan9/Perennial	11.32	11.85	101	7.47	0.90	2.60	15.60	2.94	1.87
#6	0107-7048	MI-2/Taiwan83-168-1-1//MI-2	8.15	8.30	104	6.33	0.87	2.00	14.86	4.40	2.97
#7	9955-15	Susan's Joy	8.28	11.80	101	13.40	1.80	12.53	13.82	3.99	13.13
#8	0107-7058	Kulim/HDA248	13.13	14.46	104	9.20	1.47	7.57	19.41	3.08	50.85
#9	0107-7062	MC-12	7.04	11.33	104	8.47	1.47	6.80	23.25	3.63	71.39
#10	0137-7538	PSP-11/Jin's Delight/Kulai	11.62	12.78	105	8.60	1.70	8.60	14.42	5.10	12.98
CK1	CCA5217F1	Jin's Joy//Kulim/HDA248	13.60	16.72	103	10.60	1.27	6.40	14.13	4.06	17.80
CK2	HyHot 26F1	HyHot $26F_1$	11.85	14.61	102	12.50	1.23	7.07	14.64	3.84	12.00
Mean			9.70	11.34	103	9.21	1.31	6.11	16.30	3.81	24.61
LSD (5%)			4.38	4.76	4	1.01	0.17	1.24			
CV (5%)			26.99	24.80	2	6.48	7.71	11.96			

[1]Transplanted 23 May 2003 at AVRDC.

Table 44. *Disease resistance of ICPN13 entries.*[1]

Index	Entry	Name/Pedigree	ChiVMV (% res.)	PC3 (% res.)	Anthrac. (mm)	BW (% res.)	ToMV (% res.)	PVY (% res.)	CMV (% res.)
ICPN13#1	PBC 142	PantC-1 (long term check)	100	0	-	42	0	9	21
ICPN13#2	0107-7006	FriesdorferSelex/LongFruit	0	0	8.4	64	0	100	0
ICPN13#3	0107-7011	IR/LongFruit	0	17	9.5	96	0	100	0
ICPN13#4	9852-173	Kulim/HDA 295	0	0	5.4	59	0	96	4
ICPN13#5	0107-7047	Szechwan9/Perennial	36	8	7.9	88	0	73	33
ICPN13#6	0107-7048	MI-2/Taiwan83-168-1-1//MI-2	25	0	7.6	99	0	100	83
ICPN13#7	9955-15	Susan's Joy	8	0	7.5	59	0	100	58
ICPN13#8	0107-7058	Kulim/HDA248	100	0	9.8	42	0	100	71
ICPN13#9	0107-7062	MC-12	0	0	11.2	98	0	0	0
ICPN13#10	0137-7538	PSP-11/Jin's Delight/Kulai	8	0	-	100	0	100	100
CK1	CCA5217 F1	Jin's Joy//Kulim/HDA248	-	-	-	96	0	100	92
CK2	F1 Hy Hot 26	F1 Hy Hot 26	-	-	-	100	0	100	75

[1]Disease screening was carried out in separate greenhouse trials using Taiwan pathogen strains. ChiVMV = chilli veinal mottle virus; PC3 = Phytophthora blight, race 3; Anthrac. = anthracnose; BW = bacterial wilt; ToMV = tomato mosaic virus; and PVY = potato virus Y. Numbers are the percent resistant plants after inoculation. Anthracnose = *Colletotrichum acutatum*, severe strain: value in mm is average diameter of lesion on fruit 6 days following inoculation with approximately 500 spores below cuticle.

to be one of the parents of the hybrid check CCA5217; the hybrid has equivalent yield to this parent, but gains improved resistance to bacterial wilt and CMV and superior fruit shape; reaction of the hybrid to CVMV was not recorded.

The fall season planting of the ICPN13 was sown on 5 September and transplanted on 5 October 2003, using the same experimental design as employed in the summer planting. Five harvests were made, on 8, 15 and 29 January and on 11 and 25 February 2004. Yield and fruit data are presented in Table 45. Average time to harvestable fruit maturity was three weeks later in the fall planting than in the summer season, but average fruit size and fresh yields were 2.20 and 2.29 greater during the winter harvest compared to the summer trial, respectively. The percentage of unmarketable fruit fell to less than 3%. As in the summer planting, the inbred line Kulim/HDA248 significantly ex-

Table 45. *Yield and fruit traits of entries in the fall planting of ICPN13.*[1]

ICPN13 Index	Entry	Pedigree	Marketable yield (t/ha)	Total yield (t/ha)	Days to 50% maturity	Fruit length (cm)	Fruit width (cm)	Fruit fresh wt (g)
#1	PBC 142	Pant C-1	16.54	16.7	133	7.8	1.1	3.6
#2	0107-7006	FriesdorferSelex/LongFruit	17.18	18.2	120	12.2	1.7	15.5
#3	0107-7011	IR/LongFruit	20.51	20.9	118	16.1	1.7	16.9
#4	9852-173	Kulim/HDA 295	16.37	17.2	117	10.1	1.7	10.5
#5	0107-7047	Szechwan9/Perennial	20.40	20.6	123	9.3	1.2	6.0
#6	0107-7048	MI-2/Taiwan83-168-1-1//MI-2	17.25	17.4	122	7.2	1.1	3.7
#7	9955-15	Susan's Joy	28.93	30.6	125	15.9	2.4	29.7
#8	0107-7058	Kulim/HDA248	29.73	30.1	123	12.2	1.9	14.3
#9	0107-7062	MC-12	26.13	27.6	124	11.7	2.0	15.9
#10	0137-7538	PSP-11/Jin's Delight/Kulai	22.18	23.1	126	9.8	2.1	16.3
CK1	CCA5217 F1	Jin's Joy/Kulium/HDA248	26.93	27.1	120	13.4	1.7	13.5
CK2	Hy Hot 26 F1	Hy Hot 26 F1	23.93	24.2	125	14.3	1.6	16.7
Mean			22.17	22.8	123	11.7	1.7	13.5
LSD (5%)			2.5	2.4	6.52	0.9	0.1	2.2
CV (5%)			6.7	6.3	3.12	4.3	3.7	9.6

[1]Transplanted 5 October 2003 at AVRDC.

ceeded both hybrid checks in yield. There is little evidence of entries which show a relative preference for summer growing conditions; correlation between summer and fall trial yield performances was weak (r = .387), but the same two lines (Kulim/HDA248 and its F_1 combination 'Jin's Joy//Kulim/HDA248) were the highest yielders in both trials. The entry ICPN13#10, discussed above, did not yield as well as the hybrid checks in the fall, and its fruit were only 1.9 times larger than its summer fruit size, suggesting that it may show more stability of performance over a wide range of growing conditions. Other lines, such as MC12 seem to display a distinct preference for the cooler growing conditions of the fall trial, where it produced a 3.7 fold greater yield than in the summer planting.

Development of high yielding, disease-resistant and heat-tolerant sweet pepper lines

AVRDC has endeavored to improve sweet peppers for production in tropical conditions, including incorporating resistance to diseases (principally PVY, Phytophthora, and bacterial spot diseases, with continued attention to CMV and ChiVMV) and adaptation to the more stressful conditions of the hot, humid lowlands. Broad adaptation is currently measured empirically by evaluating sets of candidate lines under several distinct growing conditions. Sampling of growing environments is accomplished at AVRDC by repeated testing in cool vs. warm seasons. The most promising materials are evaluated internationally by cooperators who conduct replicated variety trials under their conditions, returning results to AVRDC for summary comparisons.

Sweet Pepper Preliminary Yield Trials

Genetically stabilized selections out of germplasm accessions, and advanced generation selections from our breeding program are entered into two replicated preliminary yield trials (PYTs), one targeting the spring production season, and the second scheduled for production during the summer season. In 2003, both trials were established to evaluate 56 lines, using a RCBD, with 3 replications and 24 plants per plot. Plants were established on raised beds at an equivalent of 29,630 plants per hectare. Seed for the spring trial was sown on 14 February, and seedlings were transplanted on 25 March 2003. Due to flooding and extensive plant loss in mid June, only a single harvest was taken on 9 June. The summer planting was sown on 2 April, and seedlings were transplanted on 1 May; four harvests were conducted from 21 July to 2 September. Results from these trials are presented in Tables 46 and 47. Separate laboratory analyses of resistance to PVY, Phytophthora, and bacterial spot were also conducted. That data, along with fruit shape and color characteristics are presented in Table 48.

We had found that many accessions acquired by our program in the past contained substantial genetic variation and their utility as parents in crosses or in direct distribution to farmers would be enhanced substantially through a concerted effort to reselect these samples for desirable plant habit, fruit, and yield traits. This has been done, and the 2003 trials have allowed their comparative evaluation under field conditions. All but 13 of the 56 entries in this year's PYT are reselections from within a wide array of sweet pepper accessions from around the world and from reselecting among commercial hybrids; relatively few are products of our in-house crosses and selection programs.

Performance of these trials was disappointing. Heavy rains and flooding in the nursery forced an early termination of the spring trial, and marketable yields are consequently about half of what may normally be expected. Summer yields were also extremely poor due to early flooding, widespread plant losses, and generally unmarketable fruit sizes and shape. These difficult conditions nevertheless allow comparison of the entries and superior entries can be highlighted.

Some entries, e.g. the selection out of the hybrid variety Paladin (0237-7008), were able to produce comparatively high marketable yields even though half of their plants showed wilting symptoms due to soil-borne diseases. Disease resistance assays identified 19 of the 56 entries as carrying high levels of resistance to PVY, and eight lines were resistant to *Phytophthora capsici*, race 1. Five lines proved to be resistant to both. Only three lines were found to carry moderate to high levels or resistance to bacterial spot. These lines, and other promising entries, will be reevaluated in 2004 for possible release in future International Sweet Pepper Nurseries (ISPNs).

Fifth International Sweet Pepper Nursery

The ISPN trials are conducted to evaluate advanced products of the AVRDC pepper breeding program under a broad range of environments. Cooperators

Table 46. *Performance of selected entries in the Spring 2003 Sweet Pepper Preliminary Yield Trial.*[1]

Entry	Name	Days 50% maturity	Fruit fresh wt (g)	Mkt. yield (t/ha)	Total yield (t/ha)	Wilted plants (%)	Overall accept.	Plant vigor	Disease res.
							— (score 1-5)[2] —		
0037-7645	Yellow#1 sel.	118	102.7	15.1	19.0	7	4.8	4.7	4.5
PBC1553sel.	1032 Red	115	139.3	10.6	13.1	35	4.2	3.8	3.8
PBC1529sel.	Permagreen	125	44.0	10.5	15.5	23	3.5	4.7	5.0
PBC1372sel.	Morgold	111	43.7	11.7	16.0	35	3.7	3.7	4.2
PBC 762sel.	TL 791C/691	112	75.8	19.3	26.5	27	5.0	5.0	5.0
PBC 723sel.	Orange Mutant	112	30.8	12.5	17.2	42	4.7	3.8	3.8
PBC 683sel.	Lehava (Restr.)	115	17.0	14.2	16.7	28	3.8	4.0	4.5
PBC 678sel.	Cherrytime	119	25.3	12.3	16.4	7	4.0	4.0	4.2
PBC 673sel.	Antohi Romanian	113	51.2	6.3	10.2	42	4.0	3.7	3.7
PBC 628sel.	Zao Feng	116	58.0	12.1	18.1	13	3.8	4.3	4.3
PBC 623sel.	Anitbois	118	66.8	16.5	22.0	29	4.7	4.7	4.8
PBC 542sel.	ZKI 808	111	46.2	14.7	18.9	29	5.0	4.7	4.8
PBC 435sel.	All Season	118	43.8	16.1	21.9	20	4.0	5.0	4.8
PBC 396sel.	1346-FS-1	124	122.2	15.8	18.8	39	4.7	4.7	4.5
PBC 395sel.	KC 295	119	93.7	14.1	19.7	21	4.5	5.0	4.8
PBC 356sel.	Dempsey	118	132.7	16.8	19.5	41	4.2	4.0	4.0
PBC 349sel.	Delray Bell	113	98.3	14.8	20.6	18	4.8	4.3	4.8
PBC 271sel.	Milord	113	103.0	15.1	21.9	22	4.8	4.7	4.8
PBC 266sel.	Zolotoy Ubiley	115	67.2	6.2	10.7	32	3.8	3.5	3.7
PBC 253sel.	Sweet 057	118	137.2	18.3	25.1	31	4.8	4.2	4.2
PBC 164sel.	Line 16-3	127	111.7	17.4	19.6	2	4.8	4.2	4.8
PBC 116sel.	MI-Gold	114	67.8	10.4	12.5	24	4.0	4.0	4.0
PBC 5sel.	Maor	117	103.3	8.9	11.4	31	4.3	3.5	4.0
0207-7004	(F1BlueStart/ECW30R)//(KeyLargoF1/HDA249)	115	48.5	8.3	13.2	35	3.2	4.2	4.3
0207-7011	F1 Midway sel.	117	46.3	19.4	22.3	43	4.8	5.0	5.0
0207-7014	HDA252/F1BlueStar//Magda///F1ChungChiaoNo.5	122	91.5	16.5	20.4	23	3.7	4.3	4.7
0207-7019	Tisana selex/F1 Annabell	117	77.0	16.2	22.6	13	4.5	4.7	4.5
0207-7023	SP2-CMV	118	60.7	15.3	19.8	23	3.8	4.2	4.8
0207-7033	75-3-4-4-1-Bk/BruWdr//(LgFrt/HDA201//ECW20R)F3sl	116	71.4	15.3	21.1	27	3.8	5.0	5.0
0207-7036	BruinsmaWonder//YoloY/34-6-7-1-1-Bk	122	101.3	11.2	15.9	26	3.7	4.0	4.0
0207-7042	Unknown	115	88.5	14.5	19.1	18	4.3	4.0	4.0
0207-7044	F1 Mito Lee selex	116	86.8	17.8	22.8	33	4.7	5.0	4.8
0237-7007	F1 Paladin sel.	115	130.0	19.9	23.1	38	5.0	4.3	4.3
0237-7008	F1 Paladin sel.	112	148.0	20.0	24.0	51	4.8	4.3	4.7
0237-7009	F1 Paladin sel.	119	143.5	20.9	24.9	46	5.0	4.2	4.5
0237-7011	F1 Peto Wonder sel.	120	131.8	20.3	23.5	34	5.0	4.8	5.0
0237-7012	F1 Peto Wonder sel.	118	117.7	11.7	14.5	45	4.8	4.0	4.2
0237-7020	F1 Tequila/SP2BH-HR	120	66.8	11.5	14.3	32	3.8	3.7	3.7
9946-2194-1	F1 White King sel.	116	120.3	14.9	18.5	22	4.8	3.8	4.7
9946-2192	F1 PR 300-7 sel.	124	149.8	8.1	11.8	47	4.5	4.0	3.7
9852-131	HDA 249/Milord	116	37.2	17.4	22.5	8	4.7	5.0	5.0
9848-4840	SP2 BS-HR	113	44.8	16.3	22.0	30	4.0	5.0	5.0
9847-4668	HDA249/Milord	120	42.8	10.1	12.5	12	4.0	4.2	4.3
0137-7002	F1 Boynton Bell// (KeyLargoF1/HDA249)	118	69.2	11.0	15.9	11	4.0	4.3	4.5
0137-7017	F1Camlot//(KeyLgoF1/HDA249)///(KeyLgoF1/HDA249)	119	78.0	11.2	18.2	43	3.3	4.7	4.5
F1 Andalus	F1 Andalus (hybrid check)	115	133.2	19.9	27.1	15	5.0	5.0	5.0
CCA5089	(HDA249/Milord)//F1PR300-7sel.	115	81.0	21.9	26.9	42	4.8	5.0	5.0
Mean of all 56 entries		117	83.1	13.8	18.2	30	4.3	4.4	4.4
LSD (5%)		5	16.7	7.2	7.8	4.9	0.5	0.8	0.8
CV (5%)		3	12.4	32	27	54	6.2	11	11

[1,2]Transplanted 25 March 2003 at AVRDC; and rated on a scale of 1 to 5, where 1 is poor and 5 is excellent for each particular trait.

Table 47. *Performance of selected entries in the Summer 2003 Sweet Pepper Preliminary Yield Trial.*[1]

Entry	Name	Days 50% flower	Days 50% maturity	Fruit length (cm)	Fruit width (cm)	Fruit fresh wt (g)	Fruit thick. (mm)	Mkt. yield (t/ha)	Total yield (t/ha)
0037-7645	Yellow#1 sel.	72	112	4.4	5.2	47.3	4.5	1.2	4.0
PBC1553sel.	1032 Red	71	109	5.4	6.8	74.5	4.5	1.9	5.2
PBC1529sel.	Permagreen	62	119	6.1	4.2	18.9	2.3	1.1	2.4
PBC1372sel.	Morgold	58	105	6.2	4.5	32.6	6.0	3.4	10.2
PBC 762sel.	TL 791C/691	64	106	9.8	5.4	61.9	5.6	2.4	9.5
PBC 723sel.	Orange Mutant	68	106	12.5	3.1	27.2	4.5	1.0	5.4
PBC 683sel.	Lehava (Restr.)	57	109	9.6	2.2	12.2	4.6	1.1	5.2
PBC 678sel.	Cherrytime	60	113	2.8	3.8	17.5	6.1	1.3	5.7
PBC 673sel.	Antohi Romanian	66	107	6.5	4.9	42.3	6.1	2.2	8.4
PBC 628sel.	Zao Feng	63	110	4.3	5.4	32.9	4.2	1.6	4.6
PBC 623sel.	Anitbois	65	112	4.0	5.6	39.0	4.4	1.4	4.0
PBC 542sel.	ZKI 808	60	105	10.2	3.8	36.5	7.0	4.1	11.4
PBC 435sel.	All Season	73	112	6.1	4.7	33.9	7.6	4.5	13.8
PBC 396sel.	1346-FS-1	73	118	6.0	6.6	76.9	4.4	1.3	3.3
PBC 395sel.	KC 295	64	113	7.2	5.2	53.9	4.3	0.9	4.1
PBC 356sel.	Dempsey	72	112	6.6	6.8	85.3	4.8	1.2	6.7
PBC 349sel.	Delray Bell	64	107	4.7	5.5	44.4	4.6	1.4	4.7
PBC 271sel.	Milord	65	107	6.8	5.7	56.7	5.2	1.7	7.3
PBC 266sel.	Zolotoy Ubiley	71	109	3.7	5.8	45.5	5.6	1.3	4.4
PBC 253sel.	Sweet 057	69	112	6.0	7.4	86.5	5.4	4.9	9.3
PBC 164sel.	Line 16-3	69	121	5.5	6.2	68.1	5.9	2.6	10.0
PBC 116sel.	MI-Gold	66	108	6.5	5.1	46.9	6.0	1.2	5.9
PBC 5sel.	Maor	67	111	5.7	6.4	72.5	4.8	1.6	5.6
0207-7004	(F1BlueStart/ECW30R)//(KeyLargoF1/HDA249)	64	109	7.2	4.8	42.7	6.1	4.1	11.1
0207-7011	F1 Midway sel.	68	111	11.6	3.5	34.5	8.0	4.5	14.0
0207-7014	HDA252/F1BlueStar//Magda///F1ChungChiaoNo.5	65	116	6.4	5.9	58.1	5.8	4.7	10.2
0207-7019	Tisana selex/F1 Annabell	64	111	6.4	4.9	40.9	4.3	1.4	4.6
0207-7023	SP2-CMV	62	112	6.1	5.2	42.0	6.5	4.4	12.5
0207-7033	75-3-4-4-1-Bk/BruWdr//(LgFrt/HDA201//ECW20R)F3sl	64	110	6.9	5.4	52.4	6.9	3.8	14.0
0207-7036	BruinsmaWonder//YoloY/34-6-7-1-1-Bk	71	116	5.7	5.3	50.7	4.2	1.3	4.1
0207-7042	Unknown	69	109	6.0	5.5	35.1	4.0	1.4	4.9
0207-7044	F1 Mito Lee selex	63	110	11.4	4.5	47.6	3.8	0.9	4.1
0237-7007	F1 Paladin sel.	69	109	6.3	6.6	82.6	4.8	1.8	5.5
0237-7008	F1 Paladin sel.	68	106	4.8	5.7	51.2	4.1	1.8	5.5
0237-7009	F1 Paladin sel.	69	113	6.3	6.6	56.4	4.7	1.8	5.8
0237-7011	F1 Peto Wonder sel.	70	114	7.7	5.0	50.7	4.0	1.2	3.0
0237-7012	F1 Peto Wonder sel.	70	112	7.9	5.3	49.9	3.7	1.4	2.8
0237-7020	F1 Tequila/SP2BH-HR	70	114	5.6	5.0	33.5	4.3	1.6	5.0
9946-2194-1	F1 White King sel.	75	110	5.2	6.0	57.9	4.7	1.1	4.5
9946-2192	F1 PR 300-7 sel.	72	118	4.9	7.1	80.4	4.8	1.2	5.0
9852-131	HDA 249/Milord	64	110	8.6	3.4	27.8	5.9	2.4	9.2
9848-4840	SP2 BS-HR	61	107	7.5	4.5	30.7	7.5	5.4	13.6
9847-4668	HDA249/Milord	63	114	3.9	4.8	26.5	3.4	1.2	3.4
0137-7002	F1 Boynton Bell// (KeyLargoF1/HDA249)	72	112	7.1	5.0	48.3	4.8	1.5	6.1
0137-7017	F1Camlot//(KeyLgoF1/HDA249)///(KeyLgoF1/HDA249)	65	113	8.2	5.0	49.5	5.3	2.8	7.4
F1 Andalus	F1 Andalus (hybrid check)	63	109	12.5	5.0	67.8	5.4	4.1	9.7
CCA5089	(HDA249/Milord)//F1PR300-7sel.	64	109	5.8	6.2	65.7	5.8	3.2	10.3
Mean of all 56 entries		67	111	6.4	5.2	46.9	4.9	2.0	6.2
LSD (5%)		4	5	1.3	1.0	22.3	1.8	2.0	5.6
CV (5%)		4	3	12.2	12.1	29.3	22.2	64.4	55.3

[1]Transplanted 1 May 2003 at AVRDC.

Table 48. *Disease reactions and fruit colors in selected entries in the 2003 Sweet Pepper Preliminary Yield Trial.*

Entry	Name	PVY[1] (res. %)	PC1[1] (res. %)	BS-P3[1] (score)	Fruit shape	Immature color	Mature color
0037-7645	Yellow#1 sel.	0	0	5.3	Upright squash-bell	Lt grn	Yellow
PBC1553sel.	1032 Red	100	0	5.8	Upright bell	Green	Red
PBC1529sel.	Permagreen	0	18	3.2	Long bell	Green	Green
PBC1372sel.	Morgold	0	0	6.2	Upright, conical bell	Green	Yel-orange
PBC 762sel.	TL 791C/691	0	0	4.5	Long, conical bell	Yel-grn	Red
PBC 723sel.	Orange mutant	0	50	5.8	Hungarian Wax	Lt yel	Orange
PBC 683sel.	Lehava (Restr.)	0	90	4.8	Cayenne	Green	Red
PBC 678sel.	Cherrytime	0	44	6.2	Upright cherry	Green	Red
PBC 673sel.	Antohi Romanian	0	0	6.8	Conical bell	Lt yel	Lt orange-red
PBC 628sel.	Zao Feng	0	33	5.8	Bell	Green	Red
PBC 623sel.	Anitbois	0	6	4.8	Squash	Green	Red
PBC 542sel.	ZKI 808	0	44	5.8	Hungarian Wax	Yel-grn	Red
PBC 435sel.	All Season	0	28	5.0	Bell	Green	Red
PBC 396sel.	1346-FS-1	0	0	4.2	Bell	Green	Red
PBC 395sel.	KC 295	0	0	6.0	Upright bell	Lt grn	Red
PBC 356sel.	Dempsey	100	6	4.0	Upright bell	Green	Red
PBC 349sel.	Delray Bell	100	0	5.2	Bell	Green	Red
PBC 271sel.	Milord	100	100	6.2	Long bell	Green	Red
PBC 266	Zolotoy Ubiley	0	83	5.0	Squash	Lt grn	Yel-orange
PBC 253sel.	Sweet 057	100	17	5.3	Short bell	Green	Yellow
PBC 164sel.	Line 16-3	100	0	4.7	Upright bell	Green	Red
PBC 116sel.	MI-Gold	0	0	7.3	Upright, conical bell	Lt yel	Orng-red/red
PBC 5sel.	Maor	100	0	5.8	Upright bell	Green	Red
0207-7004	(F1BlueStart/ECW30R)//(KeyLargoF1/HDA249)	62	0	4.2	Long Bell	Lt grn	Red
0207-7011	F1 Midway sel.	0	0	6.7	Hungarian Wax	Yel-grn	Orange-red
0207-7014	HDA252/F1 BlueStar//Magda///F1ChungChiaoNo.5	0	0	5.2	Upright bell	Green	Red
0207-7019	Tisana selex/F1 Annabell	0	6	5.5	Pointed bell	Green	Red
0207-7023	SP2-CMV	100	0	7.3	Upright bell	Green	Red
0207-7033	75-3-4-4-1-Bk/BrWdr//((LFt/HDA201//ECW20R)F3sl	0	0	6.3	Upright, conical bell	Green	Red
0207-7036	BruinsmaWonder//YoloY/34-6-7-1-1-Bk	0	0	6.3	Upright bell	Green	Red
0207-7042	unknown	100	11	6.8	Upright bell	Green	Yel-orange
0207-7044	F1 Mito Lee selex	95	6	6.7	Upright, long bell	Green	Red
0237-7007	F1 Paladin sel.	100	100	5.8	Bell	Green	Red
0237-7008	F1 Paladin sel.	100	100	5.4	Bell	Green	Red
0237-7009	F1 Paladin sel.	100	100	5.8	Bell	Green	Red
0237-7011	F1 Peto Wonder sel.	100	0	5.7	Long bell	Green	Red
0237-7012	F1 Peto Wonder sel.	100	0	5.3	Long bell	Ggreen	Red
0237-7020	F1 Tequila/SP2BH-HR	0	0	5.2	Bell	Yel-grn	Orange
9946-2194-1	F1 White King sel.	0	17	6.2	Bell	Lt yel	Lt yel
9946-2192	F1 PR 300-7 sel.	100	17	4.2	Bell	Green	Yellow
9852-131	HDA 249/Milord	100	0	5.5	Long, conical bell	Lt grn	Red
9848-4840	SP2 BS-HR	0	0	6.0	Conical bell	Lt grn	Red
9847-4668	HDA249/Milord	100	100	5.2	Upright bell	Green	Red
0137-7002	F1 Boynton Bell// (KeyLargoF1/HDA249)	41	50	1.3	Upright, long bell	Lt grn	Yel-orange
0137-7017	F1Cmlt//(KyLgoF1/HDA249)///(KyLgoF1/HDA249)	0	17	4.7	Long bell	Lt grn	Red
F1 Andalus	F1 Andalus (hybrid check)	100	33	6.0	Long bell	Green	Red
CCA5089	(HDA249/Milord)//F1PR300-7sel.	100	94	1.3	Upright bell	Green	Red

[1]Disease screening was carried out in separate greenhouse trials using Taiwan pathogen strains. PVY = potato virus Y; PC1= Phytophthora blight, race 1. Numbers are the percent resistant plants after inoculation. BS = bacterial spot, race P3. Scores are diseased leaf area according to the Barrett-Horsfall scale, and range from 0 (healthy) to 11 (100% disease). Resistant check PBC 137 scored 1.2 for race 3.

around the world are invited to evaluate these materials under their growing conditions. All ISPNs have used the advanced line 9852-131 (HDA249/Milord) as a long-term check, and at AVRDC we also include the commercial hybrid Andalus as a standard check, as it is the sweet pepper variety most widely produced in Taiwan. We also include a F_1 hybrid sweet pepper developed by us for potential adoption by our national collaborators. As superior advanced lines are identified from our ongoing breeding nurseries, they are initially tested in replicated PYTs, and the best are taken as candidates for inclusion in the ISPN. We have evaluated candidate entries at AVRDC prior to distributing them to our global cooperators in order to have more data to share with them before they commit to the substantial task of growing and evaluating them under their field conditions.

In 2003, the 5th International Sweet Pepper Nursery (ISPN5) was evaluated twice in contrasting climatic conditions at AVRDC. Both trials were conducted as RCBD with 3 replications, 24 plants per plot, and an equivalent of 30,000 plants per hectare. Twelve entries were used, including nine advanced lines from our breeding program, and four check varieties. A support system of iron pipes with nylon string netting was stretched between the pipes to produce a grid of supporting stings at 20 cm spacing; one layer was set at 35 cm above the surface of the bed; the second was set at 50 cm above the soil. The spring trial was sown in plug flats in a greenhouse on 14 February and transplanted into the field on 25 March 2003. Four harvests were completed at approximately 10-day intervals, beginning on 9 June. The summer trial was similarly sown on 2 April, and transplanted on 1 May. Four harvests were taken from 21 July to 2 September. Fruit measurements were compiled from samples of 10 fruit typical of each cultivar's type, taken during the first harvest. Assays for resistance to numerous diseases were conducted independently of the trials, and results are presented in Tables 49–52. Seed of entries in this nursery may be requested by cooperators interested in establishing replicated variety trials under their conditions and then reporting the results to AVRDC for consolidation into a multi-location summary report.

The summer trial was particularly poor due to heavy rains in the early summer, which resulted in root disease and substantial plant mortality. High temperatures and humidity also favored heavy pressure from fruit diseases such as anthracnose. Summer conditions not only reduced marketable fruit number and size, but

Table 49. *Horticultural traits of entries in the spring planting of ISPN5.*[1]

Entry	Pedigree	Days to maturity	Plant height (cm)	Fruit length (cm)	Fruit width (cm)	Length/ width ratio	Fruit fresh wt (g)	Fruit thick. (mm)	Mkt. fruit (%)	Mkt. yield (t/ha)	Total yield (t/ha)	Mkt. fruit/ plant
ISPN5#1	HDA249/Milord (inbred ck)	117	58.2	9.1	3.6	2.53	35.8	4.3	73	39.2	48.4	56.1
ISPN5#2	75-3-4-4-1-BK/BruinsmaWonder	118	48.9	5.0	6.2	0.81	62.5	4.7	57	14.6	20.8	7.7
ISPN5#3	Andalus-seln	113	55.8	18.0	6.0	3.00	115.0	4.2	34	14.5	25.4	6.6
ISPN5#4	Camelot/97-7585-3//98-5143	115	78.6	8.2	5.6	1.46	70.3	4.3	55	27.5	39.0	18.1
ISPN5#5	HDA249/BruinsmaWonder// Jin'sGold	116	61.9	7.9	5.3	1.32	70.5	5.3	69	25.9	33.6	14.6
ISPN5#6	BruinsmaWonder//YoloY/ 34-6-7-1-1-Bk	119	51.7	6.5	7.4	0.88	105.7	5.1	56	22.1	32.3	9.4
ISPN5#7	Milord	116	50.8	7.8	6.3	1.24	87.2	5.1	50	22.1	32.7	11.6
ISPN5#8	GoldenBell-seln	113	48.5	6.7	6.5	1.03	73.3	5.0	46	17.4	30.4	6.8
ISPN5#9	Tao-Yuen Dark Red#1	120	47.5	7.6	6.9	1.10	96.0	5.1	68	24.8	31.2	11.3
ISPN5#10	T52/PBC841//ECW-20R	114	53.2	8.7	6.0	1.45	85.7	5.7	55	29.7	42.2	17.0
ISPN5#11	HDA249/Milord// PR300-7seln (hybrid check)	119	71.3	6.8	6.6	1.03	82.6	4.5	73	39.6	49.0	20.2
ISPN5#12	Andalus (hybrid check)	114	76.7	17.1	6.3	2.71	154.5	4.9	60	41.1	55.0	15.0
Mean of all entries		116	58.6	9.1	6.1	1.55	86.6	4.8	58	26.5	36.7	16.2
LSD (5%)		3.9	6.7	2.1	2.1	-	2.1	2.1	-	9.4	13.1	5.0
CV (5%)		2.0	6.7	10.3	7.2	-	20.5	11.5	-	21.0	21.1	18.3

[1]Transplanted 25 March 2003 at AVRDC.

also fruit wall thickness. Size reduction was generally proportionate, and the ratio between length and diameter remained approximately constant (correlation coefficient 0.972).

In our trials, inbred lines continue to be outpaced by hybrids, and achieving parity is not likely any time soon. The commercial hybrid Andalus yielded substantially better than virtually all other entries, with the exception in the spring trial of the other hybrid check variety (ISPN5#11), and our long-term inbred check (ISPN5#1). Similarly, with few exceptions, hybrids excelled selected inbreds in sugar content and total

Table 50. *Horticultural traits of entries in the summer planting of ISPN5.*[1]

Entry	Pedigree	Days to maturity	Plant height (cm)	Fruit length (cm)	Fruit width (cm)	Length/ width ratio	Fruit fresh wt (g)	Fruit thick. (mm)	Mkt. fruit (%)	Mkt. yield (t/ha)	Total yield (t/ha)	Mkt. fruit/ plant
ISPN5#9	Tao-Yuen Dark Red#1	120	47.5	7.6	6.9	1.10	96.0	5.1	68	24.8	31.2	11.3
ISPN5#1	HDA249/Milord (inbred ck)	111	65.8	8.2	3.2	2.55	22.7	3.3	54	4.1	6.0	8.1
ISPN5#2	75-3-4-4-1-BK/BruinsmaWonder	112	28.9	3.9	4.6	0.86	15.8	3.2	40	0.4	0.8	0.7
ISPN5#3	F1 Andalus sel.	107	36.7	9.2	3.7	2.45	34.8	3.1	40	1.3	2.2	1.4
ISPN5#4	F1 Camelot/97-7585-3//98-5143	108	62.5	8.0	5.2	1.54	52.8	3.9	44	3.6	5.9	4.9
ISPN5#5	HDA249/BruinsmaWonder// Jin's Gold	111	57.1	6.8	4.3	1.60	35.0	3.9	65	2.6	3.5	3.5
ISPN5#6	BruinsmaWonder//YoloY/ 34-6-7-1-1-Bk	111	38.9	5.1	6.2	0.83	53.1	4.1	35	1.8	3.2	1.4
ISPN5#7	Milord	109	52.1	7.5	6.2	1.20	66.9	4.2	47	4.0	6.3	3.4
ISPN5#8	GoldenBell-seln	112	47.5	5.9	5.8	1.02	50.2	3.9	28	1.8	4.4	1.4
ISPN5#9	Tao-Yuen Dark Red#1	110	33.4	5.5	5.7	0.96	47.9	4.2	45	1.2	1.7	1.0
ISPN5#10	T52/PBC841//ECW-20R	111	30.4	5.5	3.9	1.40	22.7	3.2	21	0.5	1.3	0.8
ISPN5#11	HDA249/Milord// PR300-7seln (hybrid ck)	112	59.6	5.3	5.6	0.94	49.0	4.3	59	5.2	7.1	6.0
ISPN5#12	Andalus (hybrid ck)	108	69.2	13.7	5.4	2.55	82.9	3.7	38	8.2	13.8	9.1
Mean of all entries		110	48.5	7.1	5.0	1.49	44.5	3.8	39	2.9	4.7	3.5
LSD (5%)		5.3	14.2	2.5	1.0	0.94	27.5	1.0	-	3.3	5.0	3.5
CV (%)		2.8	17.3	20.0	10.8	7.83	34.5	14.8	-	67.5	63.3	59.5

[1]Transplanted 2 May 2003 at AVRDC.

Table 51. *Instrument analyses of fruit constituents in entries of ISPN5.*[1]

Entry	Name	Solids (%)	Sugars (%)	Vitamin C (mg/g)	β-cryptoxanthin (μg/g)	β-carotene (μg/g)
ISPN5#1	HDA249/Milord	7.5	3.6	153	0.08	0.10
ISPN5#2	75-3-4-4-1-BK/BruinsmaWonder	7.2	2.5	148	0.13	0.21
ISPN5#3	Andalus-seln	-	-	-	-	-
ISPN5#4	F1 Camelot/97-7585-3//98-5143	7.3	3.1	114	0.20	0.38
ISPN5#5	HDA249/BruinsmaWonder//Jin's Gold	8.3	3.3	127	0.42	0.82
ISPN5#6	BruinsmaWonder//YoloY/34-6-7-1-1-Bk	7.8	3.1	158	0.09	0.17
ISPN5#7	Milord	7.7	3.3	174	0.17	0.28
ISPN5#8	GoldenBell-seln	7.4	3.3	141	0.02	0.27
ISPN5#9	Tao-Yuen Dark Red#1	7.5	3.2	170	0.45	0.92
ISPN5#10	T52/PBC841//ECW-20R	5.7	2.2	137	0.01	0.03
ISPN5#11	HDA249/Milord//PR300-7seln (hybrid check)	8.0	3.4	158	0.14	0.35
ISPN5#12	Andalus (hybrid check)	8.0	3.6	166	0.05	0.16
Mean of all entries		7.5	3.1	150	0.20	0.30

[1]Fruit sampled from trial transplanted 25 March 2003 at AVRDC.

Table 52. *Disease resistance in ISPN5 entries, 2002–2003.*

Entry	Name	CMV	ChiVMV	PVY	ToMV	PC1	Bacterial spot reactions[1]				
		(% resistant plants)[2]					P1	P2	P3	P7	P8
ISPN5#1	HDA 249/Milord (inbred ck)	17	0	100	0	25	6.5	6.5	7.0	6.8	5.8
ISPN5#2	75-3-4-4-1-BK/BruinsmaWonder	0	0	0	0	0	6.3	7.2	5.7	6.3	5.0
ISPN5#3	Andalus-seln	0	0	100	0	0	7.0	7.7	7.3	7.7	6.0
ISPN5#4	F1 Camelot/97-7585-3/98-5143	0	0	0	0	0	7.0	3.6	5.2	4.8	4.3
ISPN5#5	HDA249/BruinsmaWonder/ Jin's Gold	0	0	0	0	0	6.7	6.8	6.7	5.5	5.5
ISPN5#6	BruinsmaWonder/YoloY/ 34-6-7-1-1-Bk	0	0	0	0	0	7.3	7.0	7.5	6.7	5.3
ISPN5#7	Milord (check)	0	0	100	0	92	7.8	7.7	7.5	6.8	6.0
ISPN5#8	Goldenbell-seln	0	0	0	0	8	5.0	4.0	4.5	3.3	5.7
ISPN5#9	Tao-Yuen Dark Red#1	0	0	0	0	0	6.8	7.0	7.8	6.5	5.8
ISPN5#10	T52/PBC 841/ECW-20R	0	0	0	0	8	7.3	7.0	8.0	7.5	6.6
ISPN5#11	HDA249/Milord// PR300-7seln (hybrid check)	0		100	0	100					
ISPN5#12	Andalus (hybrid check)	0	0	100	0	32	8.2	8.3	8.7	8.0	5.3

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

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

solids. Nevertheless, in a few traits, some inbreds are competitive with hybrids, e.g. in the percentage of total fruit that are marketable (ISPN5#5 and 9), fruit wall thickness (ISPN5#6, 7, and 9), fruit size (ISPN5#3 and 6). Two lines (ISPN5#7 and 9) exceeded the hybrid checks in vitamin C content; and two others (ISPN5#5 and 9) measured comparatively high in carotenoids (Table 51).

As we continue to evaluate new materials in our sweet pepper breeding program, we are reminded of the impact of season and location on performance of this crop. Evaluation over several years and weather conditions is necessary to identify superior varieties. While inbreds still generally fall short of our hybrid checks, we are gratified that a hybrid combination generated at AVRDC (ISPN5#11) has proven comparable to the commercial check Andalus in yield potential. Numerous cross combinations among our advanced sweet pepper lines are being evaluated for their potential to generate superior hybrid vigor and stability across environments. Interested cooperators are encouraged to join with the AVRDC Pepper Unit in gathering information regarding response of a defined set of genotypes across a broad array of environmental conditions so that strategies to improve adaptation and yield stability can be implemented.

Development of anthracnose-resistant lines

In order to accelerate progress toward commercially useful pepper varieties with high levels of resistance to anthracnose, improved screening methodologies are needed, as well as a clearer understanding of the mode of inheritance of the resistance. Molecular analysis is currently the most attractive strategy to achieve these goals, and a mapping population has been constituted to address these objectives. The actual molecular analysis is still in progress, and will be reported elsewhere. Findings based on the underlying breeding work are presented here.

The cross IR/PBC932//3*IR///'Susan's Joy' (CCA5239) is being used as a mapping population to develop molecular markers to allow selection for resistance to anthracnose at the seedling stage, rather than needing to wait for immature fruit to be assayed under tedious, expensive, and error-prone conditions. This cross is the result of an initial interspecific cross between *Capsicum annuum* and *C. chinense*, which required embryo rescue to permit a series of three sequential backcrosses with the same *C. annuum* parent. The recurrent parent, 'IR', was one of several parents tested for compatibility in interspecific combinations; it is also resistant to bacterial wilt and tolerant

of high temperatures. Anthracnose resistance was evaluated in 187 BC_3F_2 families, and one highly resistant individual was selected. Progenies of this selection have been made available to other researchers, and they have become the basis of an energetic effort to incorporate anthracnose resistance into commercially attractive pepper backgrounds.

Resistance was reconfirmed in the BC_3F_3, and a cross was made with a BC_3F_4 parent plant. The susceptible parent 'Susan's Joy' was chosen because of its large fruit, high yield potential, and high level of susceptibility to anthracnose infection. Evaluation of anthracnose resistance followed the methodology developed by the AVRDC Mycology Unit. Briefly, mature green fruit are injected with a carefully adjusted inoculum density of a single spore culture of *Colletotrichum acutatum*, using a device that limits penetration to 0.75 mm, and the volume of suspension to 1µl, effectively depositing about 500 spores of the pathogen. Each fruit is inoculated at two locations. Inoculated fruit are maintained for 6 days in a room providing 25°C and 95% RH. Diameter of each lesion is then measured and reported in millimeters.

Preliminary frequency distributions of average lesion diameter in the 2 parents, 20 F_1 plants and an F_2 population of more than 250 plants portray a relatively simple inheritance pattern with a major dominant factor for resistance, modified by some additive effects (Fig. 12). Almost 10% of the F_2 plants correspond to the same range of lesion diameter as the resistant parent, while nearly half fall within the range defined by the F_1; there is substantial overlap, but no F_1 plant showed the very small lesion size (less than 2 mm average diameter) of the best resistant parent expression. A second peak in frequency distribution corresponds to the range of expression of the susceptible parent, but there still remain almost one-third of the segregates that had average lesion diameters intermediate between the susceptible parent and the resistant parent/hybrid ranges.

Based on the results of initial screening, some 79 plants, all with average lesion diameters less than 3.0 mm, and 50 plants with the largest average lesion diameters (9–13 mm) were chosen as the basis for amplified fragment length polymorphism (AFLP) characterization of the molecular control of resistance. To confirm measured results from the initial series of assays on the F_2 plants segregating for resistance to anthracnose, new fruit were harvested from selected individual plants, and reassayed using the same protocol as developed by the Mycology Unit at AVRDC. The resistant parent in initial tests averaged 0.9 ± 0.6 mm, compared to 3.6 mm in repeat evaluation. The susceptible parent, 'Susan's Joy', averaged 10.6 ± 0.6 mm in initial tests, and 10.2 in repeat assay. The F_1 plants of this cross produced an average lesion diameter of 7.7 mm ± 10.4 upon retesting, or an intermediate-susceptible reaction. In initial tests, the hybrid, with 12 plants tested, averaged 2.7 ± 1.1 mm lesion diameter, a resistant reaction.

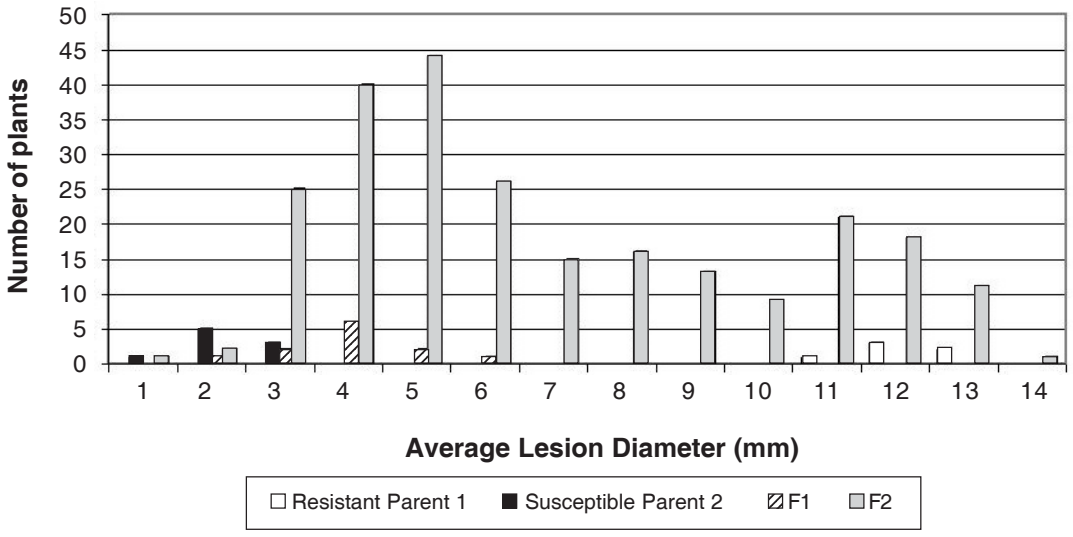

Fig.12. *Frequency distribution of average lesion diameter on mature green fruits in anthracnose mapping population parents, F_1, and F_2 generations.*

Forty of the initially nominated resistant F_2 plants repeated their performance of having average lesion diameters of 3.0 mm or less. Thirty-eight plants produced average lesion diameters between 3.0 and 6.0 mm. Only two produced average lesion diameters greater than 7.0 mm and these had initial lesion diameter results of 2.90 and 0.27 mm in initial readings. At the other extreme, only one of the fifty F_2 plants initially chosen to represent the susceptible reaction category produced results in the resistant class on repeated assay. In general, average lesion diameters of plants initially classified as susceptible were smaller on retest (1.4 ± 1.4 mm smaller). On the other hand, average lesion size of 'resistant' selections was generally larger (0.8 ± 1.3 mm larger) upon reassay than in the original screening results.

The inherent noisiness of the phenotypic assay procedure suggests that highly repeatable measures of the resistance genotype will be impossible under the current state of the assay methodology. The sources of this noise are not clear, but have been shown to be associated with the position on the fruit of the inoculation site (distal vs. proximal), the age of the fruit, and the developmental maturity of the fruit (green vs. red). These results emphasize the need for a precise molecular assessment of the genotype, so that plants that embody the highest level of potential resistance can be reliably identified and retained. The initially selected subsets can be reduced to the best 20–30 of the resistant and susceptible classes for purposes of processing the AFLP molecular marker data. This repeat of the assay on these entries has been useful in that it has identified a number of individuals that were erroneously characterized in the first sets of assays, and has revised our interpretation regarding the relative dominance of the character in the hybrid F_1 generation.

While the micro-injection inoculation procedure provides the most quantitative measurement of susceptibility or resistance to anthracnose in peppers, it is still subject to large amounts of variation. A controlled injection of spore suspension through the fruit cuticle allows for the host tissue to react to the germinating pathogen. Over the course of several days, an enlarging, more or less circular lesion may develop, sometimes with distinctive morphological features. Current assay procedures measure the diameter of these lesions after 6 days of incubation, and a given individual plant phenotype of disease severity is characterized by the average lesion diameter. Maturity of the tested fruit and position of the inoculation on the fruit can have large and unpredictable impact on the individual lesion data, and high variances in the resultant calculated average response. Further detailed investigations of the interactions between host and pathogen are warranted, but we also need to improve our screening process to allow more materials to be evaluated at a lower unit cost of labor and facilities.

Some researchers have utilized a measurement of 'disease incidence' in which a numerical percentage of fruit producing lesions greater or less than a determined threshold size is used to evaluate entries. This approach was considered for purposes of breeding and determining the limits of these phenotypes' precision. Fig. 13 presents a graph of the phenotypes of the parents, F_1 and 250 F_2 plants of the anthracnose mapping population discussed above, characterized according to the disease severity or disease incidence. The susceptible and resistant parents were clearly defined under either characterization, while the F_1 plants showed a great range according to the disease incidence rating scale. In contrast, they were fairly uniform according to the disease severity scale. The F_2 generation displayed a bimodal distribution under the disease severity scale; under a measure of disease incidence, the vast majority of plants were classified as susceptible and very few displayed the low incidence levels typical of the resistant parent. Simultaneous presentation of the data using both metrics has been helpful in that individual plants displaying both low percentages of symptomatic disease expression (incidence) and average lesion diameters (severity) are most likely to carry the highest concentration of genetic resistance factors, and hence make useful selections for generation advance, reselection, and more detailed analysis.

Field screening

Excellent progress has been made in the past several years in refining a laboratory assay method to evaluate anthracnose resistance in pepper fruit. In the meantime, however, less focus has been placed on field evaluations of candidate lines and selections. It is important to calibrate the lab assay results with real field disease reactions. In 2003, we established a field nursery to compare the disease reactions of an array of pepper genotypes that had been identified in the past as carrying good field resistance, as well as lines identified as resistant using the laboratory procedure, lines utilized in anthracnose resistance breeding tasks, and

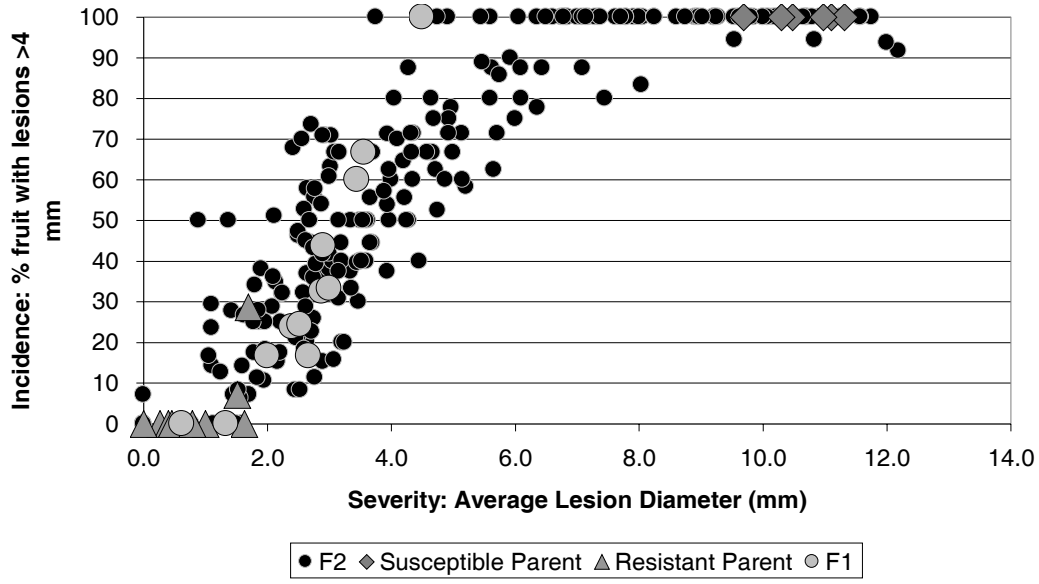

Fig. 13. *Disease incidence vs. severity in anthracnose mapping population parents, F1, and F2 generations.*

reference lines from several cooperating countries. The varieties PBC612 (Banglen), PBC550 (LV1592), and PBC613 (Praepadaeng) displayed 1.5, 3.2, and 2.3% symptomatic fruits in a replicated field trial in 1994. Sixty entries were included in this nonreplicated trial, which included border rows of a susceptible variety on one side of all of the test plots. Twelve plants of each entry were established. Only the susceptible border rows were sprayed with a suspension of *C. acutatum*, and infection of the test materials was left to natural agents of air, water, and mechanical transfer of spores from infected plants to adjacent subject plants. Inoculum was sprayed on the border rows weekly starting at the beginning of flowering, and continued for four weeks. Fruit in the trial plots were harvested eleven times, at weekly intervals between 11 August 11 and 20 October. At each harvest, all red fruit were harvested, as well as any immature fruit that showed symptoms of anthracnose infection. The percentage of total fruits free of symptoms in each harvest was calculated, and results for seven representative entries of inbred lines is displayed (Fig. 14.)

Despite intensive inoculation of the border rows, which continued until slightly before the second harvest, infection of the fruit in the test materials was slow to develop, even though rainy, humid and warm conditions prevailed beginning the week prior to the first harvest. A heavy rainfall occurred on 5 August, and was followed at approximately 8-day intervals with lighter showers, averaging 5–20 mm per day, until late September. Relative humidity increased during this period from 60–70% in July, to 70–85% from mid August until mid September, when it returned to a more moderate 60–70%. Maximum day temperatures remained in the mid 30s throughout August and September, and began moderating in October. Under the favorable conditions of high temperature and high humidity, materials became progressively more severely infected, including the most resistant lines. Subsequently, as weather conditions became less conducive (lower humidities and temperatures began in late September, at about the time of the seventh harvest), the severity of the natural infection receded. It is not known for certain why disease incidence declined in October, although the simultaneous decline in relative humidity and mean temperature may have reduced the aggressiveness of the inoculum.

Table 53 presents the results of this natural exposure on inbred lines included in this study, and generally confirms the validity of laboratory assays of resistance, but challenges earlier field rankings. For instance, of the three accessions noted in 1994 as having a very low incidence of diseased fruit, one (PBC550 [LV1592]) produced a very low level of incidence in this trial, while one (PBC613 [Praepadaeng]) produced an intermediate reaction, and one (PBC612 [Banglen]) was highly susceptible, with over 90% of harvested fruit showing disease symptoms. The two lines identi-

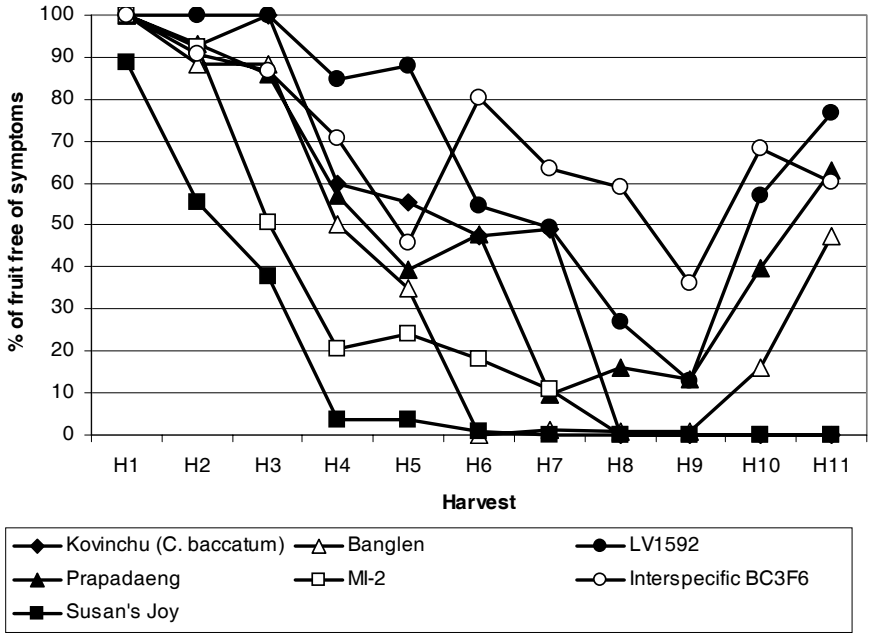

Fig. 14. *Anthracnose incidence on field-grown pepper lines exposed to high environmental concentrations of* Colletotrichum acutatum *spores.*

fied by the AVRDC Mycology Unit as carrying high levels of resistance, PBC 81 (*C. baccatum*) and PBC 932 (*C. chinense*), delivered less than 15% disease incidence, albeit with very low fruit numbers produced. With only one exception, all entries that derived some parentage from the *C. chinense* accession PBC932 produced at least 50% symptom-free fruit.

Differences in intrinsic disease resistance in genotypes tested in this trial are confounded by the noted variation in infection rates as affected by weather and the relative earliness of the varieties. For example, the entry Jatilaba scored well in this test, but primarily because it produced the majority of its fruit during the first several harvest weeks, when natural disease incidence was fairly low. The line produced few fruit later in the trial, when disease pressure was greater—virtually all of those fruit showed disease symptoms. Similarly, the very high levels of resistance found in *C. baccatum* and *C. chinense* accessions cannot be used directly, at least in the environment encountered in Taiwan, because of the very poor productivity of the lines. They have, nevertheless, proven to be effective donors of resistance to better adapted lines, through interspecific crosses and selection.

Additionally, a series of progenies from the best F_2 individuals of the anthracnose resistance mapping population were also grown out under the same field conditions. Table 54 presents the data from these F_3 families, along with related advanced lines from AVRDC's most current resistance breeding program. The average lesion diameter of the source F_2 plants, as assayed under laboratory conditions, is also presented for reference. It is quickly noted that the cumulative percentage of non-symptomatic plants in these families is fairly low. This is interpreted to indicate that the families are still segregating for resistance, which is to be expected if the resistance is conditioned by two or more genes. All of the selected F_3 families derived from F_2 plants with average lesion diameters ranging from 0 to 2.0 mm (indicates high levels of resistance) produced progeny disease incidence percentages ranging from 60 to 91%. Clearly some of these pedigrees are more promising than others. Selected plants from these families have been evaluated, and some have been advanced in other trials through the F_4 generation with continuing laboratory reassay for disease severity of the most promising individual selections.

The labor required to repeatedly harvest and grade all fruit produced on individual segregating plants over a long harvest season is prohibitive, and bulk harvests mask the individual plant differences to be found in heterogeneous families. Field evaluations such as this may be appropriate to identify superior families that warrant careful evaluation of individual plants, but are

Table 53. *Productivity and incidence of anthracnose disease symptoms in 32 selected pepper lines.*[1]

Entry	Fruit (no.)	Incidence (%)
Pan Family Large Cayenne (Pan Jia Da4 La4 Jiau)	932	98.4
PBC 546 (Poblano)	290	94.5
West River 1 (He2 Xi1 Zhau3) (from China)	2162	94.0
PBC 612 (Banglen)	4989	91.6
Phichit 1 (from Thailand)	2857	90.3
PBC 599	680	89.0
Pusa Jwala (from India)	3269	88.9
PBC 460 (KA-2)	3601	85.6
Tit-Super (from Indonesia)	2256	85.4
ICPN7#3 (Taiwan 83-168-1-1)	6560	84.6
PBC 1430 (Pasilla Apaseo)	63	84.1
0038-9250-1 (Kulai*3/PBC932)	346	82.9
Si Sa Ket 1 (from Thailand)	3133	82.5
KR-Bogor (from Indonesia)	2613	82.0
PBC 462 (MI-2)	3149	81.7
UF8752	514	77.2
G-4 (from India)	4637	76.4
PBC 1439 (Ancho Mulato)	83	74.7
Jatilaba (from Indonesia)	4143	63.9
PBC 613 (Prapadaeng)	2770	62.8
PBC 1478 (Pasilla)	86	59.3
0038-9155-5-1 (IR*3/PBC932 (BC3F6))	823	57.5
0030-773-03 (PBC932/Tumpang)	553	55.0
PBC 615 (Matikas)	221	52.9
PBC880 (Kovinchu [*C. baccatum*])	369	52.8
0038-9250-4 (Kulai*3/PBC932)	346	52.0
PBC 550-a (LV1592)	1923	40.2
0038-9153-1 (IR*3/PBC932 (BC3F5))	1446	39.4
0038-9153-2 (IR*3/PBC932 (BC3F5))	896	38.4
PBC 81 (Jin's Delight [*C. baccatum*])	29	13.8
PBC 932 (*C. chinense*)	17	11.8
0030-772-09-b ('((IR/PBC932-2)//IR) BC1F7)	1439	8.0

[1]Trial was harvested 11 times between 11 August and 20 October 2003 at AVRDC.

Table 54. *Reactions of superior F_2 plants to natural field inoculation and artificial laboratory inoculation of anthracnose (*C. acutatum*) spores.*[1]

	Field		Lab
Entry	Fruit (no.)	Incid. (%)	Lesion (mm)
0038-9155-5-1(IR/PBC932//3*IR) BC3F6	823	57.5	0.9
0038-9153-1(IR/PBC932//3*IR) BC3F5	1446	39.4	3.9
0038-9153-2 (IR/PBC932//3*IR) BC3F5	896	38.4	3.3
PBC 81 (*C. baccatum*)	29	13.8	5.1
PBC 932 (*C. chinense*)	17	11.8	0.3
9955-15 (Susan's Joy)	2031	89.3	10.5
CCA5239-2-021 (IR/...Susan's Joy) F3[2]	1237	59.3	1.3
CCA5239-2-122 (IR/...Susan's Joy) F3	1073	75.9	1.1
CCA5239-2-011 (IR/...Susan's Joy) F3	791	77.4	1.8
CCA5239-2-037 (IR/...Susan's Joy) F3	597	77.6	0
CCA5239-2-048 (IR/...Susan's Joy) F3	1641	79.2	1.3
CCA5239-2-103 (IR/...Susan's Joy) F3	1807	79.8	1.5
CCA5239-2-028 (IR/...Susan's Joy) F3	1312	80.4	2
CCA5239-2-117 (IR/...Susan's Joy) F3	1384	80.4	1.6
CCA5239-2-069 (IR/...Susan's Joy) F3	1049	80.6	1.1
CCA5239-2-039 (IR/...Susan's Joy) F3	408	82.1	1.6
CCA5239-2-023 (IR/...Susan's Joy) F3	114	82.5	1.1
CCA5239-2-139 (IR/...Susan's Joy) F3	2003	83.9	1.5
CCA5239-2-065 (IR/...Susan's Joy) F3	675	84.9	1.4
CCA5239-2-132 (IR/...Susan's Joy) F3	1327	85.4	2
CCA5239-2-022 (IR/...Susan's Joy) F3	1840	86.7	1.8
CCA5239-2-163 (IR/...Susan's Joy) F3	1398	86.7	0.8
CCA5239-2-221 (IR/...Susan's Joy) F3	2087	86.8	1.8
CCA5239-2-081 (IR/...Susan's Joy) F3	832	87.5	1.5
CCA5239-2-030 (IR/...Susan's Joy) F3	1387	87.8	2
CCA5239-2-080 (IR/...Susan's Joy) F3	584	87.8	1.7
CCA5239-2-145 (IR/...Susan's Joy) F3	1926	88	1.1
CCA5239-2-155 (IR/...Susan's Joy) F3	1181	88.1	1.1
CCA5239-2-032 (IR/...Susan's Joy) F3	2189	88.6	1.6
CCA5239-2-230 (IR/...Susan's Joy) F3	1697	88.7	1.9
CCA5239-2-141 (IR/...Susan's Joy) F3	1226	89.7	0.9
CCA5239-2-180 (IR/...Susan's Joy) F3	2009	90.6	1.9
CCA5239-2-235 (IR/...Susan's Joy) F3	1809	91	1.8
CCA5239-2-137 (IR/...Susan's Joy) F3	1024	92.7	1.6
CCA5239-2-067 (IR/...Susan's Joy) F3	1108	93	1.6
CCA5239-2-116 (IR/...Susan's Joy) F3	2177	95.5	1.9

[1]All plants are derived from the cross CCA5239 "IR/PBC932//3*IR///Susan's Joy"

[2](IR/...Susan's Joy) = (IR/PBC932//3*IR BC3F5/Susan's Joy)

not practical for direct evaluation of large numbers of individual plants. Focused screening of sampled tissue from plants, whether through inoculation of harvested fruit or molecular marker evaluation of DNA extracted from leaf tissue, will continue to be the preferred method to make breeding progress. It remains important, on the other hand, to continue to verify correlation between laboratory assays for measures of disease resistance with actual field results in genetically uniform, advanced lines. This study has provided a general validation of the value of our current laboratory assay methods, but has also emphasized the imprecision of those methods measuring the potential resistance of a genotype. Repeated assays from generation to generation, and across several environmental regimes can help to confirm resistance.

New breeding materials with resistance to anthracnose in *Capsicum annuum*

The marketable yield of pepper is reduced by infections of anthracnose (*Colletotrichum* spp.), late blight (*Phytophthora capsici*), viruses, and other diseases. Although the breeding lines KAR and PBC 81 (*Capsicum baccatum*) and PBC 932 (*C. chinense*) are used as materials for breeding varieties resistant to anthracnose, it is difficult to transfer the resistance gene from C. *baccatum* to *C. annuum* due to cross incompatibility and poor horticultural characteristics. New breeding materials with high cross-compatibility and good horticultural traits are needed to develop varieties resistant to anthracnose. This experiment was conducted to find new materials with resistance to anthracnose.

For evaluation of resistance to anthracnose, four accessions were selected from a plot managed by the AVRDC Genetic Resources and Seed Unit (Table 55). Five fruits from each of 24 or 30 plants per accession were used. Fruits tested for anthracnose were at the intermediate stage between immature and mature stage. Accessions were arranged in completely randomized design (CRD).

Table 55. *Passport data of new sources of resistance to pepper anthracnose identified from the germplasm at AVRDC.*

Accession	Code	Species	Pedigree	Origin
TC06903(R95)	PBC1430	*C. ann.*	Apaseo Pasilla	Mexico
TC06912(R97)	PBC1439	*C. ann.*	Ancho Mulato	USA
TC06941(R102)	PBC1478	*C. ann.*	Pasilla	Australia
TC06842(139)	PBC880	*C. bac.*	PBC880	Mexico

A *Colletotrichum acutatum* isolate, Cg 153, was multiplied on potato dextrose agar (PDA) medium. Inoculum of 5×10^5 conidia/ml was injected into fruit walls at two parts of each fruit using a 0.75-mm-long, 22-gauge needle. Inoculated fruits were kept at 25 ± 2°C and about 90% relative humidity (RH) in an inoculation room. The disease symptoms were recorded five days after inoculation. The degree of disease incidence on fruits was evaluated based on diameter of the lesion.

New materials resistant to anthracnose were identified in *C. annuum* during routine regeneration of *Capsicum* germplasm at AVRDC. A total of eleven plants from four heterogeneous populations were selected as resistant to anthracnose. The accessions showed within accession variation based on reaction to *C. acutatum*.

Average lesion size of the heterogeneous population was higher than for the resistant check, KAR, and lower than that of the susceptible check, Long Fruit (LF). Average lesion size of individual resistant plants within an accession, however, were similar to KAR (Table 56).

Resistance was shown by 10–17% of the plants of accessions Apaseo Pasilla (TC06903), Ancho Mulato (TC06912) and Pasilla (TC06941) (Figs. 15–17), while 50% of the plants of *C. baccatum* TC06842 showed resistance. Apaseo Pasilla, Ancho Mulato, and Pasilla have a chlorophyll retainer gene and large fruits. Eleven plants from four accessions were selected as resistant to anthracnose (Table 57). All resistant plants of Apaseo Pasilla and Pasilla, both *C. annuum* and TC06842, *C. baccatum*, showed the resistance reaction at all fruit stages. Ancho Mulato, however, showed resistance reaction only at the green fruit stage (Fig. 17).

Table 56. *Selection of plants resistant to anthracnose from germplasm at AVRDC.*

Entry	Plants inoculated (no.)	Resistant plants (<4 mm) Avg lesion (no.)	Resistant plants (<4 mm) Avg lesion diam (mm)	Susceptible plants (>4 mm) Avg lesion (no.)	Susceptible plants (>4 mm) Avg lesion diam (mm)	Overall resistant plants (%)	Overall avg lesion diam (mm)
TC06903 (R95)	30	5	3.5	25	6.7	17	6.2 b[1]
TC06912 (R97)	30	3	2.8	27	7.8	10	7.3 b
TC06941 (R102)	24	3	3.7	21	7.7	13	7.2 b
TC06842 (R139)	30	15	2.3	15	5.7	50	4.0 c
KAR (resistant ck)	3	3	4.3	-	-	-	4.3 c
LF (susceptible ck)	3	-		3	11.0	-	11.0 a

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

Fig. 15. *Selection from R95 (Apaseo Pasilla) showing resistance to anthracnose.*

Fig. 16. *Selection from R102 (Pasilla) showing resistance to anthracnose.*

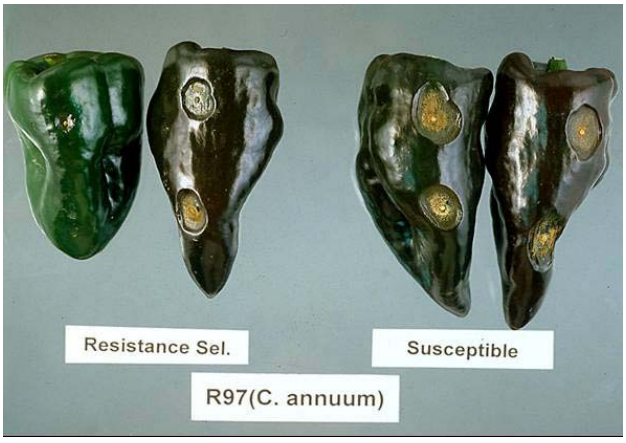

Fig. 17. *Selection from R97 (Ancho Mulato) showing resistance to anthracnose only in the immature stage (far left fruit).*

Table 57. *Selection of anthracnose-resistant individual plants within accessions.*[1]

Entry	Species	Plants (no.)	Lesion (mm)	Resistance[2]
TC06903(R95)	*C. annuum*	1	3.5 bc[3]	All stages
		11	3.8 bc	
		15	3.1 bcd	
TC06912(R97)	*C. annuum*	4	4.8 b	Green fruit
		15	2.4 bcd	
		16	2.5 bcd	
TC06941(R102)	*C. annuum*	1	4.0 bc	All stages
		4	3.6 bc	
		7	3.6 bc	
TC06842(R139)	*C. baccatum*	9	0.4 d	All stages
		29	1.2 cd	
KAR (res ck)	*C. baccatum*	-	4.3 b	All stages
Long Fruit (sus ck)	*C. annuum*	-	11.0 a	None

[1]Selection was done 10 days after inoculation.
[2]Investigation was done 5 days after inoculation.
[3]Mean separation within rows by Duncan's multiple range test at $P \leq 0.05$.

Effect of fruit age on expression of resistance to anthracnose

The objective of this study was to identify the effect of fruit age on the expression of susceptibility and resistance to anthracnose in pepper. Twelve varieties were used in this experiment. According to previous studies, PBC81, KAR and PBC 932 were resistant at all fruit ages; PBC1395, C04419 and PBC912 were moderately resistant only at green fruit stage; and Long Fruit, PBC972, PBC535, C96085, PBC1422 and C04714 were susceptible at all fruit ages. Seeds of different varieties were sown on 22 October and transplanted (10 plants each planted in 25-cm-diameter pots) in the greenhouse on 28 November 2002.

Each flower was labeled at blooming time. Fruits were detached at 3, 5, 6, and 7 weeks after flowering and were inoculated. A *Colletotrichum acutatum* isolate, Cg 153, was multiplied on potato dextrose agar (PDA) medium. Inoculum of 5×10^5 conidia/ml was injected into fruit walls using a 0.75-mm-long, 22-gauge needle on 16 April 2003. Experimental units of five fruits from each of 12 cultivars for each fruit age of the five categories were evaluated in four replications. Each fruit was inoculated at two positions. The units were laid out as a two-factor factorial in a RCBD with four replications. The two factors are fruit age and cultivar. Inoculated fruits were maintained at 25 ± 2°C and about 90% RH in an inoculation room. The disease symptoms were recorded 5 days after inoculation. The degree of disease incidence on fruits was evaluated based on diameter of the lesion.

The expressions of symptoms for different fruit ages and varieties are presented in Table 58. Despite a significant level of error, significant differences were detected among fruit ages, varieties and the interaction between fruit age and cultivar (Table 59) using the microinjection inoculation method.

Table 59. *Analysis of variance.*

Source	df	Mean squares
Rep	3	6.8050^{NS}
Fruit age (A)	4	50.6004**
Cultivar (C)	13	109.3611**
A × C	51	20.4385**
Error	192	3.6200**
Total	263	

$^{NS, *, **}$Nonsignificant and significant at $P < 0.05$ and 0.01, respectively.

Table 58. *Symptom expression in varieties inoculated with* C. acutatum *using microinjection as influenced by fruit ages.*

	Age of fruit (weeks)					
Cultivar	3	4	5	6	7	Mean
Resistant in all fruit stages (RR)						
PBC81	6.23 c[1]	7.45 bcd	6.78 cd	6.28 ef	5.00 fg	6.35
KAR	0.33 d	2.95 ef	5.73 cd	10.03 abc	5.98 efg	5.00
PBC932	0.33 d	0.33 f	0.48 e	4.48 f	3.75 g	1.87
Mean	2.30	3.58	4.33	6.93	4.91	4.41
Resistant in green fruit stage (RS)						
PBC1395	5.98 c	6.15 cde	6.53 cd	9.63 a-d	9.95 bcd	7.65
C04419	6.75 bc	4.75 de	8.53 abc	9.80 a-d	6.03 efg	7.17
PBC912	3.78 c	3.50 e	7.78 bcd	12.48 a	7.87 c-f	7.08
Mean	5.50	4.80	7.61	10.63	7.95	7.30
Susceptible at all stages (SS)						
Long Fruit	10.75 a	11.65 a	10.50 ab	10.85 ab	10.58 abc	10.87
PBC972	9.43 ab	3.90 e	4.80 d	6.55 def	13.70 a	7.68
PBC535	10.30 a	10.58 ab	10.45 ab	10.85 ab	11.35 ab	10.71
96085	10.10 a	9.20 abc	8.40 abc	6.20 ef	6.85 d-g	8.15
PBC1422	6.60 bc	8.00 bcd	8.35 abc	6.83 c-f	8.08 b-f	7.57
C04714	11.23 a	10.08 abc	11.35 a	7.88 b-e	9.10 b-e	9.93
Mean	9.73	8.90	8.98	8.19	9.94	9.15

[1]LSD (5%) = 1.51 to compare RR and RS means at each age. LSD (5%) = 1.83 to compare RR and SS means, or RS and SS means at each age. Mean separation in each column by Duncan's multiple range test at $P \leq 0.05$.

The severe symptom in most cultivars appeared at 6 or 7 weeks after flowering at which time the fruit color changed from green to red. Differences in severity between resistant and susceptible materials were larger at the immature stages, especially about 4 weeks after flowering. PBC 932 displayed a resistant reaction at all fruit stages, including green fruit stage. KAR is a material selected in Korea for resistance to *C. gloeosporiodes*; in this microinjection methodology it was highly resistant at the red fruit stage to *C. gloeosporiodes* but somewhat less resistant to *C. acutatum*.

Comparison of inoculation methods for anthracnose screening

The objective of this study was to identify the anthracnose disease reactions of susceptible and resistant pepper accessions based on different inoculation methods. Previous studies have shown that PBC81, KAR and PBC 932 are resistant to anthracnose at all fruit ages, PBC1395, C04419, PBC879 and PBC912 show moderate resistance at only the green fruit stage, and Long Fruit, PBC972, PBC535, C96085, PBC1422, PBC1425 and C04714 are susceptible in all fruit ages. Seeds of these accessions were sown on 22 October and transplanted (10 plants each in 25-cm-diam pots) in a greenhouse on 28 November 2002.

Fruits at a stage of maturity between immature and mature ripeness, which is about 5 weeks or 6 weeks after flowering depending on the particular maturity of each accession, were inoculated on 16 April 2003. A *Colletotrichum acutatum* isolate, Cg 153, was multiplied on potato dextrose agar (PDA) medium. For microinjection method, inoculum of 5×10^5 conidia/ml was injected into fruit walls using a 0.75-mm-long, 22-gauge needle. Each fruit was inoculated at two locations. The other inoculation method used high-pressure (2 kg/cm^2) spray applied to the whole fruit with inoculum Cg 153 of 10^7 conidia/ml. Experimental units of five fruits from each of 14 varieties for each inoculation method were evaluated. The units were laid out as a two-factor factorial in RCBD with four replications. The factors were inoculation method and variety. Inoculated fruits were maintained at 25 $\pm$ 2°C and about 90% RH in an inoculation room.

For fruits treated with the microinjection method, the degree of disease incidence was evaluated on the basis of lesion diameter found 5 days after inoculation. For fruits treated with the high-pressure spray inoculation, the severity of symptoms was evaluated using an index from 1 (highly resistant) to 9 (highly susceptible) 10 days after inoculation. To compare the two inoculation methods, lesion diameter measured in microinjection method was expressed in terms of corresponding with the disease index.

There was no significant difference between the two inoculation methods (Table 60). Most of the susceptible varieties, however, showed more severe symptoms with the high-pressure spray inoculation method (Table 61). Due to the large number of materials handled by the breeding program, the high-pressure method is more efficient than the microinjection inoculation method not only in saving labor but also distinguishing resistant from susceptible lines. KAR, which is resistant to anthracnose in the field, appeared to be susceptible when inoculated using microinjection

Table 60. *Analysis of variance.*

Source	df	Mean squares
Rep.	3	2.83564^{NS}
Inoculation (I)	1	2.593508^{NS}
Cultivar (C)	13	259.222251**
I × C	13	106.711839**
Error	80	26.864757**
Total	110	

$^{NS, *, **}$Nonsignificant and significant at $P \leq 0.05$ and 0.01, respectively.

Table 61. *Effect of different inoculation methods with* C. acutatum *in pepper.*

Entry	High pressure	Micro-injection	WD test[1]
PBC932 (RR)[2]	4.0 $\pm$ 2.6	2.0 $\pm$ 0.6	
PBC81 (RR)	3.3 $\pm$ 1.3	2.5 $\pm$ 2.4	
KAR (RR)	1.5 $\pm$ 1.0	6.3 $\pm$ 1.0	*
PBC1395 (RS)	3.0 $\pm$ 2.3	4.8 $\pm$ 1.7	
96085 (SS)	4.0 $\pm$ 1.2	3.3 $\pm$ 1.4	
PBC1422 (SS)	4.3 $\pm$ 1.2	5.3 $\pm$ 1.0	
PBC535 (SS)	3.0 $\pm$ 0.0	5.8 $\pm$ 1.0	*
CO4419 (RS)	5.5 $\pm$ 1.0	4.5 $\pm$ 1.0	
Long Fruit (SS)	5.5 $\pm$ 1.0	6.5 $\pm$ 1.0	
PBC1425 (SS)	6.5 $\pm$ 1.0	6.3 $\pm$ 1.3	
PBC879 (SS)	7.0 $\pm$ 2.3	7.3 $\pm$ 2.4	
PBC912 (RS)	8.0 $\pm$ 2.0	6.8 $\pm$ 1.7	
CO4714 (SS)	8.5 $\pm$ 1.0	4.3 $\pm$ 1.3	*
PBC972 (SS)	8.5 $\pm$ 1.0	7.3 $\pm$ 1.0	

[1]Significant differences between methods by Waller-Duncan test at $P \leq 0.05$.
[2]RR = resistant in all stages, RS = resistant in green stage, SS= susceptible in all stages.

method, while it had a resistant reaction with the high-pressure inoculation. The interaction between inoculation methods and varieties was significant, which indicates that the disease reaction of different varieties depends on the inoculation method.

Selection of improved breeding materials with resistance to Phytophthora blight in *Capsicum annuum*

Lines CM334, PI201234 and PI201232 (*Capsicum annuum*) are generally used as materials for breeding varieties resistant to Phytophthora blight, but these lines possess poor horticultural characteristics and are susceptible to numerous other diseases. This experiment was conducted to find improved breeding materials with resistance to Phytophthora blight.

For evaluation of resistance to Phytophthora blight, two individual plants of PBC602 were selected from a preliminary experiment and compared with sources of Phytophthora resistance and susceptibility determined by using a non-destructive screening method, which uses excised shoots from field. This screening method is very beneficial in breeding for multi-disease resistance, because we can observe horticultural traits in the progeny lines in the field without killing the plants after inoculation and we can check reactions of numerous diseases from a single plant without the worry of different diseases interacting on the sample plant.

In order to maintain freshness of the excised shoots for a period of time long enough for symptoms to develop fully, each shoot was placed on a sponge and the sponge was placed inside holes created in styrofoam sheets floating on flowing water in a hydroponics culture system (Fig. 18). Inoculum 10^5 zoospores/ml of race 1(Isolate Pc-1E) and race 3(Isolate pc-17E) was put into the sponge with 1 ml by using a needle. Treatment was arranged in a randomized complete design with two replications of five shoots per plant. The severity of symptom on shoots was evaluated using in-

Fig. 18. *Non-destructive inoculation method by using shoots to select for Phytophthora blight resistance.*

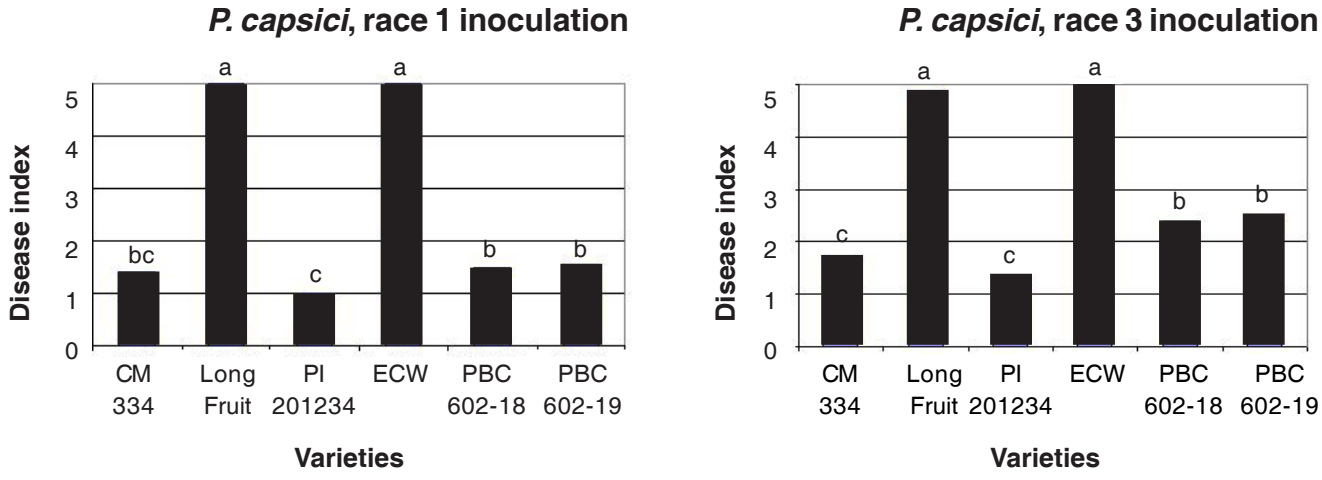

Fig. 19. *Reactions of inbred lines to inoculation of* Phytophthora capsici *races 1 (isolate Pc-1E) and 3 (isolate Pc-17E) using nondestructive inoculation method.*[1]

[1]Shoots were rated 5 days after inoculatoin using an index of 1 to 5 where 1 = highly resistant and 5 = highly susceptible. Means within lines for each inoculation group are separated using Duncan's multiple range test at $P \leq 0.05$.

Table 62. *Horticultural traits of Phytophthora-resistant inbred lines grown under field conditions at AVRDC.*

Accession	Species	Plant height (cm)	Plant growth habit[1]	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit color[2]		Phytophtora[3]		Virus[4] score	Anth.[4] score
							immat.	mature	class	(% dead)		
CM334	*C. annuum*	115.7 a[5]	6	3.9 ef	1.4 cd	1.8 ef	G	R	R	10.0 ab	3.0 c	5 c
ECW (sus ck)	*C. annuum*	56.7 f	5	4.8 ed	4.9 b	47.0 a	LG	R	S	23.3 ab	7.0 a	9 a
PI 188478	*C. annuum*	72.7 de	5	2.5 g	1.9 c	2.9 de	LG	LR	R	6.7 ab	7.0 a	9 a
PI 189550	*C. annuum*	85.0 b-d	6	3.3 fg	1.2 de	0.8 f	G	R	R	6.7 ab	7.0 a	8 ab
PI 201232	*C. annuum*	95.3 b	5	7.4 c	1.4 cd	4.3 cd	G	R	R	20.0 ab	7.0 a	8 a
PI 201234	*C. annuum*	81.7 cd	5	5.2 d	1.2 cd	4.5 cd	G	R	R	0.0 b	6.3 a	9 a
PI 201238	*C. annuum*	64.7 ef	4	9.0 b	1.8 c	4.3 cd	G	R	R	0.0 b	7.0 a	9 a
Fidel	*C. annuum*	127.7 a	6	3.4 fg	9.3 a	1.5 ef	G	O	R	0.0 b	7.0 a	6 bc
PBC602	*C. annuum*	89.0 bc	5	10.2 a	1.5 cd	9.4 b	G	R	R	0.0 b	3.7 c	6 bc
Perennial HDV	*C. annuum*	122.7 a	6	3.6 f	0.8 e	1.0 f	LG	R	R	0.0 b	3.0 c	7 ab
New Viking	C. annuum	126.7 a	5	11.0 a	1.6 cd	10.1 b	G	R	MR	0.0 b	5.0 b	8 a

[1]3 = prostrate, 5 = compact, and 7 = erect.
[2]G = green, LG = light green, LR = light red, O = orange, and R = red.
[3]MR = moderately resistant, R = resistant, S = susceptible.
[4]Rated on a scale of 1 to 9 with 1 = highly resistant and 9 = highly susceptible. Anth. = anthracnose.
[5]Mean separation in each column by Duncan's multiple range test at $P \leq 0.05$.

dex from 1 (highly resistant) to 5 (highly susceptible) 5 days after inoculation.

PBC602 showed resistance to Phytophthora in the laboratory (Fig. 19) and field (Table 62). Field testing with other Phytophthora-resistant lines showed that PBC602 produces relatively large-sized fruits and is less susceptible to viruses; however, it is susceptible to anthracnose. The highest level of resistance to Phytophthora races 1 and 3 was shown by PI201234.

Variation of antioxidants and their activity in a subset of the AVRDC *Capsicum* Core Collection

Although peppers are often prized for their color and pungency, they are also major sources of the provitamin A carotenoids β-carotene and β-cryptoxanthin, as well as vitamins C and E, all of which are also antioxidants. Pepper genotypes vary greatly in the types and densities of carotenoids, and levels of ascorbic acid, tocopherols and phenolics. The objectives of this study were to assess genetic diversity within a subset of the AVRDC *Capsicum* core collection for densities of antioxidants (AO) and antioxidant activities (AOA) and to estimate the association between AOA and specific AO and fruit components.

Forty-eight entries from the AVRDC *Capsicum* collection were included in the study of which 25 are listed in Table 63. Entries represented a wide range of origins, fruit colors, and levels of pungency. Entries were grown in AVRDC fields from October 2001–March 2002 and October 2002–March 2003. Entries were replicated twice and arranged in a RCBD. Plots included five plants in year one and ten plants in year two. Plants were staked. Fully mature fruit were harvested when most plants within plots had ripe fruit. Fruit were taken the same day to the laboratory for sample preparation.

About 300–500 g of fully ripened fruits per sample were used for analyses. Entries were assessed for AOA by the anti-radical power (ARP) and inhibition of lipid peroxidation (ILP) methods. Carotenoid and tocopherol contents were determined by high performance liquid chromatography (HPLC). Ascorbic acid and total phenolics contents were determined according to standard methods.

The two AOA assays (ARP, ILP) and eight AO (capsanthin, zeaxanthin, β-cryptoxanthin, β-carotene, ascorbic acid, α-tocopherol, γ-tocopherol, total phenolics) and dry matter were subjected to analysis of variance (ANOVA) with the SAS General Linear Model (GLM) procedure. For the ANOVA over years, year was regarded as a random effect, entry as a fixed effect, and the year × entry interaction mean square

was used to test the significance of the entry mean square and the linear contrasts. Nonindependent, single-degree-of-freedom contrasts were constructed to make comparisons among groups of entries. Entry means were separated by the Waller-Duncan test (k = 100 which is equivalent to $P = 0.05$). Linear correlations between characters were calculated with entry means averaged over years. The seven non-pungent entries (Table 63) were dropped before calculation of all correlations because plotting of means indicated they did not fit the trend of the other entries. Nose Gay, Verdano Poblano TY, Guajillo ancho, Paul Smith's Serrano, PI224706, PI441619 were dropped from correlations for ascorbic acid, α-tocopherol, and dry matter.

The AVRDC maintains one of the largest *Capsicum* collections in the world with about 7500 accessions from eight species and collected from 95 countries. The 48 entries in this study are members of AVRDC's *Capsicum* CORE1, a group of 196 accessions that were selected from a candidate pool of 1814 AVRDC *Capsicum* accessions and based primarily on morpho-horticultural characters. The entries in our subset included 36 *C. annuum*, 6 *C. chinense*, 5 *C. baccatum*, and 1 *C. frutescens*. Although CORE1 no longer represents the diversity present in the current AVRDC *Capsicum* collection, it is evident that much genetic diversity exists among this group of accessions for the nutrition-related traits evaluated in this study.

C. annuum variety market types are highly segmented according to intended use, pod type (shape, size, color), level of pungency, and regional preferences and origins. Thus we expected to find genetic differ-

Table 63. *Selected* Capsicum *accessions evaluated for antioxidant activity, antioxidants, and dry matter.*

Entry	Species	Pung.[1]	Fruit color	ILP[2] –TE (µmol/g)–	ARP[2]	Capsanthin (µg/g)	Zeaxant. (µg/g)	Cryptoxant. (µg/g)	β-caro. (µg/g)	Total Phen. (mg/g)	Ascorbic acid (mg/g)	α-tocopherol (µg/g)	γ-tocopherol (µg/g)	Dry matter (%)
P484/76	*annuum*	5	Orange	28.4	228.5	0	0	14	61	26.3	9.4	502	49	10
CAP178/77	*annuum*	0	Red	61.8	184.2	714	155	81	129	37.6	18.8	551	37	11
P161/82	*annuum*	7	Red	30.6	207.8	555	77	24	60	25.8	9.1	95	28	18
P454/82	*annuum*	0	Brown	30.2	103.5	852	147	159	179	20.7	7.2	882	23	13
Criollo de Morelos 331	*annuum*	0	Red	39.5	166.3	571	184	67	113	29.8	13.1	413	30	15
Mexico Serrano	*annuum*	5	Red	24.2	198.5	374	47	24	66	22.5	8.1	306	52	15
Agronomico 9 Lines	*annuum*	0	Red	53.0	139.1	614	136	65	102	32.4	16.7	423	21	10
Roque Mulato Poblano	*annuum*	3	Brown	32.1	160.2	555	263	58	91	28.2	14.7	466	22	18
Verdano Poblano TY	*annuum*	3	Red	42.1	153.8	1333	207	103	275	32.6	17.9	859	45	14
Guajillo ancho	*annuum*	5	Red	38.0	187.0	1585	213	128	292	29.5	14.8	759	55	20
PI414729	*annuum*	3	Red	33.9	181.5	1023	134	98	210	28.3	11.7	491	59	15
IBPGR58	*annuum*	7	Red	13.1	201.5	510	240	73	63	15.6	3.6	463	52	29
Nacional AG-506	*annuum*	0	Orange	57.4	158.3	0	0	37	50	36.5	21.0	427	17	10
Prapadaeng	*annuum*	5	Red	17.2	121.2	570	209	52	56	17.3	7.2	434	39	25
Lueng 4	*annuum*	7	Orange	24.3	174.7	0	0	62	111	24.7	10.6	405	20	19
CAB	*annuum*	7	Red	47.8	139.7	416	47	45	84	33.8	17.1	253	7	10
Pimenta	*baccatum*	5	Red	28.0	153.0	294	35	17	33	18.3	2.3	433	43	16
PI266041	*baccatum*	7	Red	22.1	165.6	372	110	34	42	19.8	2.9	377	68	17
PI441570	*baccatum*	7	Red	22.7	189.9	446	41	19	39	18.7	2.4	581	64	19
PI441576	*baccatum*	5	Red	26.0	178.2	577	59	31	67	18.7	4.6	452	51	19
PI441590	*baccatum*	1	Red	27.8	82.7	347	53	22	30	17.0	3.4	468	53	15
PI159236-C	*chinense*	5	Brown	23.9	131.3	1041	80	50	243	18.1	8.4	517	44	20
PI159236-D	*chinense*	7	Brown	26.1	230.1	971	69	43	218	18.5	7.4	429	58	19
Habanero	*chinense*	7	Orange	28.9	182.4	78	5	2	2	33.7	9.5	419	7	12
PI224706	*chinense*	5	Red	15.0	224.2	263	93	32	50	19.2	4.4	147	32	21
Waller-Duncan				6.7	80.6	481	98	44	120	4.3	3.0	206	23	3
Mean of all entries				27.4	170.6	567	114	53	101	23.5	9.0	445	41	19

All AOA and AO data are based on dry weights.

[1]Pungency rated on a scale from 0 to 7 with 0 = non pungent and 7 = highly pungent.

[2]ILP = inhibition of lipid peroxidation; ARP = anti-radical power.

ences among groups within *C. annuum*. Although based on a small number of non-pungent entries, our results show significant group differences between pungent and non-pungent types for several AO. Non-pungent entries as a group produced 69% more ascorbic acid than pungent entries and five of the seven non-pungent entries ranked among the top ten entries for ascorbic acid content (Table 64). Contrasts indicated that the group mean of the non-pungent entries was significantly greater than that of the pungent entries for ascorbic acid, total phenolics, α-tocopherol, and β-cryptoxanthin. We recommend evaluation of additional non-pungent accessions to confirm this observation.

Fruit color is related to AO content, and brown-fruited accessions, as a group, produced higher quantities of all carotenoids and about one-third more α-tocopherol than the group mean of the red-fruited accessions (Table 64). Given their high carotenoid content, including the provitamin A carotenoids β-carotene and β-cryptoxanthin, brown-fruited accessions merit further investigation, particularly for potential adaptation and promotion among vitamin A-deficient populations in sub-Saharan Africa and South Asia. Among the red-fruited entries, Verdano Poblano and Guajillo ancho, both originating from Mexico, ranked among the best entries for content of almost every AO, including individual carotenoids, ascorbic acid, α-tocopherol, and total phenolics. Certainly these two accessions are of interest to breeders. The Guajillo chili fruit type is characterized by deep red, moderately pungent, thin-walled fruit that are usually sold as a dried whole pepper. The Poblano/ancho chilis are of mild or medium pungency with heart-shaped fruit that Mexicans call Poblano in the fresh green stage and Ancho or Mulato after drying. Fully mature fruit of Mulato types such as Roque Mulato Poblano in this study become brown to almost black in color while Anchos develop a dark red appearance. Although it is not possible to draw conclusions based on the few accessions studied here, it would seem that deep rich fruit color is a common feature of many Ancho and Guajillo types, a consequence of elevated carotenoid content. Further investigation of more Ancho and Guajillo accessions might uncover others high in AO content.

Correlations between individual carotenoids were positive, highly significant, and values exceeded 0.70 except for those between capsanthin and zeaxanthin (r = 0.57**), and β-carotene and zeaxanthin (r =

Table 64. *Linear contrasts among* Capsicum *accessions.*

		ILP[1]	ARP[1]	Caps-anthin	Zea-xanthin	Crypto-xanthin	β-carotene	Phenolics	Ascorbic acid	α-toco-pherol	γ-toco pherol	Dry matter
		–TE (µmol/g) –		(µg/g)				(mg/g)	(mg/g)	(µg/g)	(µg/g)	(%)
1	Pungent (n=29)	23.9	173.8	597	130	56	105	8.7	22.4	441	45	22
	Non-pungent (n=7)	45.2	159.1	589	122	76	114	14.7	30.5	508	27	13
	Difference	-21.3**	14.7*	8	8	-20**	-8	-6.0**	-8.1**	-67*	18**	9**
2	*C. annuum* (n=36)	28.0	170.8	595	129	60	106	9.9	24.0	454	42	20
	C. baccatum (n=5)	25.3	159.3	407	60	25	42	3.1	18.5	462	56	17
	Difference	2.7*	11.5	188*	69**	35**	64**	6.8**	5.5**	-8	-14**	3**
3	*C. annuum* (n=36)	28.0	170.8	595	129	60	106	9.9	24.0	454	42	20
	C. chinense (n=6)	24.0	174.5	488	65	30	114	7.9	23.8	366	30	17
	Difference	4.0**	-3.7	107	64**	30**	-8	2.0**	0.2	88**	12*	3**
4	Red fruit (n=35)	26.8	172.2	582	115	50	92	8.4	22.8	427	45	20
	Brown fruit (n=4)	28.1	149.2	855	140	78	183	9.4	21.4	574	37	18
	Difference	1.3	23.0	-273**	-25	-28**	-91**	1.0	1.4	-147**	8*	2**
5	Red fruit (n=35)	26.8	172.2	582	115	50	92	8.4	22.8	427	45	20
	Orange fruit (n=4)	34.3	172.4	258	48	46	75	12.5	21.4	464	24	15
	Difference	-7.5**	-0.2	324**	67**	4	17	-4.1**	-1.4**	-37	21**	5**

[1]ILP = inhibition of lipid peroxidation; ARP = anti-radical power.

*, ** Significant at $P \leq 0.05$ or 0.01, respectively.

0.44**). These associations would facilitate improvement of pepper for AO content since selection for increased densities of one carotenoid would increase levels of other carotenoids also. Ascorbic acid and total phenolics demonstrated a strong positive association.

The ILP assay could be adopted for characterization of *Capsicum* germplasm or by plant breeders as a means of selection for higher AOA. Entry performance for ILP was very consistent between years, evidenced by a small and nonsignificant year × entry mean square (not shown). Furthermore, of the top ten entries for ILP in 2002, eight were among the top ten in 2003; CAP178/77, Nacional AG-506 and Agronomico 9 ranked first, second and third highest, respectively, for ILP in both 2002 and 2003. On the other hand, we found a large and highly significant year × entry mean square for ARP, caused in part by large rank changes between years. None of the top ten entries for ILP appeared among the top ten entries for ARP and the correlation between the ILP and ARP was not significantly different from zero (Table 65).

Table 65. *Linear correlations[1] between measures of antioxidant activity, antioxidants and dry matter in* Capsicum.

	ILP	Capsanthin	Zea-xanthin	Crypto-xanthin	β-carotene	Phenolics	Ascorbic acid	α-toco-pherol	γ-toco pherol	Dry matter
ARP[2]	0.07	–0.24	–0.22	–0.12	–0.20	0.32*	0.19	–0.09	–0.13	–0.31
ILP[2]		0.46**	0.05	0.31	0.47**	0.77**	0.60**	0.30	–0.17	–0.84**
Capsanthin			0.57**	0.77**	0.80**	0.17	0.20	0.39*	0.30*	–0.07
Zeaxanthin				0.72**	0.44**	0.00	0.22	0.33	0.20	0.40*
Cryptoxanthin					0.77**	0.23	0.42*	0.49**	0.20	0.23
ß-carotene						0.30	0.45*	0.39*	0.11	–0.09
Phenolics							0.79**	0.20	–0.24	–0.40*
Ascorbic acid								0.35*	–0.47**	–0.67**
α-tocopherol									0.29	–0.20
γ-tocopherol										0.36*

*, ** Significant at $P \leq 0.05$ or 0.01, respectively.

[1]Correlations were calculated using entry means averaged over two years. The seven non-pungent entries were dropped before calculation of all correlations. Nose Gay, Verdano Poblano TY, Guajillo ancho, Paul Smith's Serrano, PI224706, PI441619 were dropped from correlations for ascorbic acid, α-tocopherol, and dry matter.

[2]ARP = anti-radical power; ILP = inhibition of lipid peroxidation.

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Tomato Unit

Determinate tomato lines for the tropics

Geminivirus resistance has become an essential component of the tropical tomato, along with heat tolerance, bacterial wilt resistance, and good quality fruit. In 2001, the AVRDC released its first geminivirus resistant tomato lines coded CLN2114, CLN2116, and CLN2123 with resistance derived from the *Ty-2* gene of H24. These early lines provided effective resistance against many monopartite geminiviruses in Asia and the Middle East, and were generally well-received by the tomato breeding community; CLN2123 for example, was used as a parental line in the Tamil Nadu University hybrid CO.3 released this year. However, many collaborators have requested geminivirus-resistant lines with better fruit firmness and quality. The geminivirus resistant lines reported here are also based on *Ty-2* resistance but are superior to earlier AVRDC lines in marketable yield and fruit quality. Three preliminary yield trials (PYT) were conducted at the AVRDC during the late summer season to identify superior determinate lines for international distribution. The PYT 1 entries were fresh market inbred lines, and PYTs 2 and 3 included processing tomato inbred lines. The three PYTs were sown 25 July 2003 and transplanted on 26 August 2003. Trial plots of PYT 1 consisted of one 1.5-m-wide bed with two 4.8-m-long rows per bed (24 plants). Trial plots of PYTs 2 and 3 included two 1.5-m-wide beds with one 4.8-m-long row per bed (24 plants). Plants were staked and pruned. Entries were replicated twice and plots were arranged in a randomized complete block design (RCBD). Plots were harvested three times from 1 October to 21 December 2003.

The CLN2498-prefixed lines in PYT 1 are derived from a triple cross and underwent selection for both geminivirus and bacterial wilt resistance during generation advance; populations were screened for geminivirus resistance by exposure to viruliferous

Table 66. *Yield and horticultural characteristics of semi-determinate fresh market tomato lines in Preliminary Yield Trial 1.*[1]

Entry	Market. yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Fruit no./ plant	Solids (°Brix)	Acid[2]	Color[3] (a/b)	BW suvival[4] (%)	Disease resistance[5]
CLN2515(14)BC_1F_1-43-30-1-16-20-0	31.1	25.5	119	87	21.8	3.8	0.26	1.96	60	WTG, ToMV, F-1, GLS
CLN2498-68-15-4-20-21-14-19-0	36.9	30.3	120	71	30.3	3.8	0.30	1.92	80	WTG, ToMV, F-1
CLN2498-68-15-4-20-21-14-23-12	36.1	19.1	121	76	24.3	4.2	0.35	1.87	68	WTG , ToMV, F-1
CLN2498-68-15-22-17-19-12-17-8	51.6	29.8	120	80	29.8	3.8	0.28	1.75	62	WTG ,ToMV, F-1, GLS
CLN2498-68-15-22-17-19-18-29-2	50.5	14.4	120	85	22.7	3.9	0.27	1.76	59	WTG ,ToMV, F-1, GLS
CLN2498-68-15-22-17-19-18-29-13	47.0	21.9	121	83	24.0	4.0	0.29	1.69	68	WTG ,ToMV, F-1, GLS
CLN2498-68-15-22-17-25-19-17-0	54.0	20.0	121	88	23.3	3.9	0.26	1.85	80	WTG ,ToMV, F-1, GLS
CLN2498-68-15-22-17-25-25-36-4	43.9	14.6	122	93	19.2	4.0	0.30	1.61	75	WTG ,ToMV, F-1, GLS
CLN1962B_1F_7-A-3	30.9	29.7	119	37	29.7	4.2	0.40	2.07	37	WTG ,ToMV
CLN1962B_1F_7-A-23	33.7	34.2	118	39	34.2	4.2	0.40	1.97	60	WTG ,ToMV, F-1
LA3965	36.3	8.3	122	44	14.5	3.6	0.30	1.82	0	WTG
CLN2116C (check)	23.0	25.0	116	67	25.0	4.2	0.31	1.70		ToMV, F-1
CLN2026D (WTG-susc. check)	22.4	28.0	118	45	34.8	4.5	0.32	2.02	60	ToMV, F-1, F-2, GLS
LSD (5%)	14.6	5.6	3	10	18.8	0.5	0.05	0.26	31	
CV (%)	17.5	14.1	1	6.8	33.7	5.9	7.63	6.37	23	

[1]Transplanted 26 August 2003 at AVRDC.

[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 0. 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 pathogen in a separate greenhouse trial. Reaction of susceptible check L390 and resistant check H7996 were 0% and 95%, respectively.

[5]ToMV = tomato mosaic virus; WTG = whitefly-transmitted geminivirus; F-1 and F-2 = Fusarium wilt races 1 and 2, respectively; GLS = gray leaf spot .

whiteflies (*Bemisia tabaci*) each generation prior to transplanting from the F_1 to the F_8, and testing for bacterial wilt reaction by root dip inoculation occurred in the F_4, F_6 and F_8 generations (Table 66). Lines were screened for Fusarium wilt and gray leaf spot reactions in the F_8 generation. Outstanding entries in PYT1 for yield, fruit weight, and disease resistance included CLN2498-68-15-22-17-19-12-17-8 (re-coded CLN2498D), CLN2498-68-15-22-17-25-19-17-0 (re-coded CLN2498E) and CLN2498-68-15-22-17-19-18-29-2 (re-coded CLN2498F) (Table 66). Small seed quantities (100 seeds per recipient) are available for international distribution. The two CLN1962-prefixed lines contain geminivirus resistance derived from *L. chilense* LA1932, and LA3965 is an introgression line from *L. hirsutum* LA1777 (kindly provided by the Tomato Genetics Resource Center at the University of California-Davis). Seed of these lines are also available from AVRDC upon request.

Lines in PYT 2 and PYT 3 were selected primarily for geminivirus resistance in a processing tomato type (Tables 67 and 68). Based on yield, internal color, absence of cracking, firmness, and disease resistance, $CLN2545DC_1$-21-26-9-12-12-1 (recoded CLN2545A), $CLN2545DC_1$-21-26-9-12-12-21 (recoded CLN2545B) and $PT4722B_1F_1$-18-27-1-25-16-15 (recoded PT4722A) from PYT2, and CLN2468DC1-79-29-19-11-27-4-1 (recoded CLN2468A) will be offered internationally. Small seed quantities (100 seeds per entry per recipient) are available upon request.

Tomatoes for specialty markets

Green-shouldered fresh market tomato

Green shouldered tomatoes are very popular in selected regions of Asia. An observational trial (OYT) of indeterminate, fresh market hybrids was carried out at the AVRDC during the late spring to summer growing season to identify promising lines. All FMTT-prefixed entries are resistant to geminivirus, late blight (conferred by the *Ph-3* gene), tomato mosaic virus, bacterial wilt, and race 1 of the Fusarium wilt pathogen. The trial was sown on 26 March, transplanted 24

Table 67. *Yield and horticultural characteristics of determinate processing tomato lines evaluated in Preliminary Yield Trial 2.*[1]

Entry	Market. yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Fruit no./ plant	Solids (°Brix)	Acid[1]	Color[2] (a/b)	BW suvival[3] (%)	Disease resistance[4]
$PT4721B_1F_1$-22-18-1-7-21-8	36.7	13.6	111	50	38	4.5	0.32	1.93	0	WTG, ToMV, F-1
$PT4721B_1F_1$-22-18-1-7-22-1	34.6	12.2	108	51	49	5.0	0.41	2.06	0	WTG, ToMV, F-1
PT4721 B_1F_1-22-18-1-7-22-9	37.4	9.5	109	47	43	4.5	0.37	2.00	0	WTG, ToMV, F-1
PT4722 B_1F_1-18-27-1-25-16-15	34.8	18.6	107	58	55	4.2	0.40	2.00	40	WTG, ToMV, F-1
PT4722 B_1F_1-18-27-1-25-16-19	36.9	4.4	107	52	41	4.2	0.38	1.98	40	WTG, ToMV, F-1
PT4722 B_1F_1-18-27-1-25-18-0	32.9	8.6	108	55	36	4.2	0.44	2.05	50	WTG, ToMV, F-1
PT4722 B_1F_1-18-27-1-25-98-22	49.4	5.2	111	57	28	4.3	0.38	1.97	40	WTG, ToMV, F-1
$CLN2545DC_1$-21-26-9-12-12-1	54.7	10.5	107	48	89	4.2	0.41	1.87	35	WTG, ToMV, F-1
$CLN2545DC_1$-21-26-9-12-12-21	51.2	9.9	109	45	55	4.1	0.38	1.98	65	WTG, ToMV, F-1
$CLN2545DC_1$-21-26-9-12-13-17	37.8	12.0	106	48	43	4.5	0.40	1.91	52	WTG, ToMV, F-1
PT4727 (hybrid check)	45.3	4.6	109	74	23	4.8	0.32	2.03	85	WTG, ToMV, F-1
FMTT848 (hybrid check)	23.5	13.6	102	78	24	4.6	0.29	1.81	90	WTG, ToMV, F-1
FMTT847 (hybrid check)	42.2	10.9	102	88	35	4.7	0.32	1.92	80	WTG, ToMV, F-1
H24	25.8	0.6	111	41	7	-	-	-	-	WTG
Mean of all entries	33.9	10.4	108	55	40	4.5	0.35	1.90	-	
LSD (5%)	16.9	11.7	3	14	22	0.6	0.08	0.21	-	

Transplanted 25 July 2003 at AVRDC.

[1]Equivalent of citric acid.

[2]Values for a and b were measured with a chromometer using a red standard surface. Immature green tomatoes have an a/b ratio less than 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 pathogen in a separate greenhouse trial.

[4]ToMV = tomato mosaic virus; WTG = whitefly-transmitted geminivirus; F-1 and F-2 = Fusarium wilt races 1 and 2, respectively; GLS = gray leaf spot.

Table 68. *Yield and horticultural characteristics of determinate processing tomato lines evaluated in Preliminary Yield Trial 3.*[1]

Entry	Market. yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Fruit no./ plant	Solids (°Brix)	Acid[2]	Color[3] (a/b)	BW suvival[4] (%)	Disease resistance[5]
PT4721B_1F_1-22-18-1-7-9-0	35.5	19	99	50	60	4.6	0.39	2.03	0	WTG, ToMV, F-1
PT4721 B_1F_1-22-18-1-7-13-21-2	31.7	24	99	52	47	4.7	0.41	1.97	0	WTG, ToMV, F-1
PT4721 B_1F_1-22-18-1-7-21-6-2	36.3	19	101	49	55	4.6	0.40	1.88	0	WTG, ToMV, F-1
PT4721 B_1F_1-22-18-1-7-21-6-12	18.5	28	101	46	49	4.5	0.39	1.93	0	WTG, ToMV, F-1
PT4721 B_1F_1-22-18-7-22-9-10	21.5	21	100	48	54	4.5	0.38	1.87	0	WTG, ToMV, F-1
CLN2468DC_1-79-29-19-11-27-4-1	26.7	22	97	48	49	4.1	0.26	1.93	85	WTG, ToMV, F-1
CLN2468DC_1-79-29-19-11-15-11-1	29.4	23	100	46	46	4.4	0.24	1.79	91	WTG, ToMV, F-1
PT4721 B_1F_1-28-29-14-18-23-26-4	27.5	18	99	53	50	4.5	0.39	1.87	-	WTG, ToMV, F-1
PT4727 (hybrid check)	41.4	16	98	66	43	5.2	0.38	2.06	85	WTG, ToMV, F-1
FMTT848 (hybrid check)	27.7	21	95	78	25	4.5	0.31	1.88	90	WTG, ToMV, F-1
Mean of all entries	29.6	21	99	54	48	4.5	0.36	1.09	-	-
LSD (5%)	12.6	10	3	8	23	0.6	0.29	0.29	-	-

[1]Transplanted 26 August 2003 at AVRDC.
[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 0. 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 pathogen in a separate greenhouse trial.
[5]ToMV = tomato mosaic virus; WTG = whitefly-transmitted geminivirus; F-1 and F-2 = Fusarium wilt races 1 and 2, respectively; GLS = gray leaf spot.

April, and harvested three times between 16 July and 21 August 2003. Plots included one 1.5-m-wide bed with one 2.4-m-long row per bed (14 plants). Plants were staked and pruned. Entries were replicated twice and plots were arranged in a RCBD. The check variety, ASVEG#10, suffered severely from tomato leaf curl virus (ToLCV) and did not produce any marketable fruits. The most promising hybrids are listed in Table 69 and will be included in preliminary yield trials in the future.

Table 69. *Yield and horticultural characteristics of geminivirus-resistant, dark green-shouldered, fresh market tomato hybrids evaluated in an observational yield trial.*[1]

Entry	Market. yield (t/ha)	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[2] (%)	Color[3] (a/b)	BW survival[4] (%)
FMTT1027	22	15	68	76	5.8	0.43	1.19	93
FMTT1034	26	37	72	82	5.6	0.45	1.41	88
FMTT1046	22	22	62	74	6.0	0.46	1.57	76
FMTT1051	23	19	65	80	5.8	0.41	1.64	88
FMTT1056	23	25	61	68	5.6	0.43	1.52	85
FMTT1060	32	25	62	59	5.9	0.46	1.41	83
FMTT1098	22	19	78	84	6.0	0.45	1.42	97
ASVEG #10 (check)	0	0	-	-	-	-	-	41
Mean of all entries	17	19	67	67	5.6	0.45	1.44	77
LSD (5%)	4	11	7	21	0.8	0.07	0.37	19

[1]Transplanted 24 April 2003 at AVRDC.
[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 0. 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 pathogen in a separate greenhouse trial.

High ß-carotene cherry tomato

High ß-carotene tomatoes may be especially beneficial in vitamin A deficient areas of Africa and Asia. A group of promising hybrids were evaluated in advanced yield trials (AYTs) in the fall and summer seasons. Entries with the CHT prefix are resistant to geminivirus, tomato mosaic virus, and race 1 of the Fusarium wilt pathogen. The fall trial was sown 14 August 2002, transplanted 17 September 2002, and harvested six times between 20 October 2002 and 20 January 2003. The summer trial was sown 14 April, transplanted 17 May, and harvested six times between 14 August and 15 September 2003. Plots included three 2.0-m-wide beds with two 4.8-m-long rows per bed (72 plants). Plants were staked and pruned. Entries were replicated three times and plots were arranged in a RCBD. The superior entries are listed in Table 70 and will be considered for regional trials.

Variation of antioxidants and their activity in tomato

Tomato is one of the most widely consumed vegetables in the world and an important source of β-carotene and ascorbic acid. In addition to their importance as a provitamin or vitamin, β-carotene and ascorbic acid each serve as an antioxidant (AO). Lycopene, the major carotenoid in tomato fruit, is a powerful AO and has garnered much attention because of the linkage between lycopene-rich diets and lower risks of certain cancers, heart disease, and age-related diseases.

Tomato genotypes vary in the types and concentrations of carotenoids as well as levels of ascorbic acid and phenolics. Thus, selection for higher concentrations of a particular AO is one strategy to improve tomato for overall antioxidant activity (AOA). The objectives of this study were to assess genetic diversity within *Lycopersicon esculentum* for four AOs (lycopene, ß-carotene, ascorbic acid, and total phenolics), and for AOA using two methods (anti-radical power [ARP] and inhibition of lipid peroxidation [ILP]), and to estimate the association between AOA and specific AO.

Fifty *Lycopersicon esculentum* and three *L. pimpinellifolium* entries were included in the study (29 of these entries are listed in Table 71) and included modern and vintage varieties, landraces, and non-improved *L. esculentum*. Entries were grown in AVRDC fields from October 2001–March 2002 and October 2002–March 2003. Entries were replicated twice and arranged in a RCBD. Plots included five plants in year one and ten plants in year two. Plants were staked and pruned. At least 600 fruits at the full red stage were harvested from each plot once when one or more clusters on most plants within plots had ripe fruit. Fruit were taken the same day to the laboratory for sample preparation.

Entries were analyzed for AOA by ARP and ILP methods. ARP measures the capacity of different com-

Table 70. *Yield and horticultural characteristics of high β-carotene cherry tomato hybrids in preliminary yield trials.*[1]

Entry	Marketable yield (t/ha) Fall	Marketable yield (t/ha) Summer	Fruit set (%)	Days to maturity	Fruit weight (g)	Solids (°Brix)	Acid[2] (%)	Color[3] (a/b)	Lycopene (mg/100g)	β-carotene (mg/100g)	BW survival[4] (%)
CHT1402	92	16	54	124	16	7.2	0.48	1.03	3.02	1.74	40
CHT1410	108	12	61	120	18	7.0	0.32	1.10	3.18	1.94	51
CHT1417	109	20	68	119	12	6.4	0.34	0.67	0.91	2.54	13
CHT1421	104	20	69	118	12	7.2	0.45	0.71	1.09	2.53	13
CHT1438	119	20	68	118	13	6.5	0.32	0.80	1.76	2.47	41
CHT1442	90	23	62	118	12	7.4	0.41	0.80	1.73	2.32	25
ASVEG #6 (ck)	79	7	40	124	7	6.7	0.38	1.40	6.80	0.50	0
ASVEG #11 (ck)	105	0	51	121	12	6.9	0.35	0.77	1.78	1.61	8
Mean of all entries	101	8	59	119	13	6.9	0.38	0.91	2.53	1.95	28
LSD (5%)	14	6	9.4	0.8	1.3	0.7	0.05	0.37	0.52	0.39	16

[1]Transplanted 17 September 2002 (fall trial) and 17 May 2003 (summer trial) at AVRDC.

[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 pathogen in a separate greenhouse trial.

ponents to scavenge the ABTS radical cation as compared to the standard antioxidant Trolox (0–4 mM) in a dose response curve. Trolox is a vitamin E analog. The ability of AO samples to inhibit lipid peroxidation at pH 7 was tested using linoleic acid as a substrate and AAPH as a free radical generator. Trolox (0–4 mM) was used as the AO standard and AOA was expressed as TE (Trolox equivalents) in µmol/g tomato fruit (fresh weight basis). Carotenoid densities were determined by high-performance liquid chromatography (HPLC) and ascorbic acid, total phenolics, color, and soluble solids were determined according to standard procedures.

Variables were subjected to analysis of variance (ANOVA) for each year and over years by SAS General Linear Model (GLM) procedure. Nonindependent, single-degree-of-freedom contrasts were constructed to made comparisons among groups of entries: 1) *L. pimpinellifolium* (n = 3) vs. *L. esculentum* entries (n = 50); 2) small-fruited (n = 12) vs. large-fruited (n = 35) *L. esculentum,* where entries with fruit size scores of 1–2 were classified as "small" and 3–5 as "large";

Table 71. *Selected* Lycopersicon *accessions evaluated for antioxidant activity, antioxidants, and fruit qualities at AVRDC.*

			Antioxidant Activity		Antioxidants				Fruit qualities	
Entry[1]	Species	Fruit size[2] score	ILP[3] (µmol/g)	ARP	Lycopene	β-caro.	Phenol. (mg/100 g)	Asc. acid	Color[4] (a/b)	Solids (°Brix)
LA 1582	*pimpinellifolium*	1	5.77	6.84	23.09	0.88	156	39.7	2.09	7.7
LA 1586	*pimpinellifolium*	1	4.75	6.47	19.69	0.89	161	36.6	2.07	8.6
LA 1593	*pimpinellifolium*	1	4.96	6.40	18.04	0.89	143	28.5	1.99	7.1
Pusa Ruby	*esculentum*	4	4.21	3.60	6.91	0.46	77	15.3	1.94	4.1
LA1231	*esculentum*	3	4.36	4.43	6.79	0.75	96	19.8	1.53	4.2
LA1247	*esculentum*	1	4.49	4.59	8.93	0.55	96	21.8	1.62	5.3
LA 1289	*esculentum*	2	4.80	4.88	7.22	0.75	105	21.3	1.49	4.4
LA 1308	*esculentum*	2	4.83	5.74	8.17	1.16	117	22.6	1.47	4.8
LA1313	*esculentum*	3	4.46	5.31	6.72	0.41	98	17.5	1.68	5.1
LA1315	*esculentum*	1	5.79	6.26	10.07	0.66	143	26.5	1.72	6.3
LA 1323	*esculentum*	1	4.58	5.76	8.44	0.83	118	24.3	1.58	5.0
LA 1385	*esculentum*	2	5.50	5.89	8.23	0.66	130	22.5	1.63	4.7
LA 1455	*esculentum*	2	5.04	5.79	8.11	1.00	123	28.6	1.41	5.0
LA 1456	*esculentum*	1	5.59	6.08	8.52	1.15	134	26.2	0.99	4.4
LA 1457	*esculentum*	1	4.93	5.94	8.60	1.10	121	27.9	1.49	5.9
LA 1459	*esculentum*	2	5.02	4.46	7.76	0.73	101	20.1	1.67	5.4
PI 126410	*esculentum*	3	4.48	5.01	7.38	0.67	103	22.2	1.54	4.1
PI 129128	*esculentum*	4	3.75	3.66	10.27	0.30	92	26.4	2.13	5.3
Nagcarlan	*esculentum*	5	3.54	3.75	7.24	0.70	88	20.8	1.70	4.7
LA 1502	*esculentum*	5	3.88	3.84	8.29	0.48	81	16.9	1.88	4.6
Coldset	*esculentum*	4	2.30	2.74	5.72	0.28	65	14.6	1.78	3.7
Saladette	*esculentum*	4	4.01	3.14	5.02	0.47	67	15.8	1.65	4.0
Walter	*esculentum*	5	3.61	2.96	4.15	0.36	63	12.1	1.53	4.7
UC204A	*esculentum*	4	3.56	2.80	5.83	0.42	63	12.3	1.72	3.7
T4065 (*hp* + *og*^{c})	*esculentum*	5	2.42	2.70	10.64	0.56	63	18.0	2.16	4.6
T5019 (*dg* + *og*^{c})	*esculentum*	5	3.40	3.91	9.30	1.15	87	17.5	1.81	4.2
CLN1314G (β)	*esculentum*	5	2.86	3.23	1.18	3.73	68	13.4	0.73	4.2
97L63 (β)	*esculentum*	4	1.77	2.53	0.28	3.38	56	12.9	0.47	4.2
Waller-Duncan			1.36	1.16	2.68	0.29	29	5.3	0.27	1.0
Mean of all entries			3.97	4.11	7.20	0.73	90	19.1	1.52	4.8

[1]Gene symbols for genes affecting carotenoid patterns: *hp* = high pigment; *og*^{c} = crimson; *dg* = dark green; β = beta.

[2]1 = very small to 5 = very large.

[3]ARP = anti-radical power; ILP = inhibition of lipid peroxidation.

[4]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 fruit color becomes a dark red.

3) red fruited (n = 46) vs. high beta (n = 3) entries; and 4) large red-fruited (n = 28) entries vs. *hp* and *dg* (n = 2) entries. Entry means were separated by the Waller-Duncan test (k=100 which is equivalent to $P = 0.05$). Linear correlations between characters were calculated with entry means averaged over years. The three *L. pimpinellifolium* entries (LA1582, LA1586 and LA1593) and three high ß-carotene entries (PI 298943, CLN1314G and 97L63) were dropped before calculation of correlations because plotting of means indicated that they were outliers and did not fit the trend of the other entries.

The group mean of the three *L. pimpinellifolium* accessions (LA1582, LA1586 and LA1593) over years was significantly greater than the mean of the *L. esculentum* entries for both ILP and ARP (Table 72-contrast 1). LA1582, LA1586 and LA1593 ranked first, second and third highest, respectively, for ARP; and second, eleventh and seventh, respectively, for ILP. Small-fruited *L. esculentum* entries (< 30 g) produced significantly higher AOA than the medium and large-fruited entries (Table 72-contrast 2). LA1315, LA1385, LA1455, LA1456 and LA1457, all of which are small-fruited and classified as *L. esculentum cerasiforme* or South American landraces, demonstrated the highest levels of AOA among *L. esculentum* entries. All medium or large-fruited entries showed low or moderate AOA.

For most entries, lycopene was the major carotenoid although the range of values was wide (0.04 to 23.09 mg/100 g fresh weight). The three *L. pimpinellifolium* entries formed a distinct group of means that were significantly larger than all the *L. esculentum* entries (Table 72-contrast 1). The *L. esculentum* means ranged from 0.04–10.64 mg/100 g. The *L. esculentum* entries producing high lycopene content included T5019 and T4065 containing *dg* + *og*^{c} and *hp* + *og*^{c} genes, respectively, as well as LA1315 and PI129128. As expected, entries CLN1314G and 97L63 containing the Beta gene showed low lycopene density and the highest β-carotene levels (3.73 and 3.38 mg/100 g, respectively) compared to an average β-carotene content of 0.62 mg/100 g for the red-fruited entries.

Entry means over years for phenolics content ranged from 56–156/100 g with an overall mean of 90 mg/100 g. Entry means over years for ascorbic acid content ranged from 12–40/100 g. For both characters, average content of the *L. pimpinellifolium* entries was almost twice as large as the mean of all *L. esculentum* entries (Table 72-contrast 1). Almost all

Table 72. *Linear contrasts of* Lycopersicon *entries evaluated over two years for antioxidant activity, antioxidants, and fruit quality components.*

		Antioxidant activity[1]		Antioxidants				Fruit qualities	
		ILP	ARP	Lycopene	ß-caro.	Asc. acid	Phenol.	Color	Solids
Contrast		(µmol/g)		(mg/100 g)				(a/b[2])	(ºBrix)
1	*L. pimpinellifolium*	5.16	6.57	20.27	0.88	34.9	153	2.05	7.8
	L. esculentum	3.90	3.96	6.36	0.72	18.2	87	1.61	4.5
	Difference	1.26**	2.61**	13.85**	0.16*	16.7**	66**	0.44**	3.3**
2	Small fruit	4.92	5.47	9.98	0.79	26.1	122	1.67	5.7
	Large fruit	3.56	3.52	6.00	0.70	16.0	77	1.63	4.4
	Difference	1.56**	1.95**	3.98**	0.09*	10.1**	45**	0.04	1.3**
3	Red fruit	4.03	4.25	8.12	0.60	19.6	90	1.73	4.8
	High Beta	2.92	3.22	0.82	3.34	14.2	68	0.61	4.0
	Difference	1.11**	1.03**	7.30**	–2.74**	5.4**	22**	1.12**	0.8*
4	Large red fruit	3.72	3.77	6.81	0.47	16.7	81	1.73	4.4
	hp and *dg*[3]	2.91	3.31	9.96	0.85	17.7	74	1.99	4.4
	Difference	0.81*	0.46	–3.15**	–0.38**	–1.0	7	–0.26**	0.0

[1]ARP = Anti-radical power; ILP = inhibition of lipid peroxidation. Measured in Trolox equivalents.

[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 fruit color becomes a dark red.

[3]*hp* = high pigment; *dg* = dark green.

*, ** Significant at $P \leq 0.05$ or 0.01, respectively.

L. esculentum entries of relatively high phenolics content were small-fruited and means of almost all medium or large-fruited entries fell below 90 mg/100 g. As with phenolics content, entries producing the highest ascorbic acid content included the *L. pimpinellifolium* and small-fruited *L. esculentum* such as LA1455 and LA2644.

We found a large positive correlation between ARP and ILP (Table 73), indicating a strong linear association between the two measures of AOA. ARP and ILP were both strongly correlated with total phenolics, ß-carotene and ascorbic acid. Lycopene showed a significant positive correlation with ARP but not ILP. Except for lycopene, correlations with all traits and fruit size were negative and highly significant. Fruit size was negatively correlated with ARP (r = –0.74**) and ILP (r = –0.71**), indicating that combining large fruit size and high AOA will be challenging.

Results of our study have implications for improvement of tomato for AOA. Genetic improvement of tomato for AOA and specific AO is possible given the large genetic variation present among tomato entries. However, entries outstanding for AOA and most AO in this study were exclusively *L. pimpinellifolium* (LA1582, LA1586 and LA 1593) or small-fruited *L. esculentum* such as LA1315, LA1385 and LA1455 while the medium or large-fruited entries in this study showed average or below average AOA. Although information is lacking on the improvement status of many entries, particularly those prefixed with PI, it is almost certain that the large-fruited entries were developed in plant breeding programs while *L. pimpinellifolium* and small-fruited *L. esculentum* are non-bred germplasm. Further work is required to determine if lower AOA of the larger, and presumably bred lines, is a consequence of increased fruit size or the result of selection against certain AO, especially phenolics, in the course of domestication/ plant breeding.

ILP and ARP, the two methods used to assess AOA in this study, could be adopted by plant breeders to improve AOA in tomato. Our results suggest that ILP and ARP measure similar properties since there was a large positive correlation between the two assays (r = 0.82**) and the magnitude and range of ILP and ARP values were similar. Consequently there is no need to evaluate entries with both assays in a breeding program. Of the two methods we recommend ARP because the time required by laboratory technicians to complete this assay was about 50% less than ILP at about the same material cost.

Ascorbic acid, a hydrophilic AO, and total phenolics, a moderately hydrophilic AO, demonstrated the highest correlations with ARP and ILP. This is not surprising since conditions in the ARP assay and to a lesser extent, ILP, favored hydrophilic AO. Carotenoids are lipid-soluble and lycopene in particular is very hydrophobic so it would not be correct to rank the importance of AO according to the size of the correlations between specific AO and ILP or ARP. Rather, ILP or ARP should be measured in combination with analyses of carotenoids. Although AOA was most highly correlated with total phenolics, development of varieties of commercial fruit size with high phenolics content will be difficult. Phenolic compounds in tomato fruit are concentrated in the skin and surface area/ volume ratio decreases with increasing fruit size.

For more information, contact: Peter Hanson

Table 73. *Linear correlations between measures of antioxidant activity, antioxidants, and fruit quality components.*[1]

	ILP[2]	Lycopene	β-carotene	Ascorbic acid	Phenolics	Color	Solids	Fruit size
ARP[2]	0.82**	0.49**	0.70**	0.69**	0.90**	0.01	0.43**	–0.74**
ILP		0.17	0.53**	0.65**	0.83**	–0.22	0.54**	–0.71**
Lycopene			0.53**	0.24	0.44**	0.75	0.13	–0.16
β-carotene				0.59**	0.70**	0.18	0.18	–0.49**
Ascorbic acid					0.81**	–0.20	0.57**	–0.74**
Phenolics						–0.03	0.54**	–0.72**
Color							–0.19	0.23
Solids								–0.46**

*, **Significant at $P \leq 0.05$ and 0.01, respectively; n = 47.

[1]Correlations were calculated using entry means averaged over two years. The three *L. pimpinellifolium* and three entries with the Beta genes were dropped before calculation of correlations.

[2]ARP = anti-radical power; ILP = inhibition of lipid peroxidation.

Biotechnology Unit

MYMV reactions of mungbean RILs grown in India during kharif season

Mungbean yellow mosaic virus (MYMV) is a serious epidemic disease in South Asia, especially whenever populations of whitefly, the transmission vector, are high. The development of MYMV-resistant lines is critical for this region. Through a collaborative shuttle breeding program between AVRDC and National Institute for Agriculture and Biology, Faisalabad, Pakistan, several MYMV-resistant mungbean (MB) lines have been generated. One of the MYMV-resistant lines, NM 92, was crossed to TC 1966 (*Vigna radiata* ssp. *sublobata*), and a set of 200 recombinant inbred lines (RILs) at F_{11} stage were generated and maintained at AVRDC. The purpose of this project is to evaluate MYMV reaction of these RIL lines at one of the MYMV hot spot locations, Punjab Agriculture University (PAU) at Ludhiana, India, to elucidate the mode of inheritance for MYMV resistance.

A total of 200 mungbean RILs were planted at PAU during kharif season from July to October in 2003. Plots consisted of 4-m-long rows and were set out in a randomized complete block design with two replications. Rows were spaced 40 cm apart and in-row plant spacing was 5 cm. Susceptible checks were planted after every two test rows. The susceptible checks included a mixture of UL1, GM 86-10 and GM 86-19, which are susceptible to MYMV; ML5, which is susceptible to bacterial leaf spot (BLS) caused by *Xanthomonas campestris* pv. *phaseoli*; and ML62, which is susceptible to Cercospora leaf spot (CLS) caused by *Cercospora canescens and C. curenta*. MYMV-resistant check SML668 was planted after every 10 test rows. Agronomic traits and reactions of 200 lines for MYMV, BLS, CLS were recorded.

There was a severe attack of MYMV at PAU. MYMV reactions of these lines were rated, based on the percentage of plants and foliage damaged, using a scale of 0–9 where 0 was highly resistant and 9 was highly susceptible. The rating of the resistant check SML 668 was 5.0 (moderately susceptible) while parents NM 92 and TC 1966 expressed ratings of 6.0 (moderately susceptible to susceptible) and 8.0 (susceptible to highly susceptible), respectively. These results suggest further improvement for MYMV resistance of both NM 92 and SML 668 to MYMV strains in India are imperative. However, more than 70 RILs displayed greater resistance to MYMV compared to the resistant parent NM 92. Among them, 10 lines showed ratings below 2.5 (which corresponds to resistant or moderately resistant) (Fig. 20). Thirty-three lines were rated as 9 (highly susceptible), which is inferior to the susceptible parent TC 1966. MYMV-resistant and susceptible extremes of 200 RILs suggested several quantitative trait loci (QTLs) or interaction of genetic factors from both parents could have been involved for MYMV resistance performance. The 200 RILs will be further reviewed in 2004.

Both bacterial leaf spot (BLS) and Cercospora leaf spot (CLS), and a new mungbean disease 'pod rot' were prevalent during the planting season. Rating of these diseases ranged from 1.5 to 5.0, of which the variations were smaller than those of MYMV disease reaction. These ranges were also close to the ratings of the two parents (Fig. 21). TC1966 expressed resistance to moderate resistance for these three diseases, while NM 92 showed moderate susceptibility to these diseases. Several lines showed resistant characters superior to resistant parent TC 1966 for both CLS and BLS. Additional observations will be carried out for reliable disease profiles of these materials.

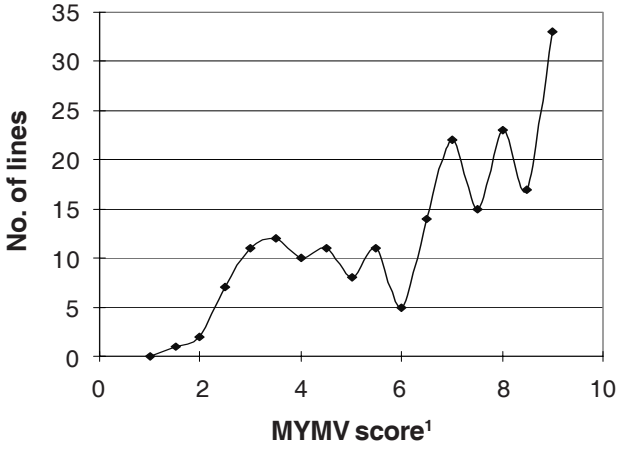

Fig. 20. *Scoring distribution of 200 mungbean recombinant inbred lines for MYMV reaction.*

[1]Based on the percentage of plants and foliage damaged, using a scale of 0–9 where 0 was highly resistant and 9 was highly susceptible. Scores of parental lines NM 92 and TC 1966 were 6.0 and 8.0, respectively.

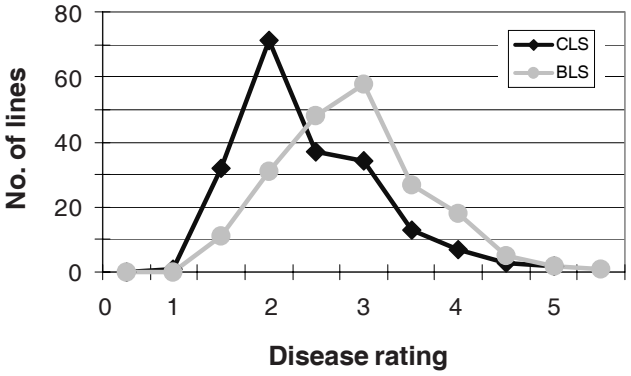

Fig. 21. *Distribution of disease rating of bacterial leaf spot (BLS) and Cercospora leaf spot (CLS) for 200 mungbean recombinant inbred lines.*[1]

[1]Based on the percentage of foliage damaged, using a scale of 0–9 where 0 indicated highly resistant and 9 indicated highly susceptible.CLS ratings for parental lines NM92 and TC1966 were 4.0 and 2.0 respectively; while BLS ratings for these were 4.5 and 2.5.

Agronomic characters of mungbean RILs

A total of 200 recombinant inbred lines (RILs) derived from a cross between MYMV-resistant line NM 92 and bruchid-resistant line TC 1966 (*Vigna radiata* ssp. *sublobata*) were generated for mapping of MYMV- and bruchid-resistant genes. Generally, F_{11} RILs carry mosaic phenotypes inherited from either parent. Since TC 1966 is a wild type of mungbean, agronomic traits such as plant height, branching, leaf size, seed color, seed weight, and yield are distinct from cultivated lines. Phenotypic data of these RILs are useful information for molecular and genetic studies of these traits. This project aimed to collect both reproductive and vegetative characters from these RILs for future molecular mapping studies.

A total of 200 RILs and their parental lines were planted at AVRDC in fall of 2002 and spring of 2003. The plot size for each line was 1 × 5 m^2 with 50-cm row spacing and 5-cm plant spacing. Six plants were randomly harvested from each plot for investigation of growth characteristics, leaf size, leaf area, plant height, leaf fresh weight. and total fresh weight. Areas of 2 m^2 were kept until final harvest for investigation of reproductive traits such as flowering date, seed no./pod, pod no./plant, and 100-seed weight. Seed germination rate was also evaluated by incubating the seeds in wet paper towel at 25 °C. Germination of TC1966 required scarification due to its hard seed coat.

Uniform plant growth was observed within each inbred line. Variation of vegetative growth characters among tested lines are summarized in Table 74. Maximum leaf size and leaf area are comparable to the large-leaf parent NM 92. However, the minimum leaf size and area values were much smaller than those of the other parent TC 1966, suggesting some genetic factor from NM 92 might further reduce leaf growth of TC 1966. Variation of plant height, leaf fresh weight, and total fresh weight ranged beyond the extremes of either parent, suggesting various QTLs may be contributed by both parents. Similar results were also observed in seed no./pod and pod no./plant (Table 74). Flowering date and 100-seed weight values were basically intermediate between parental values.

Germination rates ranged from 10 to 100% with only one-third having rates higher than 80% (Fig. 22). This suggests inhibition of seed germination by seed coat might involve multiple genes or QTLs.

A total of 60 lines produced tendrils, specifically, 24 lines produced one tendril, 13 produced two, and 23 produced three tendrils. This may imply that branching habit in mungbean may involve a few major genes.

Table 74. *Variation of vegetative and reproductive growth characters for 200 mungbean RILs.*

	Min.	Max.	Mean	NM 92	TC 1966
Plant height (cm)	13	67	35	56	29
Leaf size (cm^2)	33	192	93	188	55.8
Total leaf area (cm^2)	99	995	393	818	174
Leaf fresh weight (g)	2.9	49.7	13.6	18.0	19.3
Total fresh weight (g)	11.5	83.6	38.8	57.1	42.9
Germination rate (%)	0	100	57	100	15
Days to flowering	39	60	46	37	50
Seed no./pod	6	13	10	11	9
Pod no./plant	8	43	19	28	22
100-seed weight (g)	1.87	4.75	3.12	5.08	1.79

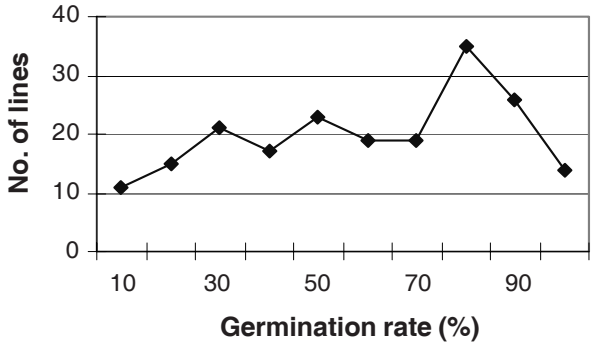

Fig. 22. *Germination rates of 200 mungbean RILs.*

Screening of polymorphic AFLP bands for identification of molecular markers associated with pepper anthracnose resistance

Pepper (*Capsicum* spp.) is one of the most popular vegetables in the world, particularly in Asia and Latin America. During the last decade, the construction of molecular linkage maps has become an essential tool for plant molecular genetics and breeding research. Amplified fragment length polymorphism (AFLP) markers are an excellent source of polymorphisms in eucaryotic genomes and have been useful on genotyping and map construction in several plant species. Anthracnose is one of the most damaging diseases of pepper during the hot-wet season. The objective of this study is to screen polymorphic AFLP bands for the identification of AFLP markers associated with anthracnose resistance in pepper.

By selfing an F_1 hybrid between the female resistant parent CCA0038-9155-5-1 and male susceptible parent CCA9955-15, the F_2 population was constructed. There were a total of 247 F_2 plants. Among them, 79 resistant F_2 plants yielded fruits with average lesion diameters less than 3 mm, and 50 susceptible F_2 plants with the largest average lesion diameters (9.2mm–12.2mm) when inoculated with *Colletotrichum acutatum* (the disease index of the F_2 plants were provided by AVRDC Pepper Unit). The genomic DNA of the pepper was extracted by standard CTAB (hexadecyltrimethyl ammonium bromide) method. AFLP analysis was carried out as described by Vos et al. (1995) using the enzyme combinations *Eco*RI/*Mse*I and *Pst*I/*Mse*I. Three *Pst*I primers, eight *Eco*RI primers, and twenty *Mse*I primers, each with two, three or four selective nucleotides, were used for surveying the AFLP between the two parental lines.

Twenty *Pst*I/*Mse*I primer combinations and 90 *Eco*RI/*Mse*I primer combinations were selected since they were able to provide higher polymorphism rates and generate a reasonable number of total bands for unambiguous scoring between two parents. From these primer combinations a total of 538 polymorphic bands between two parental lines were generated, 83 and 455 from the *Pst*I/*Mse*I and *Eco*RI/*Mse*I primer combinations, respectively. All the AFLP bands were scored as either presence or absence of a polymorphic band (Fig.23). These selected primer combinations will be used to score F_2 populations and identify AFLP markers for pepper anthracnose resistance.

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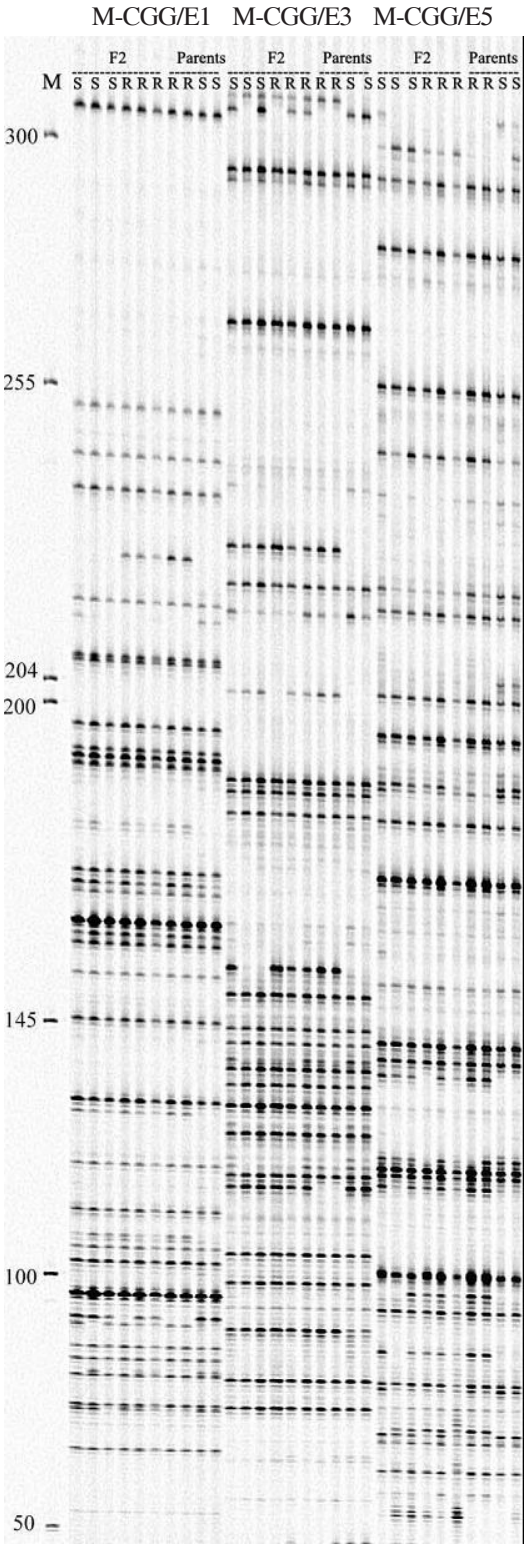

Fig. 23. *The AFLP analysis of susceptible and resistant parents, and F_2 pepper plants.*[1]

[1]Susceptible parent: CCA9955-15; resistant parent: CCA0038-9155-5-1. M: molecular weight marker. Three primer combinations, M-CGG/E1(E-AAC); M-CGG/E3(E-ACA); M-CGG/E5(E-ACC), were used.

Entomology Unit

Production of safer leafy vegetables under nethouses

Everyone wants safer food. This is especially the case with vegetables, where the use of pesticide is very high and some of the crops are consumed fresh. The need to produce attractive vegetables that fetch higher prices encourages farmers to apply prophylactic sprays of pesticides to prevent insect feeding. At the same time, numerous publicized instances of pesticide poisoning have convinced consumers and policy makers to seek ways to reduce pesticide use in vegetable production. At AVRDC we have been testing the use of nethouses and net tunnels since 2001 for production of leafy vegetables. During 2003 we continued this study under nethouses.

The nethouse that we use measures 35 × 21 × 2 m with a frame consisting of 6-cm-diameter galvanized iron tubing covered on all sides and top with 32-mesh nylon netting. The entry to the nethouse is equipped with two double doors, details of which are described in *AVRDC Report 2001*. During 2003 we cultivated five crop cycles. During each cycle, we cultivated a selection of four leafy vegetables, each occupying a quarter of the nethouse. In total, six vegetable species were used: pak-choi, Ethiopian kale, leafy rape, amaranth, lettuce, and kangkong. Crucifers (the first three species) were always rotated with non-crucifers. Observations were recorded on incidence of insect pests and diseases during each crop cycle.

In the first crop cycle (20 February–28 March), amaranth, lettuce, pak-choi and Ethiopian kale were planted; during the second (2 April–1 May), pak-choi, leafy rape, kangkong and amaranth were chosen. During subsequent cycles (13 May–10 June, 8 July–7 August, and 5 September–3 October) we rotated pak-choi and Ethiopian kale with amaranth and kangkong. Heavy rains sometimes prevented us from planting a new crop immediately after the harvest of previous crop. The yields averaged over the seasons were: amaranth, 12.70 t/ha; lettuce, 9.69 t/ha; kangkong, 13.85 t/ha; leafy rape, 11.38 t/ha; pak-choi, 9.79 t/ha; and Ethiopian kale, 8.84 t/ha. Yields were only marginally reduced during heavy rains, especially of crucifers, whereas such effect was not noticeable for amaranth and kangkong.

Common armyworm (CAW), *Spodoptera litura*, affected all crops except lettuce. The insect infestation was present throughout the year with higher levels of damage occurring from May–June. Gravid female moths, which are responsible for spread of the pest epidemic, are large insects unable to pass through the 32-mesh net. However, they have the peculiar habit of laying eggs on nylon netting both at the top and along side walls. The larvae hatching from the eggs, especially those laid on the top, fall on the plants inside the nethouse, thus initiating infestation. Whenever possible, physical removal of these larvae, especially when damage caused by larval feeding is obvious, will negate the use of chemical pesticides. Other pests—thrips, aphids, mites and whiteflies—all of which can pass through 32-mesh netting, were present sporadically but only damage from aphids was visible. Aphids caused significant damage to one crop of amaranth in March–April 2003, but this is highly unusual and we do not suggest use of any pesticide to control these pests. However, CAW will remain problematic and we recommend growers to remain vigilant against this pest.

This concludes the third and final year of our research on safer leafy vegetable production project under nethouses. We have published an illustrative brochure "How to Produce Safer Leafy Vegetables Under Nethouses and Net Tunnels". Copies of this publication can be availed by writing to AVRDC or downloading at <www.avrdc.org/publications.html>.

Production of safer summer tomato under plastic houses

Starting in 2002, we conducted research on production of safer tomatoes under plastic houses during hot-humid summer months, when supplies of this sought-after vegetable is low and prices are high. During this season, heavy rains, flooding, and bacterial wilt (BW) caused by the soil-borne pathogen, *Ralstonia solanacearum*, reduce tomato production in open fields. Whitefly-transmitted geminiviruses (WTG), vectored by *Bemisia tabaci*, have become equally important biological constraints throughout the year. To overcome BW, we grafted tomato seedlings onto BW-

resistant eggplant rootstock (EG203). Two types of tomatoes, fresh market (FMTT904) and cherry (CHT1313) were cultivated; both types are resistant to WTG and moderately tolerant to BW.

They were used in three treatment combinations: FMTT904 alone, FMTT904 grafted on EG203, and CHT501 grafted on EG203. The crop was transplanted in three 22 × 1.5 m plots inside each 25 × 6.5 m plastic house. The structures had a semi-circular top covered with UV-protectant clear plastic. In the center of the semicircular top, a 30-cm portion along the entire length was left free of plastic cover but closed using a 32-mesh nylon net. This was done to facilitate ventilation and reduce build-up of heat inside the plastic house. The ventilation facility was made rainproof by erecting a transparent plastic shade 15 cm high and 50 cm wide over the top. The longitudinal side walls were covered with two layers of 32-mesh nylon netting with a spacing of 10 cm between the nets at the soil level and narrowed gradually until closed at 1.6 m above soil level. One end of the tunnel was closed with a single layer of 60-mesh nylon netting and at the other end we installed double doors, similar to those described earlier for nethouse, utilizing 60-mesh netting. In each of the three plastic houses, one 22-m-long row of each treatment was transplanted on 8 May 2003. The crop was raised using standard cultural practices, including timely application of fertilizers, weeding, pruning, and trellising of vines for easy management and harvest. Yellow sticky traps were hung at several locations above and among the plants to monitor incidence of whitefly. When insect populations increased, we applied insecticides imidacloprid and acetamiprid.

Infestations of common armyworm (CAW) occurred, albeit sporadically. We surmise this to be due to oviposition of this moth on the nylon net that lines the ventilation facilities at the top of the house. CAW larvae were controlled by applications of insecticides binfenthrin, mevinphos and thiodicarb in rotation. Midway through the season, tomato vines showed symptoms of magnesium deficiency.

Blossom end rot, caused by the deficiency of calcium, was a serious problem. To overcome this, we sprayed calcium chloride twice during June. Among the diseases, southern blight (*Sclerotium rolfsii*) was found frequently and late blight (*Phytophthora infestans*) occasionally. We sprayed etridiazole and flutolanil in rotation whenever disease symptoms were visible. For bacterial spot (*Xanthomonas campestris* pv. *vesicatoria*) we sprayed kasugamycin + copper oxychloride twice during July. Symptoms of black leaf mold (*Pseudocercospora fuligena*) were not present during 2003, although this disease was a problem in 2002.

One week after the final sprays of acetamiprid, thiodicarb, kasugamycin and copper oxychloride, we sent marketable size fruit samples to Taiwan Agricultural Chemicals and Toxic Substance Research Institute (TACTRI) for analysis of pesticide residues. On FMTT904, acetamiprid residues were 0.05 ppm (maximum permissible limit, 1.0 ppm), thiodicarb, 0.04 ppm (maximum permissible limit, 1.0 ppm), and on CHT1313, 0.09 ppm of each insecticide. Application of these insecticides do not pose a health hazard to consumers if the crop raised inside the plastic houses is harvested one week after the pesticide application date. Copper oxychloride residues on FMTT904 and CHT1313 tomatoes were 0.82 and 1.82 ppm, respectively. Other chemicals were below detectable limits.

Fruits were harvested five times at the height of summer between 14 July and 20 August. The results of quality of harvested fruits and pest damage are summarized in Table 75. The only visible pest damage to harvested fruits was that of CAW, larvae of which initially fed on foliage but later bore inside fruits. The damage was very minor and occurred in fruits harvested on 5 August in all three plots of one plastic house and one plot of another plastic house. Blossom end rot caused major damage to fruits and was responsible for overwhelming portions of unmarketable fruits. A few fruits were lost to cracking damage. BW damage was not found in any plot. Grafting FMTT904 on eggplant rootstock reduced fruit yield significantly ($t = 3.75$, $P \leq 0.05$)

These results show that it is possible to produce marketable tomato fruits during hot and rainy summer

Table 75. *Yield and marketable quality of tomato fruits grown under plastic houses.*[1]

Treatment	Marketable yield (t/ha)	Unmarketable yield (t/ha)	CAW-damaged fruits (%)[2]
FMTT904	20.27 ± 3.50	3.49 ± 1.81	0.10
FMTT904 grafted[3]	12.45 ± 2.63	32.52 ± 3.92	0.13
CHT1313 grafted[3]	6.07 ± 0.38	0.20 ± 0.04	0.03

[1]Transplanted 8 May 2003 at AVRDC.
[2]Damage was found in all three treatment plots in one plastic house and only one treatment plot in another plastic house.
[3]Plants were grafted with eggplant EG203.

months using minimal pesticides. The residues of pesticides we used were far below the maximum permission limit. We plan to repeat this experiment during summer of 2004 before closing the project.

Identification of chemical attractants in crucifer plants to striped flea beetle

Striped flea beetle (SFB), *Phyllotreta striolata*, is a pest of crucifers worldwide and is especially serious in the tropics. Adult beetles lay eggs near the base of crucifer plants which subsequently hatch into larvae that feed on plant debris in soil before pupating there. SFB adults, however, are crucifer-specific feeders, creating shotholes in leaves that kill young seedlings or reduce yields in established plants. Farmers can control this pest by using large quantities of chemical pesticides to kill adults, but soil-inhabitating larvae are difficult to be killed by such treatments. Since adults of this insect only feed on crucifer foliage, we have been attempting to extract and identify chemicals in crucifer foliage that attracts SFB. Such chemical(s) can possibly be used in controlling SFB without resorting to the use of toxic chemical pesticides. In this regard, we have employed numerous solvents and extraction procedures to isolate and identify these chemicals.

Extraction procedures

Pak-choi (*Brassica rapa* L. cv. *pak-choi*), a crucifer, was raised in the greenhouse and entire aboveground portions of plants were harvested after 4–5 weeks. The following extraction procedures were then used:

Plants were extracted in water by blending in a Waring blender. The slurry was filtered through Whatman #1 filter paper and the filtrate were bioassayed for attraction of SFB adults.

Plants were blended in 1:1 mixture of hexane and acetone. Hexane extract was partitioned by adding water to the mixture in a separatory funnel, which separated the extract into hexane and a water-acetone mixture. Hexane extract was drained and dried by filtering through a plug of anhydrous sodium sulfate. The acetone-water mixture was subjected to flash evaporation until all acetone evaporated, leaving behind only water extract. The water extract was extracted further by ethyl acetate. The hexane, ethyl acetate, and the water extract before and after extraction with ethyl acetate, were bioassayed for attraction of SFB adults.

Plants were extracted in ethyl acetate alone, blending the solvent and plants in a Waring blender, and ethyl acetate extract was bioassayed for attraction of SFB adults.

Plants were extracted in hexane alone, blending the solvent and plants in a Waring blender. The hexane extract was bioassayed for attraction of SFB adults.

Plants were blended with water in a Waring blender and the slurry was subjected to steam distillation by introduction of steam through the slurry. Distillates were collected and aliquots of distillate were extracted with hexane, ethyl ether, dichloromethane, chloroform or toluene. The individual solvent extracts and distillates before and after extraction were bioassayed for attraction of SFB adults.

Potted pak-choi plants were confined in an airtight rectangular acrylic chamber equipped with one inlet and one outlet hole at the top. Two small fans attached to the inner sides of opposing walls facilitated circulation of air within the chamber. The outlet tube was connected to an inlet of a glass aspirator containing a 22-cm-tall, 3-cm-diameter column of hexane, and the outlet of this aspirator was connected to the inlet of a similar aspirator containing acetone. The outlet of the latter aspirator was connected to a source of suction, and air from over the pak-choi plants was sucked continuously into hexane followed by acetone columns for 48 h to facilitate dissolution of plant volatiles in hexane or acetone. The hexane and acetone extracts were bioassayed for attraction of SFB adults.

Pak-choi plants were dipped in hexane, which was confined in a glass beaker for 30 s, and the beaker with plants immersed in solvent was placed in a household microwave oven and run for 30 s. The pak-choi plants were discarded and the extract was poured in a separatory funnel. This resulted in formation of two layers. The small water extract layer at the bottom and large hexane layer at the top were isolated and bioassayed for attraction of SFB adults.

Bioassays of various extracts were performed on SFB adults reared in laboratory on potted pak-choi plants. The insects were denied access to any food for 24 h before bioassay. The extract to be bioassayed was absorbed on a plug of cotton, and solvents were allowed to evaporate. The cotton plug was placed at one end of a 1.2-m-long, 4.5-cm-diameter hollow glass tube. At the opposite end, a cotton plug dipped in solvent only was placed. In the central 20-cm-long de-

tachable portion of the tube, we placed SFB adults. The center of the detachable tube was equipped with an outlet hole in the middle. The outlet was attached to a source of suction. The entire tube was covered with dark cloth. Air from the tube was sucked continuously for 4 h and the numbers of SFB adults congregated around the plant extract or solvent check were recorded. Each such bioassay was repeated at least four times. A similar bioassay was also conducted using intact fresh leaves of pak-choi and *Cleome gynandra*, a closely related non-crucifer plant that is a host to several crucifer-specific insect pests such as *Plutella xylostella*, *Hellula undalis*, and *Pieris rapae*. Check arms of both such tests were left empty.

Fresh pak-choi and *Cleome* leaves attracted significantly more SFB adults than the check (Table 76). Based on the results of this initial test, especially with pak-choi leaves, we pursued our research on isolating chemical(s) in pak-choi that could be responsible for attraction of SFB to crucifers. However, none of the extracts, except polar fraction of microwave-assisted extraction in hexane of pak-choi plants, showed consistent attraction of SFB adults (Table 76). The solid fibers after extraction of pak-choi plants with water also attracted a significant number of SFB adults. We are now pursuing further studies using the polar phase of microwave-assisted extract with the purpose of identification of active chemicals in this fraction.

Table 76. *Influence of various plant materials and extracts on attraction of striped flea beetle (SFB) adults.*

Plant material or extracts	No. of SFB adults attracted: Sample side	Check side	*t*-values
Pak-choi leaves	15.10	1.86	12.03**
Cleome leaves	11.60	4.00	6.29**
Plant fiber after extraction with water	12.25	4.50	8.16**
Polar phase of microwave-assisted extract in hexane of pak-choi	10.67	1.89	10.84**

**All *t* values significant at 1% probability level.

Control of common armyworm in leafy vegetables grown under nethouses

Production of leafy vegetables in nethouses is gaining popularity in East Asia because the structures make it possible to grow these crops throughout the year, especially during the rainy season. Currently farmers are using 16-mesh nets to cover nethouses, but this size of mesh does not exclude diamondback moth and striped flea beetle from entering. Farmers, therefore, still continue to use chemical pesticides as they do in open fields to control these pests. By replacing 16-mesh net with 32-mesh net, installing two double doors perpendicular to each other, and maintaining the integrity of the nets, AVRDC researchers have been able to prevent entry of DBM and SFB inside nethouses, thus reducing the need for applying pesticides. However, no matter whether one uses 16-mesh or 32-mesh nets, common armyworm (CAW), *Spodoptera litura*, remains a problematic pest. CAW moths lay eggs on the net, and larvae hatching from eggs descend inside and damage the crops within the nethouse. If this pest is not controlled in its larval stage, with no natural enemies in the nethouse, the population of CAW may rapidly increase, forcing farmers to use insecticides. During 2003 we studied the oviposition habit of CAW in order to further modify the nethouse structure and exclude the pest.

Flying habit study

In our past studies, we determined the flying height of a related moth pest, beet armyworm (BAW) *Spodoptera exigua*, by pasting 20 cm × 20 cm sticky white boards at 1, 2, 3, and 4 m heights on poles erected around an onion field and then releasing moths downwind. BAW adults readily flew to the onion field and were trapped on the boards. When this technique was tried with CAW, however, it failed to trap the moths. Therefore, instead of sticky traps, we attached a 15-cm-wide strip of nylon net, at 1, 2, 3, and 4 m above soil surface, around a 20 m × 20 m nethouse planted to common cabbage. The upper edge of the two-layer strip was attached to the net, leaving the lower edge hanging loose. CAW adults landed on the walls of the nethouse, then crawled under the nylon net folds, but could not easily come out of folds, eventually dying.

The results of this study are summarized in Table 77. We surmise that the moths caught in a particular fold are for those landing at that height and 1 m below. Over 77% of the insects were trapped at 2 m height—a common height of nethouses in Taiwan. The eggs

they laid up to the 2 m height amounted to 95% of eggs. However, still more than 22% insects flew over 2 m high, and these insects included credible numbers of females. Such high-flying insects are responsible for laying eggs over the nethouses and causing infestation under the net. Since CAW is a highly fecund and mobile insect, a few females can create significant levels of damage.

Table 77. *Capture of common armyworm moths in nylon net folds erected at various heights.*

Fold height (m)	Adults trapped (no.)	Adults trapped (%)	Female moths (%)	Egg masses laid (%)
1	30	68.1	11.4	53
2	4	9.1	2.3	42
3	9	20.5	9.0	5
4	1	2.3	0	0

Effect of height of net barrier on infestation of vegetables inside nethouse

Since our earlier study indicated that CAW moth can fly up to 4 m high but we failed to capture any female moth or egg masses at that height, we compared infestation of this pest to cabbage in two specially constructed nethouses. Both nethouses were 20 × 20 x 2.5 m, with all sides and top covered with 32-mesh net. In one nethouse, however, the height of four walls was extended to 4 m. The added 1.5 m height was wrapped in 16-mesh net since CAW moth cannot pass through such net. Netting material above the height of 4 m was extended and pulled out 40 cm making an angle of 75° against the net wall. This was done to provide CAW moths trying to enter the nethouse with a shelter in the angled area. These angled areas also provided shelter for predators. Chinese cabbage or common cabbage was planted in the nethouses. Soon after planting, at irregular time intervals, we released equal numbers of CAW adults at 20 m downwind from both nethouses. Three such trials were conducted during the year. Two weeks after transplanting of the crop and continuing approximately every week, we observed the number of CAW larvae on 30 randomly selected plants in both nethouses.

The results of the insect infestation are summarized in Table 78. There was no obvious difference in damage to cabbage grown under the nethouses whether the crop was cultivated in a nethouse of 2.5 m height or whether the walls of the nethouse were extended to 4 m in height. The CAW adults obviously were able to fly over the 4 m height and lay eggs on the top of the nethouse, a precursor to initiation of infestation.

We conclude that CAW infestation inside the nethouse cannot be prevented by any practical physical means. Covering the entire top completely with a plastic sheet is one possibility, but such practice would only be feasible in small structures and would increase costs of production. A different approach must be developed to prevent female CAW moths from laying eggs on the tops of nethouses. One approach could be the application of biological pesticides, but few such pesticides are available in the region. Use of chemical pesticide is not advisable due to health hazard and insecticide resistance problems.

Table 78. *Common armyworm damage inside nethouse.*

Observation	Date	Higher barrier	Lower barrier	Higher barrier	Lower barrier
		Larvae/plant		Egg masses/plant	
First	19 Feb.	0	0	0	0
	26 Feb.	0	0.02	0	0
	5 Mar.	0	0.02	0	0
	12 Mar.	0	0.02	0	0
	19 Mar.	0.10	0.02	0	0
Second	07 July	0	0.40	0	0
	24 July	0.04	0.36	0	0
	30 July	0.02	0	0	0
	13 Aug.	0.02	4.50	0	0
Third	23 Sep.	0.46	0.08	0	0
	30 Sep.	1.24	0.30	0	0
	07 Oct.	1.00	7.04	0.02	0
	14 Oct.	5.84	2.68	1.04	0.58
	21 Oct.	42.60	36.86	1.20	1.18
	28 Oct.	76.16	83.80	0	1.34

Identification of oviposition attractants to trap CAW female adults

Whether in open field or nethouse, it is the female moth of CAW that spreads its epidemic. In order to restrict the spread of CAW, all males have to be trapped and killed before they mate with females, or an attractant has to be found to trap females before they lay eggs. For the first option, female sex pheromones, now commercially available, can be used with partial success. The second option, if developed, is likely to give supe-

rior control. Since a CAW female moth visits host plants solely for the purpose of egg laying, the host plants probably are producing oviposition-attracting chemicals.

We attempted to extract these chemicals from susceptible host plants such as castor (*Ricinus communis*) and pak-choi (*Brassica rapa* L. cv. *pak-choi*). Certain varieties of castor have been found to be highly susceptible to CAW and this property has been utilized in controlling CAW on tobacco and chili in India. Among four castor varieties tested, foliage of the Mahyco variety received the highest numbers of egg masses and eggs laid by CAW. We, therefore, used this variety along with a local variety of pak-choi for extracting plant chemicals that will potentially attract CAW for oviposition. A 2.3-m-long, 15-cm-diameter acrylic tube, which included a detachable 0.3-m-long central portion of the tube, was used the study. The plant extract to be bioassayed was placed at one end and the check or extract of the other plant was placed at the other end. Gravid females were placed in the center, and air from within the tunnel was sucked continuously through a hole made in the middle of the detachable central tube for 24–48 h. The tunnel was wrapped in black cloth and maintained in the dark. The number of egg masses and total number of eggs laid at either end were recorded to judge the oviposition attracting or repelling property of the plant extracts. Fresh leaves of both young and older castor plants attracted similarly high numbers of egg masses and eggs. Castor leaves had more egg masses and total eggs than cabbage leaves, but pak-choi leaves suffered from more feeding CAW larvae compared to castor leaves. When leaf surface chemicals of both castor and pak-choi were extracted in hexane by microwave-assisted extraction procedure (see procedure under earlier report for striped flea beetle), and bioassayed for CAW egg laying, insects laid substantial numbers of eggs (>800). Presence of this extract inside the wind tunnel seemed to have stimulated oviposition but often eggs were laid randomly all over the inner surface of the wind tunnel. Insects laid substantially greater numbers of eggs on the pak-choi side compared to the castor side of the tunnel. Because of the expected wide range of variation in such studies, it was not possible to get statistically significant differences between the two samples. We are, however, certain that both castor and pak-choi have chemicals that attract CAW for laying eggs and more efforts are needed to isolate and identify these chemicals.

Evaluation of parasitism of diamondback moth by introduced pupal parasitoid, *Diadromus collaris*

In highland areas of Asia, diamondback moth (DBM), *Plutella xylostella* (L.) can be effectively controlled with the larval parasitoid *Diadegma semiclausum*. In the lowlands, the larval parasitoid *Cotesia plutellae* is present, but it is much less effective in controlling DBM. The presence of other crucifer pests such as cabbage webworm (*Hellula undalis*), cabbagehead caterpillar (*Crocidolomia binotalis*), and striped flea beetle (*Phyllotreta striolata*) in the lowlands affect biological control of DBM there, because pesticides used for the control of these pests will also kill *C. plutellae*. We are, therefore, looking for a high temperature-tolerant pupal parasitoid that could survive in the lowlands. This pupal parasitoid will not compete with *C. plutellae*, but rather supplement it by killing DBM pupae, the larvae of which escaped *C. plutellae* attack. Through a collaborative project with the International Centre of Insect Physiology and Ecology (ICIPE) on biological control of DBM in southern and eastern Africa, we have been exploring potentially high temperature-tolerant species in Europe. This work is done by the European Biological Control Laboratory (EBCL) of the United States Department of Agriculture (USDA). Late in 2002, EBCL provided us with pure culture of *Diadromus collaris*, a pupal parasitoid of DBM, which they collected in Turkey. In 2003, we conducted laboratory tests to evaluate the level of high temperature tolerance for *D. collaris*, and field tests to study its potential in combating DBM.

Heat tolerance

Fresh pupae of DBM and fresh adults of *D. collaris* were collected from AVRDC's insect rearing facilities. Both pest pupae and the parasitoid adults were held at 15, 20, 25, 30, and 35°C for 4 h to acclimatize them at these temperatures. One hundred DBM pupae were placed on cabbage leaves in each of three acrylic jars (15 cm in diameter, 30 cm in length) and then exposed to two pairs of mated *D. collaris* adults. Insects were held at specific temperature environments 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 five temperatures: 15, 20, 25, 30, and 35°C. A total of four such tests were conducted.

The extent of parasitism of DBM by *D. collaris* is shown in Table 79. The rate of parasitism in general

was quite low, which is not unusual for this pupal parasitoid. We observed a similar trend with *D. collaris* imported from Uzbekistan in 2000. Except for one test, the level of parasitism between 20 to 30°C was similar. In all tests, parasitism dropped substantially at 35°C. This strain of *D. collaris* thus appears to be similar to the Uzbekistan and Taiwan strains, and is not suitable for controlling DBM in most lowland tropical regions.

Table 79. *Influence of temperature on parasitism of DBM pupae by* Diadromus collaris collected from Turkey.

	Parasitism (%) in various tests			
Temp. (°C)	1	2	3	4
15	6.3 ± 1.2	17.0 ± 3.6	2.0 ± 2.0	1.7 ± 1.2
20	19.0 ± 2.0	14.3 ± 5.5	7.0 ± 3.5	6.0 ± 3.6
25	26.3 ± 13.6	10.0 ± 3.5	11.7 ± 5.5	12.0 ± 7.0
30	27.3 ± 8.6	20.0 ± 14.7	12.0 ± 8.0	9.7 ± 1.2
35	2.7 ± 1.2	1.0 ± 1.0	0.0 ± 0.0	2.0 ± 1.0

Parasitoid efficiency in the field

In the field, efficacy of Turkey strain of *D. collaris* was studied in two 20 × 20 × 2.5 m nethouses located 10 m apart. Both structures on all four sides and the top were covered with 16-mesh nylon netting. A local variety of common cabbage was transplanted inside each nethouse. Three weeks after transplanting, at irregular intervals, we released equal numbers of DBM larvae, pupae and adults inside each cage to initiate pest infestation. Two weeks after initiation of release of DBM, we initiated release of adults of *D. collaris* in one cage; the other cage was maintained as a check. Starting 10 days after initiation of release of *D. collaris* and once a week thereafter, we observed 30 plants at random within each nethouse and recorded the number of DBM larvae and pupae. All the pupae were brought to the laboratory and maintained in a cage until either DBM or parasitoid adults emerged. The percent parasitism was calculated by dividing the number of parasitoid adults emerged by the sum of parasitoids and DBM adults emerged and multiplying the product by 100. We also recorded the number of CAW larvae found in sampled plants. At times CAW can cause serious damage to leafy vegetables inside nethouses.

The results of infestation of common cabbage by DBM and CAW and level of parasitism of DBM by *D. collaris* are summarized in Table 80. DBM infestation increased gradually in both cages as the season progressed. At the height of infestation, the pest population in the cage with *D. collaris* was less than in the check cage. At full crop maturity, the DBM population in the check cage declined because mature plants are less preferred than young plants by the pest. In the cage with *D. collaris*, the decline in DBM population was much greater than in the check cage. The parasitism of DBM pupae by *D. collaris* increased gradually during the season reaching up to 85%, which is unusually high for this parasitoid. It must be mentioned though that the experiment was conducted during relatively cool winter months.

CAW damage was not significant and unlikely to have contributed to yield loss. Individual cabbage head weight and total yield was marginally higher in the cage with parasitoids.

Table 80. *Influence of* Diadromus collaris *on parasitism and infestation of DBM, and cabbage yield in nethouses.*

	Check cage		*D. collaris*-release cage		
Item	DBM larvae + pupae/ plant	CAW larvae/ 30 plants	DBM larvae +pupae plant	Parasitism (%)	CAW larvae/ 30 plants
Date					
19 Feb.	1.16	0	1.16	15.4	0
26 Feb.	1.00	0	1.50	72.0	1
05 Mar.	7.32	0	3.72	48.0	1
12 Mar.	10.62	0	8.10	57.0	1
19 Mar.	2.88	5	0.44	85.0	1
Marketable yield					
Weight (kg/head)	2.23		2.39		
Yield (t/ha)	44.65		47.53		

Mating and sex pheromone related behavior of eggplant fruit and shoot borer in the presence of synthetic sex pheromone

The use of synthetic sex pheromone is playing an increasingly important role as a component of IPM, especially in managing high-value and pest-sensitive vegetable and fruit crop insect pests. Sex pheromone is an essential component in the AVRDC-developed IPM of eggplant fruit and shoot borer (EFSB), *Leucinodes orbonalis*, a damaging pest of eggplant in South Asia where this crop is one of most important vegetables. Sex pheromone of EFSB is now commercialized in India and Bangladesh but there is need to refine its use to make it even more effective and economical for farmers to use. The sex pheromone of EFSB consists of 100:1 mixture of two chemicals (E-11-hexadecenyl acetate (E-11-16:AC) and E-11-hexadecenol (E-11-16:OH)) both of which are "cis" or "E" form chemicals. The purpose of this research was to study whether the presence of elevated concentrations of sex pheromones in the environment, which occur normally when these chemicals are used commercially, affect the behavior of female or male moths and whether the trans or 'Z' isomers of the sex pheromone can affect mating of EFSB.

Effect of synthetic sex pheromone on calling behavior of females and males

Two newly emerged female or male moths were placed in each of two 16-L clear plastic containers. In one container we placed a pheromone lure containing 3 mg pheromone whereas the other container had no pheromone lure. The lids of the containers were closed tightly to prevent escape of pheromone and they were placed in a darkroom 2 m apart. Starting at 1900 HR, we observed the containers every 10 min for the calling behavior of female moths, which is characterized by the raising of the distal part of the abdomen and movement of abdominal tips in that position, presumably in preparation for release of sex pheromone chemical, which is essential for mating. Mating behavior in males was also observed, characterized by rapid movement of antennae, fluttering of wings, and short flights. A red touch light was used while observing the insects. The observation continued until 2400 HR, when the mating period of EFSB normally ceases. In all cases we observed six female and four male moth pairs with and without sex pheromone treatments.

The results of the initiation and duration of calling behavior of female moth in the presence and absence of sex pheromone are summarized in Fig. 24. In the check, calling behavior invariably started at 1930 HR and lasted just past midnight. In the presence of synthetic sex pheromone the initiation of calling behavior was delayed to at least until 2115 HR and in some cases well past 2300 HR or it ceased until well past midnight. High concentration of pheromone in the environment appears to have suppressed the rhythm of production of normal sex pheromone in female moths.

In the case of male moths, in the presence of sex pheromone, insects showed normal pheromone response starting at 2000 HR and such response continued until midnight when the observation was discontinued. In the absence of pheromone no such sustained behavior was evident. The initiation of mating behavior in males was always later than initiation of calling behavior in EFSB females.

Effects of 'E' and 'Z' isomers of sex pheromone on mating and egg laying in EFSB

We placed one newly emerged pair of EFSB male and female moths together in each of two 15-cm-diameter, 30-cm-long acrylic cylinders. Both ends of the cylinder were wrapped in 32-mesh net nylon net. In one cylinder we placed a normal pheromone lure containing 3 mg of 100:1 mixture of 'E' isomers of both chemicals ('E' type) and the other cylinder was without a lure and kept as a check. The two cylinders were placed in two separate darkrooms. A cotton plug dipped in sugar solution maintained in a small petri dish served as food to adults. Starting at 1900 HR, we observed insects once every 30 min and recorded the time when insects started mating and the duration of each mating. These observations continued for two consecutive nights. On the third day, we removed female adults and placed them in an oviposition chamber for laying eggs. The oviposition chamber consisted of a 15-cm-diameter, 30-cm-long acrylic cylinder, the inner sides of which were wrapped in 32-mesh nylon net. A cotton plug dipped in honey was provided as food and a fresh eggplant shoot, the cut portion of which was dipped in water, was placed inside the chamber. After 48 h we collected and recorded the number of eggs laid by each female. We maintained the eggs on moist filter paper in a petri dish and recorded the number of larvae emerged. We performed the whole experiment using four pairs of EFSB adults with pheromone and

four pairs without pheromone. An identical experiment was conducted with lures made from 'Z' isomers of both components utilizing 600µg: 6 µg of Z-11-16:AC : Z-11-16:OH.

The results of mating duration, egg laying, and eggs hatching utilizing normal 'E' isomer pheromone and 'Z' isomer mixture are summarized in Table 81, respectively. The presence of relatively high concentrations of sex pheromone obviously resulted in mating failure resulting in the production of infertile eggs. This happened when we used normal pheromone as well as 'Z' isomer pheromone. In our earlier study, we observed adverse effects of high concentrations of normal pheromone in calling behavior of females, which presumably resulted in failure to produce sex pheromone, and thus, in failed mating. It is likely that 'Z' isomer pheromone also causes similar adverse effect on pheromone production in EFSB female moth. Whether Z isomer pheromone can also attract EFSB males needs to be investigated.

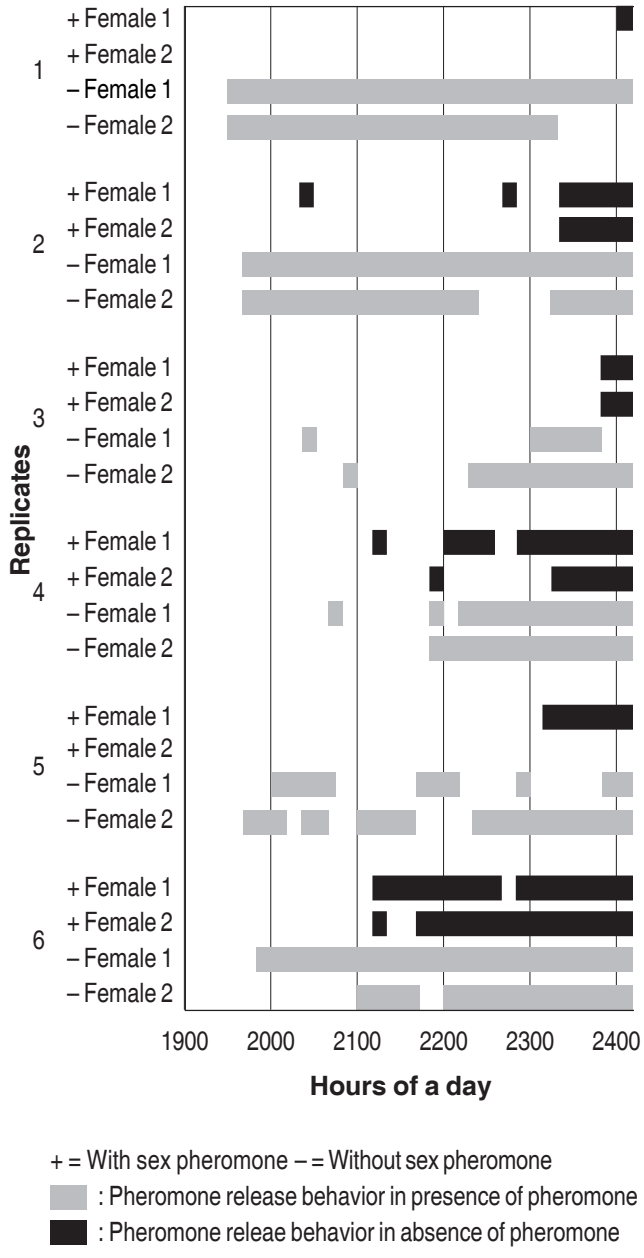

Fig. 24. *Influence of sex pheromone of EFSB on pheromone release behavior of EFSB females.*

Table 81. *Mating success and egg production of EFSB mating pairs in the presence and absence of sex pheromone, and Z analog of EFSB sex pheromone.*

Treatment	Insect pairs	Eggs laid	Larvae emerged	Egg hatch (%)
Without pheromone	1	155	119	76.8
	2	140	125	89.3
	3	216	149	69.0
With pheromone	1	11	0	0
	2	18	0	0
	3	22	0	0
Without Z analog	1	98	69	70.4
	2	49	46	93.9
	3	133	122	91.7
	4	81	63	77.8
With Z analog	1	27	0	0
	2	1	0	0
	3	6	0	0
	4	0	0	0

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Bacteriology Unit

Transgenic tomato plants expressing Arabidopsis *NPR1* gene confer enhanced resistance to a broad spectrum of diseases

Genetic engineering of disease resistance through transferring plant defense-related genes has been a well-adapted approach. Among the strategies, the employment of systemic acquired resistance (SAR) is of special interest. In an incompatible plant-pathogen interaction, SAR is established in uninfected parts of the plant for resistance to a broad spectrum of pathogens. This resistance is in addition to the immediate activation of a whole complex defense network and hypersensitive response that blocks pathogen growth at the site of initial infection. SAR is long lasting and often associated with local and systemic accumulations of salicylic acid and an induced expression of a number of defense-related genes, including a group of pathogenesis-related genes. Therefore, more durable resistance to a broader spectrum of pathogens may be expected from inducing multiple facets of defense reactions that are more closely related to the natural defense mechanisms. A key regulatory gene, *NPR1*, has been identified in Arabidopsis involved in the signal transduction of SAR leading to general acquired resistance responses. Overexpression of this gene in Arabidopsis and rice could lead to a non-specific resistance to certain fungal and bacterial diseases. Therefore, the objective of this study is to explore the potential of employing Arabidopsis *NPR1*, for genetic engineering of enhanced resistance/tolerance to multiple diseases in tomato.

The transgenic lines were generated and molecularly characterized in the Institute of BioAgricultural Sciences, Academia Sinica, Taiwan. The tomato line used for the transformation was CL5915-93D4-1-0-3 (CL5915), a highly heat-tolerant line that has been used as a parental line for generating heat-tolerant hybrid cultivars. Based on the transgene transcript levels, the transgenic lines could be classified into three groups: (1) lines 9, 26, and 27 were high transgene expressers and (2) line 49 was a medium transgene expresser, each based on Northern blot analyses; and (3) lines 14, 46 and 48 were low transgene expressers in which transgene transcripts could only be detected by reverse transcription polymerase chain reaction (PCR). The expected size of the transgene protein in most of the transgenic lines (except Line 14), but not in wild-type plants was detected by Western blot analysis using an antiserum raised against *NPR1* recombinant proteins. These results indicated that the transgene expression patterns were inheritable, and that no transgene silencing occurred in the successive generations of the transgenic lines.

For future adaptation of the promising transgenic tomato in the tropics, important diseases of tomato were selected as our evaluation targets. These included fungal diseases such as Fusarium wilt (FW) caused by *Fusarium oxysporum* f. sp. *lycopersici*, gray leaf spot (GLS) caused by *Stemphylium solani*, and late blight (LB) caused by *Phytophthora infestans*, bacterial diseases such as bacterial spot (BS) caused by *Xanthomonas campestris* pv. *vesicatoria* and bacterial wilt (BW) caused by *Ralstonia solanacearum*, and viral diseases such as cucumber mosaic virus (CMV), tomato mosaic virus (ToMV), and tomato yellow leaf curl virus (TYLCV). Disease evaluations were conducted at seedling stage following routine protocols used at the AVRDC. The isolates used were Fol-34ssl (race 2) for FW, Pi39A for LB, Pss4 (race 1, biovar 4) for BW, and XVP28 (race P1) for BS. Tomato varieties resistant and susceptible to each disease were included in each evaluation as controls to ensure reliability of results. Seedlings were raised in 2-inch pots with pasteurized potting mixture, except for FW where seedlings were grown in plastic trays with cell size of 4 × 4 cm. For all the evaluations, plants were kept in a greenhouse with mean temperature at 28°C, except for FW (25°C) and LB (20°C). All evaluations were conducted at the R1 and R2 stage with 12 to 24 plants following complete randomized design. Except in the case of BW, evaluations followed randomized complete block design (RCBD) with 3 replications and 12 plants per replication. Two statistical methods were used to check whether the transgenic lines performed differently from the wild-type plants, CL5915, or other control varieties. For BW screening, the percentage data were transformed by arcsin square root for ANOVA and means comparison. For the other diseases with rating scores, the Mann Whitney nonparametric U test was conducted to test the null hy-

pothesis that the ratio of CL5915 to wild-type plants across the rating scores was equal to the ratio observed for the transgenic lines.

Seven transgenic lines at R1 stage and three transgenic lines (Line 9, 14 and 26) at R2 stage were subjected to the disease evaluation. Tomato CL5915 originally possessed resistance to ToMV and all of the tested R1 and R2 transgenic lines remained resistant to ToMV. When challenged with TYLCV, CMV, and the pathogens of LB, all R1 lines performed similarly with CL5915. However, the tested R1 transgenic lines exhibited significant levels of enhanced resistance to the pathogens of FW and BW (Table 82) and minor levels of enhanced resistance to BS and GLS. Selected R2 lines derived from the R1 lines showing enhanced resistance were evaluated for their response to the same eight diseases. The results were very similar with that of the R1 lines (Table 82), where significant enhancement on the resistance to FW and BW, moderate enhancement on the resistance to GLS and BS, and no enhanced resistance to LB, TYLCV and CMV were observed. R2 lines with specific disease abbreviations in their codes were derived from individual plants that conferred resistance to the specific diseases in the R1 screening. The other R2 lines were advanced without any prior selection. Results showed that R2 lines derived from these two ways behaved similarly. However, not all the R2 lines derived from the same R1 line exhibited similar patterns of enhanced resistance. For example, only one of the fourteen derived R2 lines showed significantly enhanced resistance to BW, and surprisingly, most of the fourteen derived R2 lines showed significantly enhanced resistance to FW, which was not observed in the original R1 lines. In addition, although no apparent correlation between the transgene expression levels and the enhanced resistance to individual diseases was observed in R2 lines, transgenic lines that accumulated higher levels of *NPR1* proteins tended to confer more significant enhancement on a specific disease or a broader spectrum of enhanced resistance. For instance, Line 9-BW54 and 26-36, which expressed high levels of *NPR1* proteins,

Table 82. *Evaluation of transgenic tomato planting expressing* NPR1 *on their responses to pathogens of Fusarium wilt (FW), gray leaf spot (GLS), bacterial wilt (BW), and bacterial spot (BS). Data presented are maximum severity of each disease.*[1]

R1 lines	FW[2] R1 / CL5915	BW[3] R1 / CL5915	R2 lines	FW[2]	GLS[2]	BW[3]	BW2[3]	BS[2]
9	2.2 / 7.6 **	50.0 / 91.7 *	9-11	3.2 **	3.0 **	25.0 **	33.3 **	3.2 NS
14	7.1 / 7.6 NS	16.7 / 91.7 *	9-34	2.1 **	2.8 **	58.3 NS	NT[4]	3.5 NS
26	0.6 / 7.2 **	33.3 / 100.0 *	9-FW51	3.0 **	2.6 **	33.3 *	25.0 **	2.3 **
27	0.3 / 7.2 **	75.0 / 100.0 NS	9-BW54	1.0 **	2.4 **	25.0 **	33.3 **.	2.7 NS
46	8.3 / 6.5 **	66.7 / 91.7 NS	14-15	3.9 *	3.4 **	41.7 NS	NT	3.2 NS
48	6.4 / 6.5 NS	100.0 / 91.7 NS	14-25	2.8 **	3.8 NS	41.7 NS	NT	3.2 NS
49	6.5 / 6.5 NS	33.3 / 91.7 *	14-31	5.2 NS	3.7 NS	50.0 NS	NT	3.3 NS
R[1]	0.0	11.3	14-32	2.6 **	2.9 **	41.7 NS	NT	2.7 NS
S[1]	9.4	100.0	14-BW54	3.2 **	3.2 **	25.0 **	29.2 **	3.2 NS
			26-36	0.6 **	3.2 **	25.0 **	29.2 **	3.2 NS
			26-FW51	2.5 **	3.4 **	25.0 **	58.3 **	3.3 NS
			26-FW52	2.6 **	3.3 **	33.3 *	33.3 **	2.8 NS
			26-BW54	3.8 *	3.5 **	58.4 NS	45.8 **	3.0 NS
			CL5915[1]	5.7	3.9	58.3	95.8	3.3
			R[1]	0.2	0.4	8.3	12.5	1.0
			S[1]	8.5	4.0	100.0	100.0	3.3

[1]Varieties resistant (R) and susceptible (S) to each disease were used as controls. They were MH1 (R) and Bonny Best (S) for FW, UC82-L (R) and Bonny Best (S) for GLS, Hawaii 7996 (R) and L390 (S) for BW, and Hawaii 7998 (R) and Bonny Best (S) for BS. Data of the control varieties in the R1 evaluations were means over trials.

[2]Data presented were mean severity scores. Results of the Mann Whitney U non-parametric test were marked as nonsignificant (NS) and significantly different at $P \leq 0.05$ (*) or 0.01 (**) levels. Comparison of each R1 line was made with CL5915 in the specific trial.

[3]Data presented were mean percent wilted plant. The results of mean comparison by LSD were marked as nonsignificant (NS) and significantly different at $P \leq 0.05$ (*) or 0.01 (**) levels.

[4]NT = not tested.

conferred similar levels of FW resistance with MH-1, in addition to the enhanced resistance to BW and GLS. Line 9-BW51, which also expressed high level of *NPR1* proteins, displayed not only enhanced broad-range resistance to FW, GLS and BW, but also increased resistance to BS.

In summary, we demonstrated that the expression of a heterogeneous *NPR1* in tomato could effectively activate certain defense signal transduction pathways leading to enhanced non-specific resistance to important fungal and bacterial pathogens. Furthermore, although most *NPR1*-transgenic tomato plants conferred enhanced resistance to a broad range of diseases, no gene silencing nor deleterious effects on plant growth and development were observed over three generations (R0 to R2). These transgenic lines could be utilized further in breeding for resistance to multiple diseases, particularly viral diseases.

Characterization of *Ralstonia solanacearum* strains isolated from pepper in Taiwan

Bacterial wilt (BW), caused by *Ralstonia solanacearum,* is an important disease for pepper production in the hot, humid tropics. The disease restricts the flow of water within the plant and complete yield loss is possible. The soil-borne pathogen can survive in the soil for a long time and has very wide host range that includes several hundred species of plants belonging to 44 families. Sowing resistant varieties would be an efficient way for farmers to manage this disease and AVRDC has identified varieties that resist a single Taiwanese strain of the pathogen. It is known that the strains isolated from tomato are highly diverse both in genotypes and in their aggressiveness; however, little is known on the diversity of pepper strains. Moreover, the resistance to BW in tomato has been determined to be location-specific and strain-specific; this is not known with pepper. Therefore, the objective of the study is to characterize pepper BW strains collected in Taiwan and applying the results to assess the stability of the identified resistant varieties.

Twenty-nine BW strains collected from 1975 to 1997 in main pepper production areas in Taiwan were used in the study. Strains were preserved in 30% glycerol at –80 °C and cultured first on 2, 3, 5-triphenyl tetrazolium chloride (TTC) medium and then on 523 medium for preparing inoculum. The biovar of each strain was determined based on Hayward's method.

Variations of aggressiveness among strains were evaluated by inoculations on a moderately resistant pepper line, PBC142 (Pant C-1). Inoculations were conducted on 28-day-old seedlings. The roots of each seedling were severed with a knife by cutting into soil along one side of the plant. Then, a 30-ml suspension (10^8 cfu/ml) of each strain was poured over the severed roots. Inoculated plants were kept in a greenhouse with mean temperature at 28°C. Symptom severity was rated over time until 28 days after inoculation using a scale from 0 to 5, where 0 means no symptoms and 5 means complete collapse. A final disease index (DI) was calculated following Kelman and Winstead formulas and used for cluster analysis with the average linkage method to group the strains based on their aggressiveness. Several aggressive strains were selected to evaluate the stability of a set of 12 resistance sources with the same inoculation method. A combined analysis of variance was conducted to test the effects of disease index (H), strain (S) and H × S. Genetic variations among strains were assessed based on the genomic fingerprints revealed by the repetitive element PCR with the BOX1A primer, which was derived from the BOX element. Genomic DNA from each strain was extracted following the method of Jaunet and Wang. The 25-µl reaction mixture consisted of 15.5 µl of ddH_2O, 2.0 µl of dNTP (2.5mM), 2.5 µl of 10X buffer (Mg^{2+} included), 3.0 µl of primer (10 pmol/µl), 1.0 µl of DNA polymerase (2U), and 1.0 µl of purified DNA. The PCR programs is: 95°C for 7 min, followed by 30 cycles with 94°C for 1 min, 53 °C for 1 min, 65°C for 8 min, and 65°C for 15 min. The presence or absence of a band at each position along a lane was converted to binary data (1 for presence and 0 for absence). The Nei and Li coefficient of similarity was calculated by NTSYS-pc (version 2.1; Exeter Software). The number of each haplotype was used in an analysis of molecular variance (AMOVA) to determine the factors related to genetic variability.

Large variations in aggressiveness were observed, with the final DI ranged from 3 to 82% among the tested strains on PBC142. Results of cluster analysis suggested the grouping of the 29 pepper strains into 4 pathotypes, i.e. strains with similar aggressiveness. The mean DI of each pathotype was 43% (11 strains), 25% (8 strains), 22% (3 strains), and 10% (7 strains). A total of 18 and 11 strains belonged to biovar 3 and 4, respectively, with the mean DI of 55.4% and 44.6%.

To determine their stability, 12 identified resistant lines were inoculated with two strains (Pss272 and

229) from the most aggressive pathotype and Pss71 (the strain used to identify the resistant lines). The mean DI over entries for Pss272, Pss229, and Pss71 were 22.8%, 19.6%, and 9.0%, confirming the high aggressiveness of Pss272 and Pss229. Statistical analyses indicated the significance of entry, strain, and entry × strain effects ($P < 0.001$). PBC1347, PBC204, PBC473, PBC384 and PBC375 had good stability with less than 5% DI over strains, while PBC535 and PBC631-B showed good resistance to Pss71 but not to the other strains (Table 83).

BOX1A primers revealed large genetic variations among the tested strains. Twenty-three bands were scored, ranging from 350 to 2100 bp, and 17 haplotypes were identified among the 29 pepper strains. Mean similarity coefficient among strains was 0.77.

Table 83. *Evaluation of resistance to* R. solanacearum *strains with different aggressiveness in pepper.*

Entry	Mean disease index[1]		
	Pss272	Pss229	Pss71
PBC384	0.0 d[2]	4.0 de	0.0 c
PBC473	0.0 d	2.7 de	0.0 c
PBC1347	0.0 d	0.0 e	0.0 c
PBC204	1.0 d	0.0 e	0.0 c
PBC375	2.7 d	1.0 de	0.0 c
PBC631-A	7.3 c	1.7 de	1.0 c
PBC066	17.3 c	6.7 de	1.0 c
PBC535	18.3 c	27.7 c	0.7 c
PBC743	19.3 c	7.7 d	1.7 c
PBC385	21.7 c	1.7 de	0.0 c
PBC631-B	55.7 b	26.0 c	0.7 c
PBC067	60.3 b	76.7 b	23.3 b
PBC1367	94.7 a	99.3 a	88.7 a

[1]Mean disease index recorded at 28 days after inoculation. Disease index was calculated following $[(N_0*0+N_1*1+N_2*2+N_3*3+N_4*4+N_5*5) / (N_T*5)]*100\%$, where N_0 to N_5 were the number of plants in each severity scale and N_T is the total number of plants.

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

The degree of variation among the pepper strains was similar with that of the tomato strains in Taiwan (0.69) reported by Jaunet and Wang in 1999. Three clusters were identified by the cluster analyses of SHAN and the average linkage method with the distribution of 16, 10, and 3 strains over clusters. The AMOVA indicated that genetic variability was not related with pathotype or biovar, whereas almost the entire variation originated from within each pathotype or biovar (Table 84). Other factors important in differentiating the population and determining the trends of evolution of the pathogens will need to be identified at a later date.

This study revealed the large variation of the Taiwanese pepper strains on genotype and in aggressiveness. No relationship was identified between the two variations. Since resistance to bacterial wilt in pepper could be strain-dependent, evaluation over several strains and locations will be necessary in determining the stability of the identified resistant varieties. Efforts are ongoing to determine the variation and relatedness of pepper strains present in other Asian countries.

Table 84. *AMOVA showing the biovar and pathotype effect on the genetic variability within* R. solanacearum *strains isolated from pepper*

Source of variation	Variance component	% of total	*P*[1]
Among biovar	–0.008	–1.65	0.77
Within biovar	0.474	101.65	
Among pathotype	0.009	1.90	0.07
Within pathotype	0.464	98.10	

[1]Probability of having larger values than those observed with 1000 randomizations of the different treatment.

Farmer's knowledge, practices, and sources of information on managing tomato bacterial wilt

Bacterial wilt (BW) caused by *Ralstonia solanacearum* is a major constraint for tomato production in the hot, humid tropics. The pathogen is soilborne, can survive in the soil for a long period, and can be transmitted via water, soil, and seedlings. It has a wide host range and is highly variable. All these properties make the control of this disease a difficult task. No effective chemicals or stable resistant varieties are available; therefore, an integrated approach in managing BW is important. Currently, research efforts focus on breeding for genetic resistance, grafting with resistant rootstock, and applying soil amendments. Many practices routinely applied by farmers may also contribute to managing the disease, such as crop rotation and water management. The objective of this study is to understand farmers' knowledge on BW, information sources they use, their current management practices, and their potential acceptance of control methods. The information collected will be valuable in for-

mulating strategies for disseminating integrated management technology and to identify future research directions.

Production sites located in southern (Kuantian, Tainan; KT) and northern (Chiunglin, Hsinchu; CL) Taiwan were chosen. Tomato is grown in both sites, usually in rotation with rice. The climate, production system, and ethnic group differ between the two sites, enabling us to explore potential influences of agro-ecological and cultural settings on the farmers' practices and knowledge. Eighty-seven farmers who planted tomato in 2000 and 2001 were randomly selected with the assistance of the local farmer associations. The survey was conducted during the fall of 2002.

Tomato farmers both in KT and CL are relatively old, literate, and highly experienced in growing tomato (Table 85). In CL, tomato production covers a greater share of overall farm area and contributes more to overall farm income than in KT (Table 85). When asked to state their biggest constraint in tomato production, 38.8% of farmers in KT considered marketing and 36.7% considered diseases. Nearly half (48.6%) of farmers in CL stated that diseases are their most important constraint. Based on a set of photos showing major diseases in tomato production, 35.4% of KT farmers identified tomato leaf curl as their major disease problem, 26.5% stated southern blight, and 24.5% felt it was bacterial wilt; while 48.5% of CL farmers identified bacterial wilt as their major disease problem, with tomato leaf curl selected by 20.6% of farmers. The mean yield loss due to BW during 1999 to 2001 ranged from 27.2 to 31.6% in KT and 18.3 to 24.4% in CL. It is noteworthy that many CL farmers consider BW as the most important disease although their average yield loss due to BW was lower than in KT. This may be due to the importance of their tomato crop for their income.

CL farmers were better in diagnosing BW. About 70% of the farmers could associate the wilting or vascular browning symptoms with BW, while only 60% of KT farmers could do the same. Most farmers take action when the disease occurs (Table 86). Although pesticides are ineffective, some farmers apply them. When removing the infested plants, most farmers know they should not leave them in the plot to prevent further spread of the pathogen. Most farmers state that if encountering the disease they would make some changes for the next crop, including rotating plots, varieties, and/or other management practices (KT: 82.4%; CL: 92.6%). This indicates that farmers are eager to manage the disease and that the efficacy of their current practices may not be satisfactory.

Table 85. *Profiles of farmer-respondents, 52 farmers in Kuantian (KT) and 35 farmers in Chiunglin (CL), Taiwan, Fall 2002.*

Category	KT	CL
Age	57.9	59.6
Education (0/ G9/ above)	11.5/ 78.9/ 9.6%	2.9/ 71.4/ 25.7%
Members of farmer association	94.2%	77.1%
Tomato growing experience (years)	11.8	17.2
1 to 2 crops per year	94.2%	88.2%
Importance of tomato		
• Share of agriculture land in tomato production	19%	35%
• Grew tomato for income	34.0%	59.5%
• Share of tomato income among agriculture income	12.5%	58.6%

Table 86. *Disease management practices followed by farmer-respondents' in controlling tomato bacterial wilt in infested crops, Kuantian (KT) and Chiunglin (CL), Taiwan, Fall 2002*

Management methods	KT	CL
1. Remove diseased plants and bring them out from the plot	31.6	47.4
2. Water management (reduce irrigation frequency or avoid water movement in diseased areas)	31.5	22.8
3. Spray or drench pesticides	14.7	12.3
4. Do nothing	11.6	10.5
5. Remove diseased plants and leave them in the plot	4.2	1.8

Crop rotation appears to be a routine practice, as the majority of farmers rotate plots every crop or every year (KT: 88.5%; CL: 79.4%) and farmers indicate that the main reason for rotating crops is to prevent disease infestation (KT: 80.4%; CL: 77.4%). Such a practice can contribute positively to reducing soilborne diseases and improving soil management overall, and thus, should be encouraged.

Considering the potential transmission routes of the pathogen, attempts were made to correlate the yield loss caused by BW with the previous tomato planting time in the same plot, the incidence of the disease in the neighboring plots, and the share of plowing machine, water source, or waterway with neighboring BW plots. However, no significant correlation was identified. This implies there could be other important sources or mechanisms for the pathogen transmission. Moreover, the quantity of pathogens introduced or remaining in a plot as well as conditions for disease development in each plot could be different. Therefore, more epidemiological studies should be conducted to identify the key agro-ecological factors associated with BW.

When adopting a new variety or practice for controlling BW, farmers are most concerned about the efficacy (41% in KT; 61% in CL), followed by marketability of the fruits (25% in KT; 15% in CL), and the cost (14% in KT; 12% in CL). Farmers were presented with three possible control methods for BW, and the responses in both sites were similar. Farmers preferred planting resistant varieties with good fruit characters (68.8%), followed by applying soil amendment (25.0%), and using grafted seedlings on resistant rootstock (6.3%).

Farmers use similar information sources in both sites. The sources ranked by popularity were farmer associations (30.2%), local public extension service (16.5%), self-experience (16.0%), and lead farmers (16.5%). Good fruit characters are the main consideration when changing or adopting a new variety (79% of KT farmers, 53% of CL farmers). Other traits considered include market price and resistance to disease. KT farmers have more diverse sources of seeds including farmer associations (54.3%), seed companies (21.7%) and seed dealers (17.4%), while 72.7% of CL farmers purchase their seeds from their local farmer association.

The important sources of influence on the choice of tomato varieties were quite different between the two sites. The local farmer association is the most important source of information for variety selection of most (58.1%) farmers in KT, while farmers in CL either make their own decisions (33.3% of farmers), or are influenced by the local farmer association (22.2%) or local public extension service (22.2%). This indicates that farmers in CL are more open or active in collecting information from various sources, but still rely on their local farmer association for other services.

In conclusion, this study highlights the need for research on breeding for resistant varieties with fruit characteristics acceptable to the market, and more epidemiological studies. Farmers in both sites have similar considerations when adopting control methods and use similar sources for information for producing their tomato crops; however, farmers in CL showed greater knowledge and skills in disease identification and management. CL farmers seemed to be more dynamic and self-determined in adopting new varieties. This behavior could be due to the greater importance of tomato as a main income source for these farmers.

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Mycology Unit

Evaluation of phenotypic and molecular criteria for the identification of *Colletotrichum* species causing pepper anthracnose in Taiwan

Pepper anthracnose is one of the major constraints for pepper production in the hot, humid tropics and subtropics. Survey and morphological identification results of AVRDC suggested that *Colletotrichum acutatum* (Ca), *C. gloeosporioides* (Cg) and *C. capsici* (Cc) are the causal agents of the disease in Taiwan. However, this result needs to be confirmed, as the identification was mostly based on conidial morphology. Morphological plasticity of *Colletotrichum* is well known and often leads to misidentification of the species. Understanding the pathogen profile is a prerequisite for managing the disease, including breeding for resistance. Therefore, the objective of this study is to evaluate several phenotypic traits and specific primers for differentiating *Colletotrichum* species associated with pepper anthracnose in Taiwan in order to establish identification criteria.

Twenty-five isolates, formally identified as Ca, Cg and Cc at AVRDC, were selected for this study. All isolates were single conidial cultures and maintained on silica gel at 4°C as described by Perkins (1962). Each isolate was transferred from stored cultures to potato dextrose agar (PDA) for 5 days as an initial working culture, which were subsequently transferred to PDA, casein hydrolysis medium (CHM) or potato dextrose broth (PDB) for the following evaluations. To determine the suitable growth temperature and to compare the growth rate, a mycelium plug from the margin of the working culture was placed in the center of a PDA plate. The radial diameter of the culture was measured at 7-day intervals after incubating at 16, 20, 24, 28, 32, and 36°C. Growth rate (mm per day) of each isolate was determined by measuring colony diameter of 4-day-old PDA culture at 28°C. Colony and conidial morphologies were observed from the same or older PDA cultures. To determine the protease activity of each isolate, fungal isolates were grown on CHM at 28°C according to Paterson and Bridge (1994). Both colony and clear zone diameter on CHM were recorded on the fourth day. Three replications of each isolate were conducted for the above evaluations.

Several species-specific PCR primers derived from the sequence of the internal transcribed spacer (ITS) region of the rDNA gene have been reported for identifying *Colletotrichum* species. Primer CaINT2 (5'-GGGGAAGCCTCTCGCGG-3') (Sreenivasaprasad et al., 1996) and CgINT (5'-GGCCTCCCGCCTCCGGGCGG-3') (Mills et al., 1992) were tested in this study for their specificity to Ca and Cg isolates, respectively. Because no specific primer of Cc was published, four ITS sequences of Taiwan Cc isolates (Coll 318, 322, 388, and 433) were analyzed through multiple sequence alignment with eight published Ca and Cg sequences from the National Center for Biotechnology Information web site. A specific primer for Cc was designed from ITS1 (CcINT; 5'-TCTCCCCGTCCGCGGGTGG-3'). To determine their specificity, the three primers were paired with a reverse primer ITS4 (5'-TCCTCCGCTTATTGATATGC-3'). Mycelium collected from 100-ml samples of 7-day-old PDB cultures were used for genomic DNA extraction following the CTAB procedure (modified Graham et al., 1994). PCR was performed in a total volume of 25 µl mixture, containing 20 ng of template DNA, 0.5 unit of YEA polymerase, 50 µM of dNTP, 2.5 µl of 10X reaction buffer, 1 µl of specific primer (10µM), and 1 µl of primer ITS4 (10µM). The PCR programs are: 1 cycle of denaturing (94°C, 5 min); 35 cycles of amplification (94°C, 30 s); 58°C for CaINT2 and CgINT or 63°C for CcINT, 30 s; 72°C, 1.5 min; and 1 cycle of final extension (72°C, 10 min). Amplification products were revealed using 1.5% agarose gel electrophoresis.

Results of phenotypic and molecular characterization are summarized in Table 87. Large variations of colony and conidia morphology were observed within species. This confirms the difficulty for using these traits for species identification. The most reliable criteria were the falcate conidia shape of Cc (Fig. 25). Among the evaluated criteria, growth rate and specific-PCR were considered reliable for assisting species identification. Overall, Cg had the fastest growth and all Cc had no protease activity. Results of specific-PCR showed good specificity of both CaINT2 and CcINT against tested Ca or Cc isolates, respectively. The expected single specific fragment (490 bp

or 460 bp) was amplified from all tested Ca or Cc isolates, but not from the other species. However, poor specificity of primer pairs CgINT/ITS4 was observed. The expected product (450 bp) was amplified from six of the eight tested Cg isolates, as well as from few Ca and Cc isolates. This reflects the complexity of Cg species in Taiwan, and a specific sequence in ITS for all Cg isolates might not exist.

In summary, the three major species of pepper anthracnose can be identified by conidia shape and growth rate on PDA, and then confirmed by Ca/Cc-specific primer. More isolates will be used to confirm the usefulness of this identification procedure. Such a procedure could be applied to determine the distribution of *Colletotrichum* species in many pepper production areas.

Table 87. *Comparisons of putative* Colletotrichum *species associated with pepper anthracnose over phenotypic and molecular criteria.*

Criteria	*C. acutatum* (10 isolates)	*C. gloeosporioides* (8 isolates)	*C. capsici* (7 isolates)
Mycelium color	White to gray	White to dark gray	White to gray
Reverse colony color	Orange-pink or dark olive	Black, gray, white or pink	Dark brown
Presence of acervuli	Nil	Nil	Often present
Conidia shape	Fusiform or cylindrical, most with acute end	Cylindrical with obtuse end	Falcate with acute apex
Conidia size	15.1(12.8–16.9) × 4.8(4.0–5.7) µm	15.7(12.7-16.7) × 5.0(4.2-5.9) µm	23.9(21.8-28.4) × 4.8(4.4-5.4) µm
Optimal temperature	28°C	28°C	28°C
Growth rate at 28°C (mm/day)	5.3 (4.0–6.0)	10.5 (9.0–13.0)	7.3 (5.8–8.6)
Protease activity	Most with strong protease activity	Except one, all showed low or no protease activity	No protease activity
Specific primers	Good specificity of CaINT2/ITS4	Poor specificity of CgINT/ITS4	Good specificity of CcINT2/ITS4

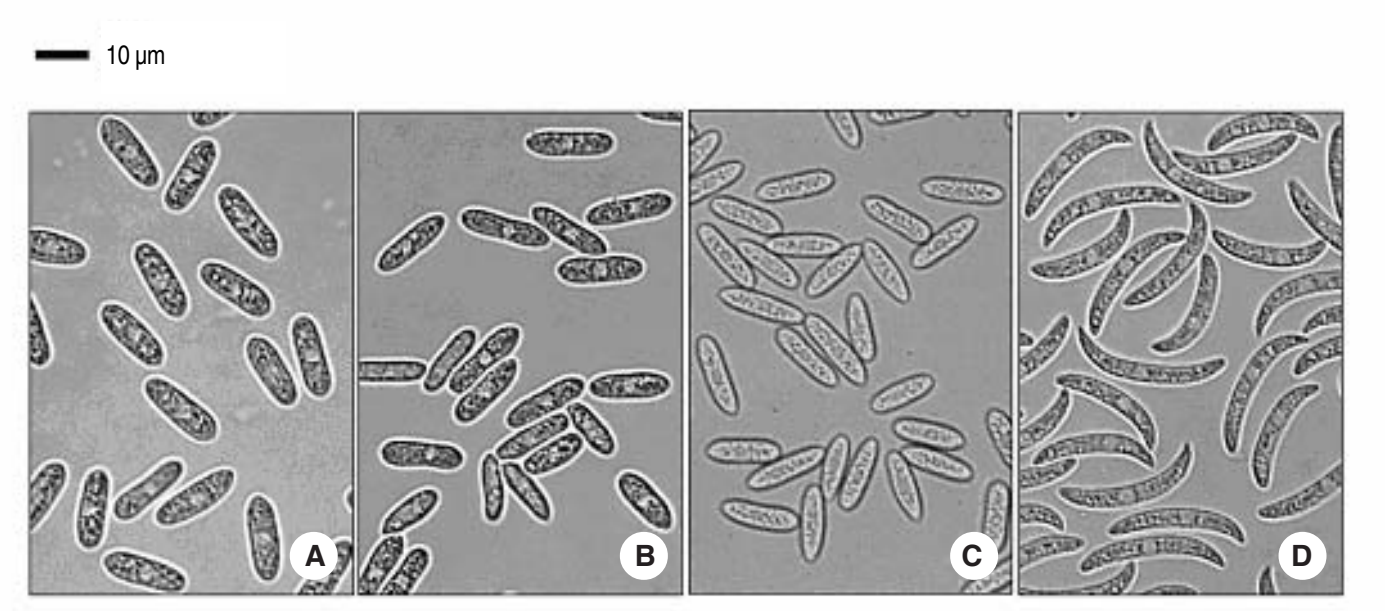

Fig. 25. *Conidia type observed under light microscopy with magnification 400X. A: typical* C. gloeosporioides *(Coll310); B: atypical* C. acutatum *with wider spore (Coll417); C: typical* C. acutatum *with acute end (Coll360); and D: typical* C. capsici *(Coll318).*

Population shift of *Phytophthora infestans* associated with tomato in Taiwan

Late blight, caused by *Phytophthora infestans*, is a highly destructive disease affecting both tomato and potato. The disease occurs wherever tomato is grown and can cause very serious economic losses, particularly when the weather is consistently cool and rainy. The late blight pathogen has been responsible for numerous epidemics on tomato and potato crops since it was first described. In recent years the disease has increased in severity in many parts of the world. This has been associated with migration of new and more aggressive populations of the pathogen. Severe late blight epidemics have occurred on tomato and potato crops in Taiwan since 1998. In response, AVRDC has been collecting and characterizing the late blight pathogen population in Taiwan, as part of our breeding for resistance and disease management program. It is obvious that the epidemic outbreak is concomitant with the appearance of a new genotype, US-11. By 2000 the new genotype had completely displaced the old US-1 genotype to which all Taiwan isolates collected from 1991–1997 belong. The US-11 genotype appears to be more aggressive and carries resistance to metalaxyl. Herein we report our survey results from 2003 and summarize the pathogen population shift from 1997 to 2003.

A total of 342 isolates of *P. infestans*, mostly from tomato, have been collected in Taiwan since 1991 and maintained by AVRDC, including 101 isolates collected in 2003 (Table 88). These isolates were characterized for their mating type, metalaxyl sensitivity, and putative physiological race at AVRDC. The molecular genotype of each isolate was characterized with the assistance of the United States Department of Agriculture Vegetable Laboratory in Beltsville, Maryland, USA. The mating type of each isolate was determined by pairing each testing isolate with tester strains of known mating types on rye A agar plates at 20°C in the dark for two weeks and observing the formation of oospores/oogonia. The assessment of metalaxyl sensitivity in vitro of each isolate was conducted on rye A agar plates amended with 100 ppm of metalaxyl. Sensitivity to metalaxyl was determined by comparing the mean radial diameter of each isolate with the standard isolate, Pi16, which is sensitive to metalaxyl. Molecular genotype characterization of each isolate was analyzed by using the allozyme genotype analyses at the glucose-6-phosphate isomerase (*Gpi*) and peptidase (*Pep*) loci; DNA fingerprint analysis using the RG57 probe; and mitochondrial haplotyping through polymerase chain reaction (PCR) amplification and restriction fragment length polymorphism (RFLP) analysis of the polymorphic regions of the mitochondrial genome. Putative physiological races were determined by inoculating each isolate on a set of differential varieties (Table 89). Foliar inoculation with a 5×10^4 sporangia/ml suspension was conducted on 35-day-old seedlings. Severity scores were recorded after a 7-day incubation at 20°C.

Introduction of A2 mating type isolates of *P. infestans* is a major concern in disease management due to the pathogen's potential to genetically recom-

Table 88. *The phenotype and genotype characteristics of* Phytophthora infestans *isolates collected in Taiwan during 1991 to 2003.*

Year	No. of isolates collected	Metalaxyl (100 ppm)		Mating type		RG 57[1]		*Gpi/Pep*[2]			Mt DNA haplotype[3]			
		Sensitive	Resistant	A1	A2	US-1	US-11	86/100 92/100	86/100 100/100	100/111 100/100	Ia	Ib	IIa	IIb
1991–1997	30	30	0	30	0	17	0	16	7	0	0	15	0	0
1998	33	6	27	33	0	2	5	1	2	5	0	1	0	2
1999	24	1	23	24	0	1	22	1	0	36	0	0	0	23
2000	36	0	36	36	0	0	36	0	0	57	0	0	0	29
2001	60	0	60	60	0	0	57	0	0	57	0	0	0	57
2002	58	0	58	58	0	1	57	1	0	57	0	1	0	57
2003	101	1	100	101	0	1	99	1	0	99	0	1	0	99

[1]DNA fingerprint analysis using the RG57 probe.
[2]Allozyme genotype analyses.
[3]Mitochondrial haplotyping through PCR amplification and RFLP analysis.

bine via sexual reproduction. All isolates collected from 1991 to 2003 were A1 mating type, suggesting that the A2 mating type had not yet become established in Taiwan (Table 88). Local farmers commonly use metalaxyl fungicide in controlling late blight. All isolates obtained before 1997 were very sensitive to metalaxyl; however, only two isolates obtained from 1999 to 2003 were sensitive to the fungicide (Table 88). This indicates metalaxyl will not be effective in managing the disease. A significant shift on the genotype of local late blight pathogen was observed around 1998. The isolates obtained before 1997 were all US-1 genotype, Ib MtDNA haplotype, and either 86/100 and 92/100 or 86/100 and 100/100 for *Gpi* and *Pep*, respectively (Table 88). A new genotype that belongs to the US-11 colonial lineage first appeared during the 1997–1998 potato-growing season. This new genotype spread very rapidly, displacing the old genotype US-1 in Taiwan. It is highly plausible that the new genotype US-11 was introduced on imported table potatoes during the 1997–1998 growing season. A total of 274 among 277 tested isolates of *P. infestans* collected from 1999–2003 were of US-11 genotype and had allozyme genotype 100/111 and 100/100 for *Gpi* and *Pep*, respectively, and shifted to mitochondrial DNA IIb (Table 88). The three exceptions, all US-1 isolates, were collected during from Puli Branch Station of Taichung District Agricultural Improvement Station, one each in 1999, 2002 and 2003. This station is 500 m above sea level and isolated from other major tomato production areas. As our collection was made mostly in lowland areas, more isolates need to be collected from the highlands in order to confirm the distribution of US-1 genotype.

Table 89. *Designation of putative physiological races of* Phytophthora infestans *isolates collected from tomato in Taiwan from 1994 to 2003.*

Race	TS19 (*Ph+*)	TS33 (*Ph1*)	W.Va.700 (*Ph2*)	L3708 (*Ph3*)	LA1033 (*Ph4*)[1]
T1	S	S	R	R	R
T1,2	S	S	S	R	R
T1,2,3	S	S	S	S	R
T1,2,4	S	S	S	R	S
T1,4	S	S	R	R	S
T1,3	S	S	R	S	R
T1,2,3,4	S	S	S	S	S

[1]Gene(s) conditioning late blight resistance in this accession are not yet characterized.

AVRDC began characterizing physiological races of *P. infestans* among Taiwan isolates in 1994, when only race T1,2 was identified, which overcomes the P*h*1 and *Ph*2 resistance genes found in some commercial tomato varieties (Table 89). Resistance to race T1, 2 was identified in *L. pimpinellifolium* accessions (L3707, L3708 and others) and *L. hirsutum* accessions (L3683, L3684, LA1033 and others). A new race called T1,2,3 was identified at Puli Branch Station near the end of spring season in 1997 as well as in 1998, which was highly aggressive to L3708 and tomato lines derived from it. New races continued to appear in Taiwan. Based on the results of 120 isolates collected from 1999 to 2001, new races T1; T1,4; and T1,2,4 were identified. Another two new races T1,3 and T1,2,3,4 appeared in 2002 and 2003, which overcome the resistance of AVRDC late blight-resistant lines derived from L3708, but not L3708 nor LA1033. These results imply that L3708 may possess more than one R gene for late blight resistance, but only one of the genes was introgressed into the advanced lines.

Data from the current study indicate that migration and asexual reproduction were the predominant mechanisms influencing *P. infestans* population structure in Taiwan from 1991 to 2003. The results have three major implications for managing late blight in Taiwan. First, since the new population is largely metalaxyl-resistant, the effect of metalaxyl in controlling the disease in the field needs to be re-evaluated. Second, the data indicate that the A2 mating type of *P. infestans* has not yet been introduced into Taiwan, although it has been identified in China. Stringent local quarantine measures need to be in place as part of the overall disease management program. Third, the continuous appearance of new races of *P. infestans* presents the need to enhance breeding efficiency possibly by molecular markers for precise introgression of the desired resistance trait. Moreover, further studies on pathogen population genetics by applying additional molecular markers, e.g. virulence genes, may reveal recombination events and allow better understanding of the genetic variability and gene flow in the local *P. infestans* populations.

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Studies on tomato (yellow) leaf curl geminiviruses

Tomato (yellow) leaf curl disease, caused by whitefly-transmitted geminiviruses (TYLCVs) is the major production constraint of tomato in the tropics and subtropics. Commercial varieties with stable resistance are not yet available, which is why AVRDC has been addressing this problem from various aspects: breeding for resistance, documenting its geographic distribution, identifying its genetic diversity, understanding the epidemiology of the virus and vector, identifying and testing the stability of genes for resistance, and developing diagnostic techniques.

Geographic distribution

Leaf samples from tomato, *Capsicum* spp., and weeds exhibiting symptoms (leaf yellowing, vein yellowing, yellow mosaic, leaf curling, upright stem tips) were collected in 2003 from 18 countries in Asia, Central America and Africa and tested by polymerase chain reaction (PCR) for the presence of geminiviruses. For the first time, we detected geminiviruses on tomato in several African countries (Uganda, Sudan and Ethiopia) and in Central America (Mexico and El Salvador) (Table 90). The common weeds *Ageratum* sp. and *Croton* sp. were also found infected with geminiviruses, but only sequence analysis will prove whether these geminiviruses are the same as those infecting tomato.

Molecular characterization and geminivirus diversity

Nine geminiviruses, including four of tomato originating from Taiwan, Cambodia, Nepal and Malaysia, four of pepper originating. from Pakistan, Nepal and Malaysia, and one from squash from Pakistan were cloned and sequenced (Table 91). Great molecular diversity was observed in these viruses. Clones CaT1 from Cambodia and MYT from Malaysia were distinct new viruses, the latter from the highlands, transmitted by *Trialeurodes vaporariorum.* The tomato geminivirus from Nepal is the same as, or a very closely related strain of the resistance-breaking ToLCV previously identified from Gujarat, India.

Table 90. *Geminivirus survey of major solanaceous crops and weeds in 2003.*

Country	Host	Sample no.	Positive sample no.	(%)[1]
Bangladesh	Tomato	3	1	(33)
	Pepper	3	0	
	Eggplant	2	0	
	Weed[2]	1	1	(100)
Barbados	Pepper	6	0	
Cambodia	Tomato	4	4	(100)
China	Tomato	52	29	(56)
EL Salvador	Tomato	4	3	(75)
Ethiopia	Tomato	17	14	(82)
Ghana	Tomato	4	0	
Indonesia	Tomato	25	0	
	Pepper	4	3	(75)
Laos	Tomato	2	1	(50)
Mauritius	Pepper	1	0	
Mexico	Tomato	4	2	(50)
Myanmar	Tomato	2	2	(100)
	Pepper	3	0	
	Weed[3]	4	3	(75)
Sri Lanka	Tomato	8	3	(38)
	Pepper	2	0	
	Weed[4]	11	1	(9)
Sudan	Tomato	2	1	(50)
Taiwan	Tomato	179	169	(94)
	Pepper	2	0	
	Weed[3]	3	1	(33)
Tanzania	Tomato	17	0	
Thailand	Tomato	2	2	(100)
Uganda	Tomato	12	11	(92)
Vietnam	Tomato	26	17	(65)
	Pepper	1	0	
	Weed[5]	1	0	
Total	Tomato	346	245	(71)
	Pepper	22	3	(14)
	Weed	20	6	(30)

[1]Polymerase chain reaction using the degenerate primer pair PAL1v1978B/PAR1c715H.
[2]*Croton* sp.
[3]*Ageratum* sp.
[4]*Ageratum conyzoides, Hibiscus esculentus, Passiflora foetida, Euphorbia heterophylla, Atylosia* scarabeoides, *Syzygium fergusonii.*
[5]*Ageratum conyzoides.*

Table 91. *Geminiviruses cloned and sequenced in 2003.*

Country/location	Crop	Clone	DNA type	Virus with highest sequence similarity (GenBank accession)	Sequence similarity (%)
Taiwan (Hsinchu)	Tomato	HS7	A	Ageratum yellow vein virus-Taiwan/Hualien	93
Cambodia (near Kbol Koh)	Tomato	CaT1	A	Tomato leaf curl Indonesia virus 2(AB 100305)	86
Pakistan	Squash	Squash #58	A	Tomato leaf curl New Delhi virus-[Severe](U 15015)	96
Pakistan (Khanewal)	Chili pepper	PC2-1	A	Chilli leaf curl Bangladesh virus (AF 314531)	91
		PC2-2	A	Tomato leaf curl New Delhi virus-[Severe](U 15015)	98
Nepal (Panchkhal)	Tomato	NepT4	A	Tomato leaf curl Gujarat virus (AF 449999)	99
Nepal (Parwanipur)	Chili pepper	NP11	A	Tomato leaf curl New Delhi virus (AY 428769)	97
Malaysia (Cameron highland)	Tomato	MYT	A	Tomato yellow leaf curl Thailand virus 2(AF 511530)	76
Malaysia (Cameron highland)	Sweet pepper	MYP	A	Malaysia tomato leaf curl virus (MYT)	99

The tomato geminivirus from Taiwan (HS7) is the third distinct geminivirus found to infect tomato on the island. It has 93% sequence homology with Ageratum yellow vein virus (AYVV) a geminivirus infecting *Ageratum* sp., a common weed in and around tomato fields. Sequence analysis showed that HS7 is a recombinant of two viruses, i.e. ToLCV-TW1/Hualien (92% sequence identity in the 2047-2733 nucleotide region) and AYVV-TW/Hualien (99% sequence identity in the remaining region). It is not known whether the recombination effect has taken place within the plant or within the vector upon multiple virus infection or ingestation respectively. Such recombination on the DNA level leads to the wide genetic diversity of the TYLCVs for which it will become increasingly difficult to find effective host plant resistance genes.

Multiple infection seems to be a common phenomenon. Two distinct geminiviruses were identified from one single chili plant from Pakistan; one was a strain of the chilli leafcurl virus from Bangladesh, whereas the other one was the same as, or a very closely related strain of the tomato leafcurl New Delhi virus-[Severe]. The latter, which is known to be widely distributed on tomato in India was also detected in a sample of squash collected from Pakistan, indicating that this geminivirus may have a wide host range. Multiple geminivirus infection of Solanaceous crops has been noted in many cases and is believed to be the reason for the appearance of new geminivirus species because of genomic recombination.

Development of improved diagnostics

Because of the high genetic diversity of the tomato infecting geminiviruses (TGVs), specific diagnostics are needed for their rapid detection. A more efficient general degenerate primer pair has previously been developed (*AVRDC Report 2000*, p. 35–36) that detects all whitefly-transmitted geminiviruses. Specific primers are useful for investigating the geographic distribution of distinct TGVs, for detecting multiple geminivirus infection, and for detecting new TGVs.

Specific primers were developed by selection of highly heterologous DNA regions following sequence alignments for two TGVs from Vietnam (i.e. VN1SPV1/C1 and VN2SPV1/C1 of 913 and 842 bp respectively), one TGV from the Philippines (PH1SPV1/C1 of 319 bp), and for two TGVs from Taiwan (i.e. KDPAV1/C1 and CTPAV2/C2 of 1549 and 720 bp, respectively). Tomato samples collected from Vietnam and Taiwan were first tested by PCR with the general primer pair, followed by PCR with the specific primer pairs. The results (Table 92) show that VN1 is widely distributed throughout northern Vietnam whereas VN2 could so far only be detected in southern regions of Vietnam. In Taiwan, TW1 is present throughout the island and TW2 could not be detected, even in the location (Hsinchu) where it was originally found. There was also no indication of the presence of exotic viruses, e.g. VN1, VN2 or PH1 in Taiwan. One sample each was identified in Vietnam and Taiwan, which reacted with the general primer pair but not with any of the specific primers, strongly indicating that these samples may be infected with new geminiviruses, different from those already identified. These are presently being cloned to verify this.

Table 92. *Detection of geminiviruses in Vietnam and Taiwan.*[1]

Location	Sample no.	PCR[2]				
		General	VN1	VN2	TW1	TW2
Vietnam						
Hong Thai-An Duong, Hai Phong City	1	1	0	0	NT	NT
Tan Lien, Vinh Bho, Hai Phong Province	2	2	2	0	NT	NT
RIFAV, Tran Quy, Gialam, Hanoi	4	4	4	0	NT	NT
Dong Sa Coop. Near RIFAV	2	2	2	0	NT	NT
Tien Phong – Molinh – Vinbphui	1	1	1	0	NT	NT
Bac Nih	2	2	2	0	NT	NT
Can Tho University (CTU), Cantho	3	3	0	3	NT	NT
Taiwan						
Tainan	8	8	0	0	8	0
Hsinchu	7	4	0	0	3	0
Changhua	4	4	0	0	4	0
Taitung	4	4	0	0	4	0
Hualien	4	4	0	0	4	0
Pingtung	4	3	0	0	3	0
Chiayi	4	4	0	0	4	0
Nantou	5	3	0	0	3	0
Ilan	5	3	0	0	3	0

[1]All samples from Taiwan were also tested for presence of PH1 and found negative.

[2]General = general primer that detects whitefly-transmitted geminiviruses; VN1 = ToLCV VN1 GenBank Acc. AF 264063 (cloned and sequenced by AVRDC from a tomato sample collected from Nhue-Tu, Liem-Hanpi, Vietnam); VN2 = TYLCV VN2, cloned and sequenced by AVRDC from a tomato sample collected from Mytho, Vietnam; (70% sequence homology with VN1); TW1 = ToLCV TW1 GenBank Acc. U 88692; (cloned and sequenced by AVRDC from a tomato sample collected from Tainan); TW2 = ToLCV TW2, cloned and sequenced by AVRDC from a tomato sample collected in Hsinchu; (78% sequence homology with TW-1).

Multilocation testing of resistance sources and ToLCV-resistant AVRDC tomato hybrids

Three wild *Lycopersicon* species, one *L. esculentum* (H-24) previously found resistant to the Taiwan tomato leafcurl virus (ToLCV-TW1) and two tomato hybrids (FMTT847, PT4727) developed by AVRDC and carrying the *Ty-2* resistance gene were tested in farmers' fields in 14 locations throughout Taiwan. The trials were non-replicated and consisted of 24 plants per entry. Transplanting dates were from March 25 to April 24 and from October 2 to 16. Leaf samples were collected from all plants at 42 to 69 days after transplanting or when the susceptible check showed 100% infection. All samples were tested for presence of geminivirus by NAH and PCR, as previously described.

The results (Table 93) show that TYLCV infection is high both in the spring and in the fall season, especially in central and southern Taiwan (Changhua, Chiayi, Tainan, Kaohsiung and Pingtung). Despite the high disease pressure, *L. chilense* held up at all 14 locations, whereas *L. hirsutum* was found to be infected in Tainan and Chiayi and *L. peruvianum* and *L. esculentum* H-24 in Chiayi. One of the AVRDC TYLCV-resistant hybrids (FMTT847) became infected in Chiayi, and the other one (PT4727) in Chiayi, Tainan and Kaohsiung.

Several factors were originally thought to be responsible for the breakdown of resistance in these lines: 1) the *Ty-2* gene for resistance is not present; 2) the *Ty-2* gene offers only tolerance but not resistance; 3) the presence of a new resistance breaking TYLCV strain; and 4) the presence of an aggressive whitefly biotype in these locations. The latter can be excluded, since all the whiteflies collected from each of the 14 locations were of biotype-B, as demonstrated by RAPD-PCR tests for all 14 locations, conducted at National Taiwan University by Dr. C.C. Kuo.

To determine the presence of resistance-breaking TYLCVs, the geminivurses from infected "resistance sources" are presently being cloned and sequenced. To determine whether the AVRDC hybrids contained

Table 93. *Field testing of resistance sources and AVRDC ToLCV-resistant hybrids in different locations in Taiwan.*[1]

Source[2]	Tainan 1	Tainan 2	Tainan 3	Pingtung	Chiayi 1	Chiayi 2	Hsinchu	Nantou	Hualien	Taitung	Changhua 1	Changhua 2	Ilan	Kaohsiung
VL 259 (*L. hirsutum*)	0	9	0	0	4	26	0	0	0	0	0	0	0	0
VL383 (*L. chilense*)	0	0	0	0	0	0	D[3]	0	0	0	D	0	0	0
VL215 (*L. peruvianum*)	0	0	0	0	0	4	0	0	0	0	0	0	0	0
H24	0	0	0	0	0	13	0	0	0	0	0	0	0	0
FMTT847 F_1	0	0	0	0	4	50	0	0	0	0	0	0	0	4
PT4727 F_1	0	0	10	0	0	21	0	0	0	0	0	0	0	21
TK 70 (check)	100	100	86	100	100	100	33	27	27	30	57	79	63	100
Days in field	50	42	58	30	42	63	56	51	56	56	43	69	54	57
Transplanted	Ap 07	Mr 25	Oc 7	Ap 09	Ap 10	Oc 02	Mr 27	Ap 16	Ap 02	Ap 02	Mr 31	Oc 04	Ap 24	Oc 16
PCR/ NAH	My 26	My 05	De 3	My 08	My 21	De 03	My 21	Jn 05	My 27	My 27	My 12	De 11	Jn 16	De 11

[1]Tainan 1 = Shanhua; Tainan 2 = Kuantien; Tainan 3 = Shanhua; Chiayi 1 = Minhsiung; Chiayi 2 = Liujean; Changhua 1 = Chutan; Changhua 2 = Puyan; Pingtung = Yenpu; Hsinchu = Hsiunglin; Nantou = Puli; Hualien = Chian; Taitung = Kuanshan; Kaohsiung = Alien.

[2]Sources are *Lycopersicon esculentum*, unless stated otherwise.

[3]D = all plants died after transplanting.

the *Ty-2* gene, 28 plants of FMTT847 grown in the AVRDC breeding field and showing various types of symptoms typical of TYLCV infection were tested for presence of geminivirus by PCR and for the presence of the *Ty-2* gene by the AVRDC molecular biology unit using the RFLP molecular marker TG36. As expected, all plants contained the *Ty-2* gene. These tests clearly demonstrate that the *Ty-2* gene alone is not sufficient to protect tomato against TYLCV under Taiwan's conditions. Factors 2 and 3 will be further investigated.

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Crop and Ecosystem Management Unit

Development of in-situ N monitoring technology for low-nitrate leafy vegetable production systems

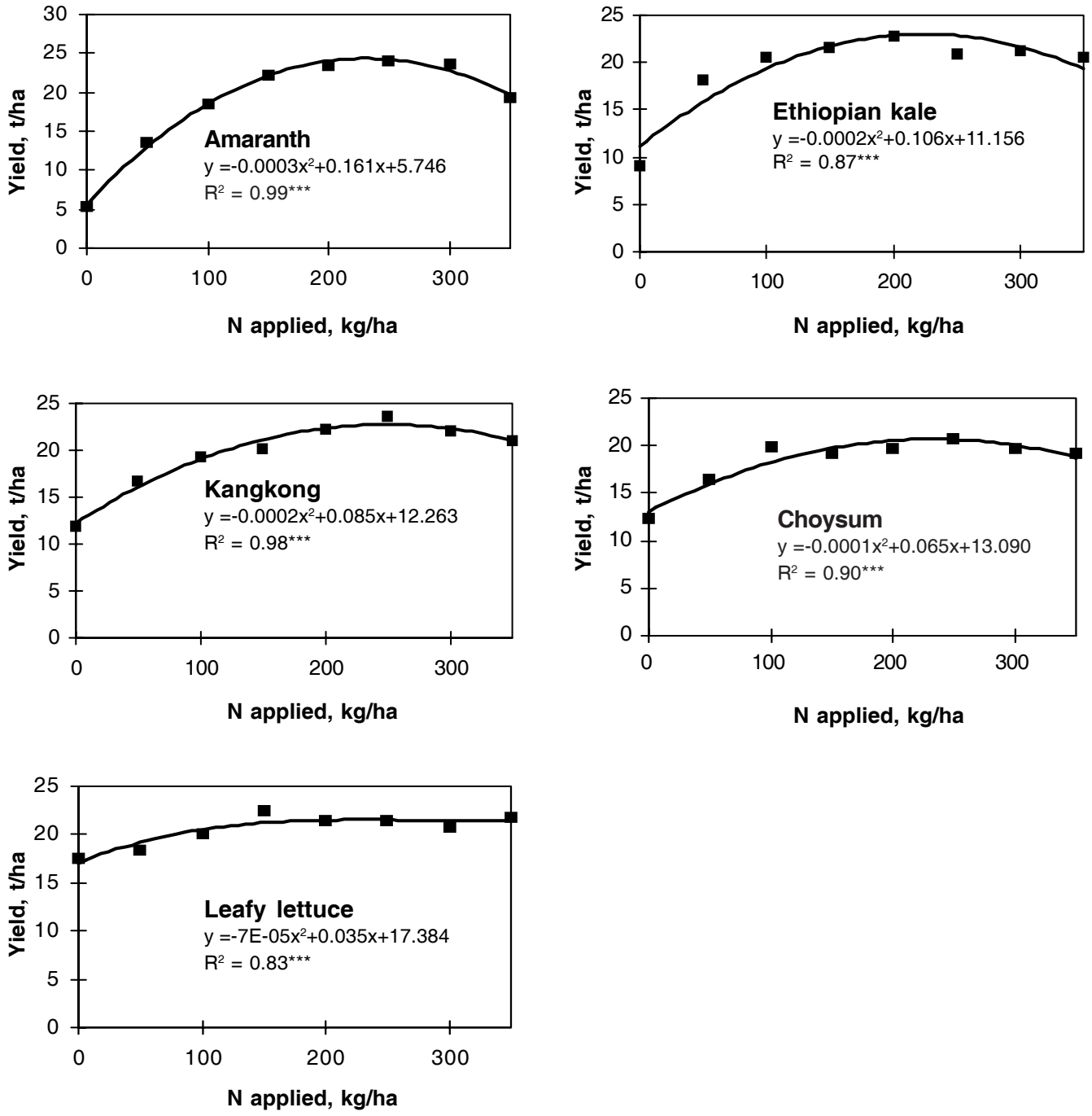
Intensive cultivation of leafy vegetables in nethouses is a common production system in peri-urban areas. High levels of nitrogen fertilizer are generally used in these systems, creating a risk of harmful nitrate levels in vegetables as well as environmental pollution caused by the leaching of nitrates into water supplies. Improved N management technologies are needed to produce safe leafy vegetables grown in nethouses.

The methods for determining nitrate levels in plant tissue and for assessment of potential available N in soil have been well established in laboratories. However, most methods of analysis require a few days to obtain the results. Recent advances in soil and plant N testing, e.g., the pre-sidedress soil nitrate test (PSNT), Cardy nitrate meter determination, and leaf chlorophyll meter reading (LCMR) systems, provide opportunities for more efficient use of fertilizers and manures. A study on LCMR showed that extremely rapid, in-situ measurement of leaf "greenness" was as accurate as the PSNT in identifying N-sufficient sites. The objectives of the following study were to develop rapid, low-cost, and non-destructive N diagnostic technologies for safe leafy vegetable production and to develop guidelines for Good Agricultural Practices (GAPs) for leafy vegetables in intensive rotation systems.

The trials were carried out in a 32-mesh nethouse (21 × 35 m) with double doors to exclude insect pests. The experimental design was RCBD with three replications of eight N fertilizer treatments. N fertilization regimes were 0, 50, 100, 150, 200, 250, 300, 350 kg N/ha split in three applications per crop. Hard plastic sheets were buried down to 45 cm around each plot to prevent mutual effects of N fertilizers. The area in the nethouse was divided into three sections and crops were grown separately within each section at different times. Plot size was 4 × 1.6 m with four beds in each plot. Four rows of leafy vegetables were planted on each bed with 6.7, 5, 10, 6.7 and 8 cm between plants for amaranth, kangkong, Ethiopian kale, leafy lettuce and choysum, respectively. Amaranth (*Amaranthus tricolor*) and pak-choi (*Brassica rapa* L. cv. *pak-choi*) were sown on 29 May and harvested on 25 June 2003. Due to Fusarium wilt, the data for pak-choi are not presented. Kangkong (*Ipomoea aquatica*) and Ethiopian kale (*Brassica carinata*) were sown and transplanted on 20 August, respectively, and harvested on 11 September. In the third cultivation, choysum (*Brassica campestris* ssp. *parachinensis*) and leafy lettuce (*Lactuca indica*) were sown on 15 October and harvested on 12 and 28 November, respectively. At harvest, plant samples were collected, and nitrate contents in tissue saps were determined in fully expanded leaf blades, petioles, and whole plants by using a Cardy nitrate meter. The correlation between nitrate concentration in leaf sap of leafy vegetables and N application rates was determined. Chlorophyll content readings were measured in the same leaf by using leaf chlorophyll meter and the correlation between LCMR of leafy vegetables versus N application rates was established. Fresh and dry matter yields were determined at each harvest, and total N content in plant and N uptakes were analyzed (data not shown).

After the cultivation of amaranth was completed, kangkong and leafy Chinese cabbage (*Brassica campestris* spp. *chinensis*) followed as second and third crops in sequence. Composite core soil samples at three depths (15, 30 and 45 cm) were collected before planting and after each harvest. Soil nitrate concentrations were analyzed and N accumulations in soil and nitrate leaching were monitored through the whole crop sequence. The quantified relationships among crop yields, N applications, in-situ soil nitrate determinations, nitrate content in leaf sap, and leaf chlorophyll content readings were established. Based on the relationships developed, the optimum level of N fertilization can be identified for production of low-nitrate, safe vegetables.

Fig. 26 presents the relationships between fresh yield and N application for five leafy vegetables tested. The yield response curves are best fitted to quadratic equations. The constant value for variable X reflects the extent of leafy vegetable yield responses to N. Leafy vegetables' growth patterns are easily affected by N fertilization. Fresh yields of all leafy vegetables increased as N application increased, and reached their maximum when N applications were 200–250 kg/ha. Afterward, yields declined or remained the same as

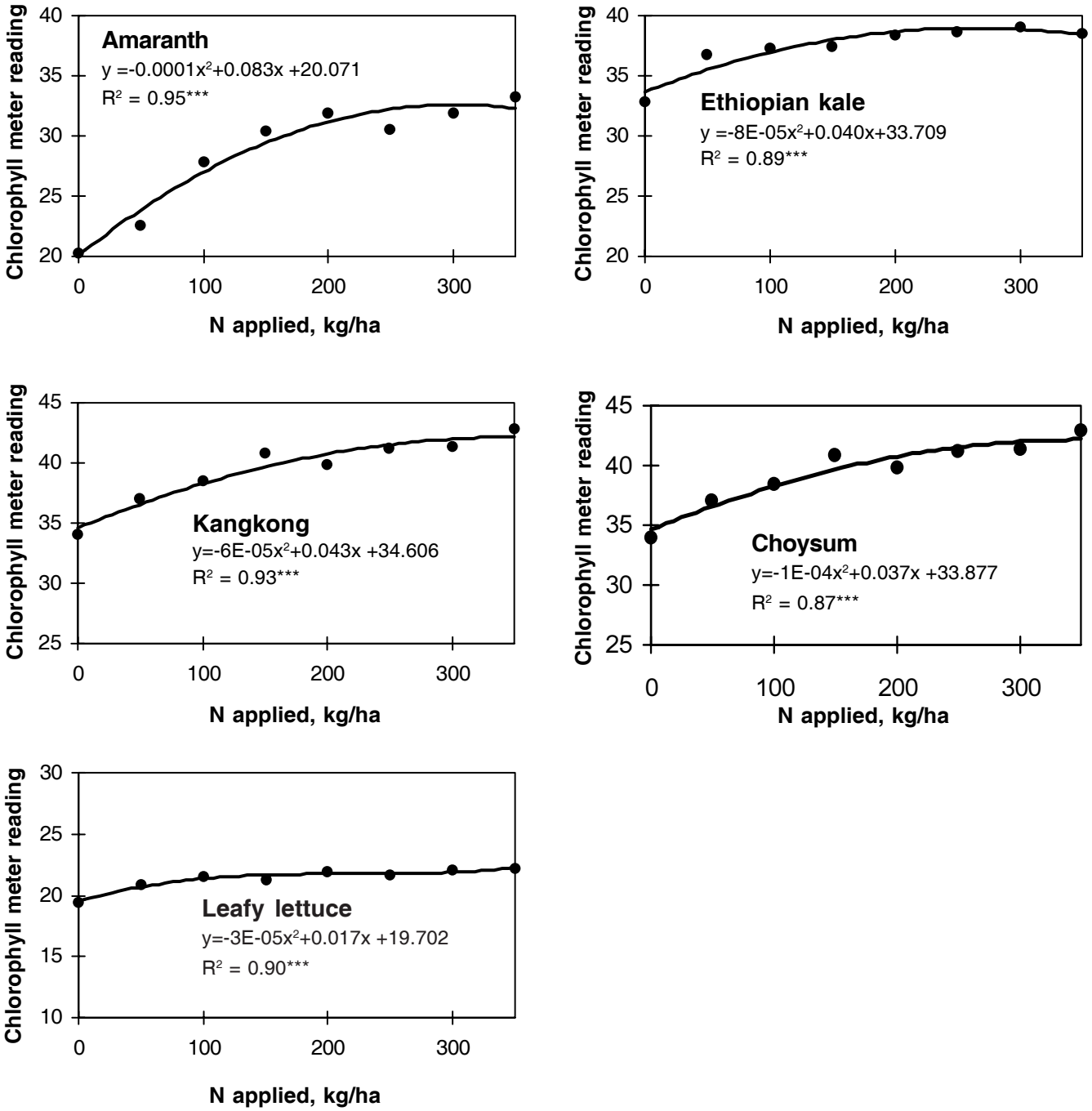


***R^2 values are significant at $P \leq 0.001$.

Fig. 26. *Relationships between fresh yields of leafy vegetables and N application amounts.*

applications of N exceeded 250 kg/ha. Amaranth exhibited the most significant relationship to N application, followed by Ethiopian kale; leafy lettuce had least response to N.

Relationships between N application rate and LCMR measured on fully expanded leaves at harvest are illustrated in Fig 27. The relationships were similar to those of yield response curves. The relationships also fitted well to the quadratic equations. LCMR measurements increased as the N rate increased, but the increments became smaller once N applications exceeded 200 kg/ha. However, except for choysum, the greenness of the leaf increased regardless of decreasing yield in amaranth and kangkong at N applications



***R^2 values are significant at $P \leq 0.001$.

Fig. 27. *Relationships between N application amount and leaf chlorophyll meter reading of leafy vegetables at harvest.*

above 200 kg/ha. These results matched with the results in the yield response curves, indicating that LCMR can be a simple, non-destructive tool to identify optimum N requirement for leafy vegetables. N fertilization influenced the leaf greenness most on amaranth, followed by kangkong and Ethiopian kale, and less so on choysum and leafy lettuce. The constants of the equations provided a relative index of genetic leaf greenness for leafy vegetables.

Fig. 28 shows the effects of N on the nitrate concentrations in saps of leaf blade, petiole, and whole plants as measured by the Cardy nitrate meter. Significant correlations existed among these parameters and N rates, indicating the feasibility of using the simple

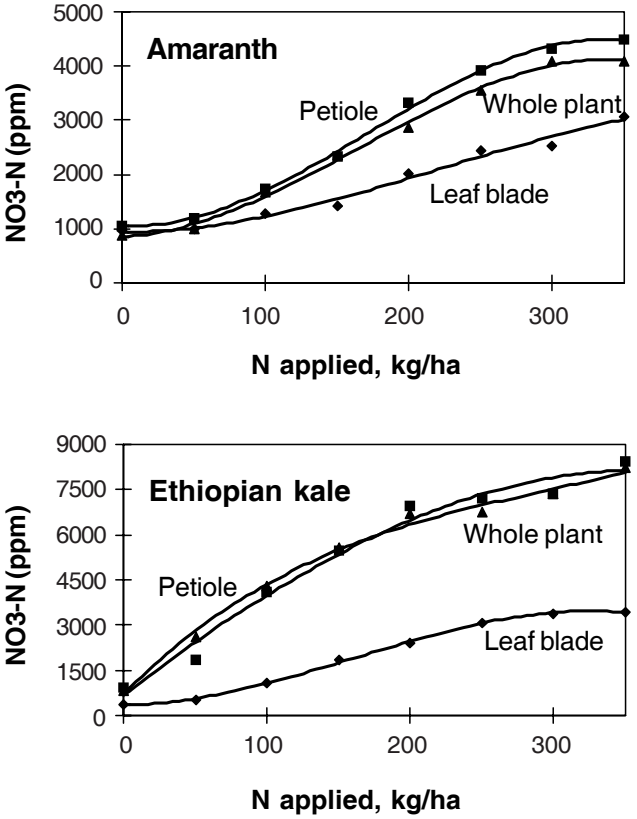
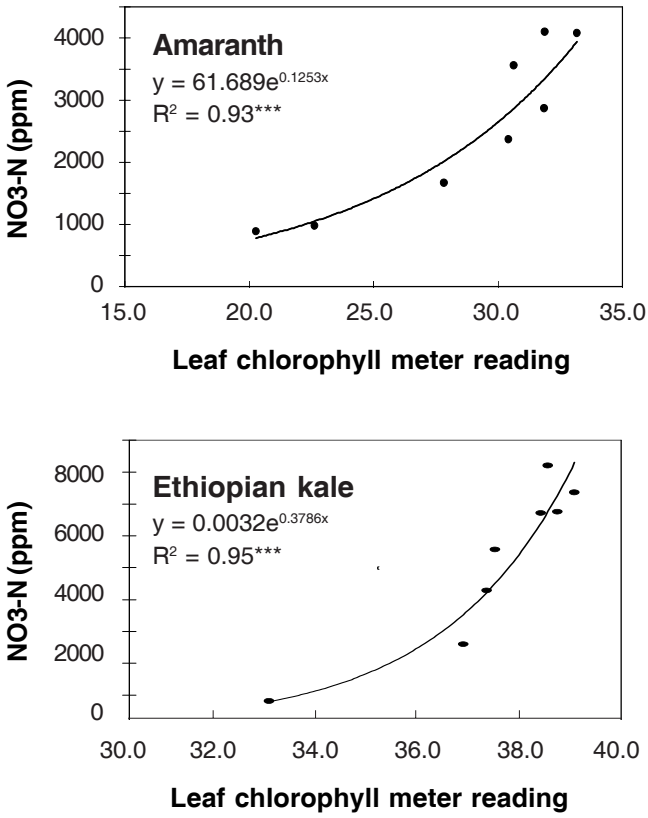


Fig. 28. *Relationships among N application rates, nitrate quick test values in saps of leaf-blade, petiole, and whole plant pastes.*



***R^2 values are significant at $P \leq 0.001$.

Fig. 29. *Correlations between leaf chlorophyll meter reading and nitrate content in whole plant (amaranth and Ethiopian kale).*

nitrate meter as a tool for monitoring N status in field as well as nitrate in plants. The nitrate contents in whole plant were measured in the filtrate after blending whole plant tissue with a small amount of distilled water. The nitrate contents in petiole were measured by pressing the saps out of the petiole tissue. The nitrate concentrations in whole plant were similar to the concentration in the petiole as shown in Fig. 28. Therefore, instead of measuring a whole plant, the measurement of nitrate content in petiole sap in-situ by Cardy nitrate meter can be a rapid N monitoring technology for safe leafy vegetable production. It is relatively convenient and can eliminate the tedious procedure for handling the whole plant samples. A critical level of N fertilization can also be identified for production of low-nitrate, safe vegetables. On the other hand, the petiole saps from kangkong and leafy lettuce contained some glutinous materials that were not applicable to the sensors of the nitrate meter. The nitrate accumulation in whole plants of these two leafy vegetables could only be monitored using whole plant filtrate.

The study on nitrate contents indicated that nitrate accumulations varied with different species of leafy vegetable. Using the N application rate of 200 kg/ha as an example, the nitrate accumulation in Ethiopian kale was highest (7000 ppm), followed by kangkong (4000 ppm), amaranth (3500 ppm), and leafy lettuce (1200 ppm). These results also suggest that proper selection of vegetable species can be used to avoid overconsumption of high nitrate-containing vegetables.

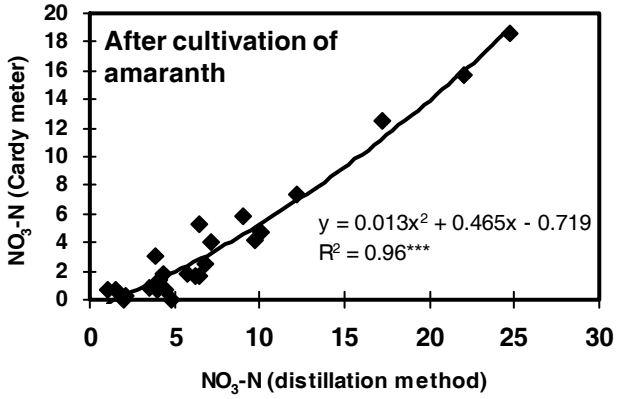
Fig. 29 presents relationships of LCMR measurements and the nitrate content in whole plants of two leafy vegetables. The relationships fitted well to exponential equations. These results showed that the LCMR measurement can be an easier, quicker and non-destructive technique than the Cardy nitrate meter for predicting nitrate accumulation in plant tissue as well as monitoring N status in soils.

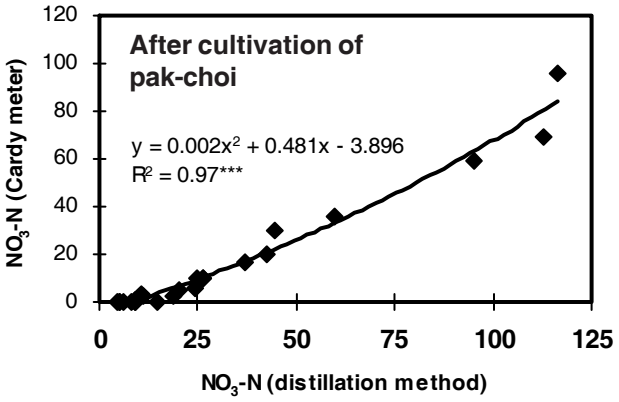
The conventional analytical method for soil nitrate uses extraction with 2 M potassium chloride, and mea-

sures the nitrate concentration in the extract by distillation. The "quick nitrate meter test" involves direct stirring of soil with 0.025 M aluminum sulfate solution, then inserting a filter paper into the soil suspension, getting a few drops of filtrate, and putting the filtrate on the sensor of Cardy nitrate meter for determination. Due to great diversity in these two methods, two sets of soil samples were analyzed for comparison. Fig. 30 shows the correlation between soil nitrate concentrations measured by two analytical methods. There were significant correlations between the soil nitrate concentrations measured by these two methods regardless of nitrate-N levels in soils. This indicates that the quick nitrate meter test is sensitive enough to detect nitrate-N even when its concentration is below 20 ppm. Therefore, the Cardy nitrate meter can substitute for the conventional method as a more rapid and convenient tool for N diagnosis.

Soil monitoring data indicated that even after the first cultivation of leafy vegetable, some nitrates had leached down to 45 cm depth in soil applied with 350 kg N/ha. In this crop sequence study, soil ammonium and nitrate N were monitored after each harvest. As presented in Fig. 31, after the first crop, only plots applied with N more than 250 kg/ha showed slight increases in ammonium and nitrate N. After the second crop, even plots that received 200 kg/ha N showed an accumulation of nitrate N. After the third crop of leafy vegetables, large amounts of N in both ammonium and nitrate forms accumulated in soil that was continuously applied with N levels exceeding 150 kg/ha. These results indicate that the most sustainable N management strategy for leafy vegetables is the application of 100–150 N kg/ha for each crop.

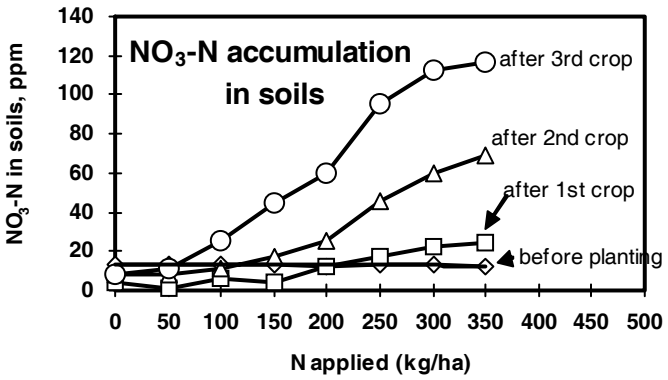
Nitrate accumulations in vegetables are influenced by many factors. There are no absolute toxic levels for target vegetables. Nitrate toxicity may occur when consumption levels exceed the Acceptable Daily In-





***R^2 values are significant at $P \leq 0.001$.

Fig. 30. *Comparisons between conventional (distillation) method and Cardy quick nitrate meter method for the analysis of soil nitrate.*[1]



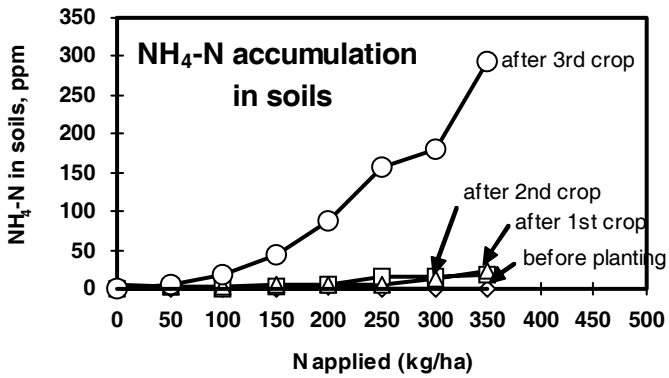


Fig. 31. *Accumulation of NH_4-N and NO_3-N in soils after three cultivations of leafy vegetables with same rates of N applied in the same plots.*

take (ADI) of a person. According to the World Health Organization, the ADI of nitrate is 3.7 mg/kg body weight/day for an adult. In Taiwan, the minimum vegetable consumption recommendation is 73 kg/adult/year. On average, the daily consumption amount is 200 g/person/day. Assuming an adult with a body weight of 65 kg, the maximum ADI of nitrate is 240 mg/day/person. It is concluded that if this person consumes 200 g of fresh leafy vegetables daily, then the nitrate in the leafy vegetable must be below 1200 ppm. From this study, to produce amaranth with nitrate content below 1200 ppm, the N application rate should be in the range of only 60–70 kg/ha. However, the fresh yield of leafy vegetables will be greatly reduced by this recommendation. Therefore, it is suggested that proper selection of low-nitrate vegetable species is a practical way to avoid the potential risks from nitrate toxicity.

The results show the feasibility of using the Cardy nitrate meter test and LCMR for monitoring the production of low-nitrate, safe vegetables. Through this research, farmers can easily adopt these technologies for more efficient N management in their leafy vegetable production systems.

Starter solution technology for chili pepper production

Previous studies at AVRDC have shown that the use of liquid NPK supplements as starter solutions can boost early growth and overall yields of cherry tomato, cabbage, and leafy vegetables. The starter fertilizers provide vital nutrients to young plants before their root systems are well established. In some cases, the use of starter fertilizers can substitute for a large portion of other fertilizers used in production. The objective of this trial was to evaluate the use of starter fertilizers for increasing efficiency of fertilization requirements in chili pepper production.

Chili pepper variety Jin's Joy Selex (PP No. 9848-5032) was used in the trial. The experiment was arranged in a RCBD with four replications. Organic fertilizers were banded at 10 cm below the surface of beds as a basal application before transplanting. Small amounts of inorganic fertilizer were prepared as liquid fertilizer and applied immediately after transplanting or at critical periods during crop growth. Additional details for the trial are listed in Table 94. Twin rows were planted on 1.5-m-wide raised beds with in-row spacing of 45 cm, resulted in a planting density of 29,600 plants/ha. Cultural practices followed the AVRDC standard open field production practices, which included silver mulching covered with rice straw, supporting plants with stakes, and using IPM practices.

Seedlings of chili pepper were transplanted on 3 and 4 September and harvested weekly beginning on 26 November 2003. The initial and mid-stage growth responses were evaluated using dry weights of tops (leaf, stem, and fruit) at 25 and 75 days after transplant (DAT). Fruit weight and number were measured at each harvest.

Starter fertilizers gave a significant boost to both early plant growth and early yields compared to plants fertilized with chicken manure compost (CM) alone or the standard inorganic check (SI) (Table 94). This is important since healthy young plants can resist diseases and their early yields can increase income to farmers.

Plots with organic fertilizer sustained higher yields longer into the harvest season compared to plots using only inorganic fertilizers (Table 94). Among the organically fertilized plots, those with starter fertilizers applied at critical times of plant growth yielded 18–31% higher than CM alone.

Table 94. *Effects of fertilizer treatments on the growth and yield of chili pepper.*[1]

Fertilizer treatment[2]	Biomass dry wt 25 DAT (g/plant)	Biomass dry wt 75 DAT (g/plant)	Market. yield (t/ha)
CM	7.2 e	88.9 cd	13.8 ab
2CM	4.1 f	83.9 d	12.7 b
CM+ST_0	11.3 bc	99.2 bc	15.0 ab
CM+ST_0+ST_1+ST_2 +ST_3 +ST_5	9.6 cd	115.1 a	16.6 a
— +ST_0+ST_1+ST_2 +ST_3 +ST_5	8.2 de	103.1 b	15.8 ab
CM+ST_0+$Side_1$	11.3 bc	109.7 ab	15.5 ab
CM+ST_0+$Side_1$ +$Side_3$	12.2 ab	110.3 ab	16.8 a
SI+ST_0	14.2 a	106.0 ab	14.7 ab
Standard inorganic (SI)	7.2 e	106.5 ab	13.4 b

[1]Transplanted 3 and 4 September 2003 at AVRDC.

[2]Standard inorganic fertilizer (SI) comprised a basal application of N-P_2O_5-K_2O, 80N–40.9P–74.7K kg/ha, and four sidedressings, each of 40N–4.3P–16.6K kg/ha at 12, 25, 36 and 50 days after transplanting (DAT), and two additional sidedressings, each of 30N–3.2P–12.5K kg/ha at 72 and 96 DAT. Composted chicken manure (CM) applications were equivalent to 2x and 1x the rate of N applied as inorganic solid fertilizer (20.8 and 10.4 t/ha of CM). Starter solution (ST) was applied at a rate of 240N–206.4P–199.2K mg in 50 ml water per plant (equivalent to 7.1N–6.1P–5.9K kg/ha) for one application after transplanting (ST_0) and at four sidedressings (ST_1,ST_2, ST_3 and ST_5).

The highest yield was achieved when: 1) CM was combined with starter fertilizer at transplanting and then sidedressed with solid inorganic fertilizers 12 and 36 days later; and 2) CM was supplemented with a starter fertilizer and four additional liquid solutions at critical stages of plant growth. The yields of these two treatments were 24–26% higher than the SI check and were less costly to growers.

Additional studies are planned with the objective of sustaining the booster effects of the liquid supplements in later production stages.

Flood-tolerant chili pepper lines

Flooding during the hot-wet season can destroy crops of cultivated sweet and chili pepper (*Capsicum annuum*). In 2002, we identified several chili pepper lines, many from wild species, which could tolerate flooded conditions. In 2003, we expanded our study with the goal of identifying chili pepper lines for production in flood-prone areas or for use as rootstocks for sweet pepper production during the hot-wet season, when market prices are most favorable.

Eighty accessions, consisting of accessions that performed well in last summer's testing, newly developed lines, and standard bell pepper varieties, were selected for the study. The experiment was designed in a RCBD with three replications. Individual plot size was 1.5 m × 4.0 m; two rows were planted per bed. Plant spacing was 4.0 cm between plants and the plant density was 16 plants per plot. Plants were transplanted on 3 July 2003 and grown using standard open field production practices, which included silver mulching covered with rice straw, bamboo staking, and IPM practices.

Six transplants were selected randomly for each plot and measured weekly for height. Flowering, fruit setting, plant growth characteristics, and incidences of diseases were monitored every other day. The day before flooding, we removed one representative plant from each plot and measured its leaf area, plant height, and root number (only roots 8 cm or longer were counted). After that, we dried each of these plants and measured aboveground weight (biomass). We removed the leaves of another plant to measure the water potential.

The field was flooded from 7–8 August and water maintained 2–3 cm above the soil surface for 30 hr. Most accessions had reached the flowering stage at this time. Accessions were rated for wilting on 12 and 19 August.

In general, those lines that tolerated flooding in 2002 also tolerated flooding in 2003. This consistency gives us confidence that we can select lines that tolerate flooding. The following lines had survival rates of over 90% (those in italics showed a similar response in 2002 and those in standard type were introduced in 2003 testing): C04396, C04399, *C04436A, C04550, C04728, C05534-B, C05535,* C04386, *C04240, C0129, C048248, C04398A, C04819, C04200, C05534, C01378,* C0242-58, C04436B, *C04077,* Toom-1, PBC535, C04400, 9852-54, *C02548, C04389, C04751, C01555,* C0242-75, C0242-63, C04765, *C04870.* Commercial sweet pepper cultivars Andalus and Blue Star had survival rates of 55 and 45%, respectively.

Significant differences were detected among the accessions for flooding tolerance and a wide range of morphological and production traits (Table 95).

A correlation test was conducted to understand the relationships among the measured traits. Results are presented in Table 96. As expected, leaf area index, total dry weight, and plant height were all positively and significantly correlated to each other. These traits all relate to aboveground biomass of plants. We also found that leaf area index and total dry weight were positively correlated to root number.

Wilting measurements were positively and significantly correlated with plant height and root number.

Table 95. *Table of mean squares.*

Source	Leaf water potential	Leaf Area Index	Plant height	Root number	Total dry weight	Wilting % 4 DAF[1]	Wilting % 11 DAF
Rep	1.55**	0.13**	39.72	8.35*	128.73**	479.17	30.75
Treatment	0.06	0.08**	266.78**	3.25	56.54**	1376.60**	819.88**

[1]DAF = days after flooding.

*, ** Significant at $P \leq 0.05$ and 0.01, respectively.

Table 96. *Pearson correlation coefficients for measured traits.*

Source	Leaf water potential	Leaf area index	Plant height	Root number	Total dry weight	Wilting % 4 DAF[1]	Wilting % 11 DAF[1]
Leaf water potential	1.00	0.24 *	–0.09	0.03	0.13	-0.05	0.02
Leaf area index		1.00	0.23*	0.68**	0.89**	-0.02	0.05
Plant height			1.00	0.15	0.52**	0.34**	0.25*
Root number				1.00	0.55**	–0.34**	–0.24*
Total dry weight					1.00	0.19	0.19
Wilting % 4 DAF						1.00	0.85**
Wilting % 11DAF							1.00

[1]DAF = days after flooding.
*, ** Significant at $P \leq 0.05$ and 0.01, respectively. N = 80.

During flooding, the roots are wounded and they struggle to transport water normally. Taller plants tend to be more prone to wiliting than shorter plants since it takes more time and energy for roots to pump water to the upper portion.

The correlation between root number and wilting is fairly low but statistically significant (Table 96). Plants with plentiful roots have greater ability to absorb water. So although roots are wounded during flooding, the abundance of roots allows the root system to provide for the needs of the plant.

Currently AVRDC recommends Toom-1 and 9852-54 for use as rootstocks in pepper production during the hot-wet season; however, results from this study indicate several lines may be superior to the recommended lines. With this in mind, plots were flooded again on 8–10 September, this time for 48 hr. *C. baccatum* lines C04077, C04200, C04386 and C01298, *C. frutescens* lines C01378 and C-4751, *C. chacoense* line C04389 were most tolerant to flooding damage. Among *C. annuum* lines, only 97-7195-1 and 0242-65 had greater than 45% survival after two floodings. Future research will test selections of these lines as rootstocks in sweet and chili pepper production, the first research of its kind.

Eggplant and hybrid tomato rootstocks for tomato production in the hot-wet season

The use of grafted tomato is becoming a popular option for farmers producing tomato in the hot-wet season. Selected rootstocks can protect tomato crops from damage caused by soil-borne diseases and flooding. The objective of this research was to compare the performance of different rootstock materials, namely eggplant, inbred tomato, and hybrid tomato rootstocks.

Plants were grown in a 50-mesh nethouse to exclude whiteflies, which transmit tomato leaf curl virus (ToLCV). This experiment used a RCBD with four replications. Fourteen rootstocks were tested: seven eggplant lines which have proven to perform well as rootstocks in previous tests, one disease-resistant wild eggplant line *Solanum sisymbrifolium*, three tomato inbreds with resistance to soil-borne diseases, and three F_1 tomato hybrids from those inbreds. Heat-tolerant hybrid CHT501 was used as the scion for all rootstocks. A non-grafted check was also included.

Plants were transplanted on 2 June in twin rows on raised beds at a spacing of 50 cm between plants in rows spaced 70 cm apart. Plots consisted of 16 plants. The planting was managed using AVRDC hot-wet season cultural practices, including silver mulching topped with rice straw, staking, furrow irrigation, IPM, and use of fruit-setting hormone. Mean monthly air temperatures and relative humidity levels from June to October ranged from 30.1–31.4°C and 67.2–74.2%, respectively. Harvesting operations terminated on 24 November.

Although CHT 501 is susceptible to ToLCV, only 3 of 1200 plants in the trial suffered from the disease, evidence that the nethouse successfully excluded white-

flies. Eggplant rootstocks generally produced more vine biomass than tomato rootstocks, and showed more consistent levels of protection against bacterial wilt (Table 97). The tomato and wild eggplant lines also provided more protection against bacterial wilt compared to the non-grafted treatment.

The tomato hybrid rootstocks produced the highest yields, with crosses CRA66 × BF101 and H7996 × CRA66 producing yields over 100 t/ha (Table 97).

Plants grown with eggplant rootstocks, in general, showed a slight reduction in yield and individual fruit weight compared to non-grafted plants. Eggplant rootstocks can protect tomato vines from damage caused by flooding or waterlogged conditions (tomato rootstocks cannot tolerate such conditions). In this trial, rainfall amounts were lower than normal and flooding was not a problem.

We conclude that these hybrid tomato rootstocks can generate a yield advantage over non-grafted plants when flooding is not a concern. Yields in the hot-wet season under nethouse-protected conditions can be especially impressive, exceeding 100 t/ha, using the proper scion and rootstock combination. Eggplant rootstocks remain the best option for growers facing risk of flooding and soil-borne diseases.

Grafted tomato production under rain shelters in the hot-wet season

The use of grafted tomato plants can prevent damage caused by flooding and soil-borne diseases in the hot-wet season. In recent years, tomato leaf curl virus (ToLCV) has emerged as another major constraint to tomato production in developing countries. In response, AVRDC has developed a series of ToLCV-resistant hybrids, including TLCV15 and FMTT847. Another popular AVRDC hybrid, CHT501, is well known for its heat tolerance. The objective of this experiment was to evaluate the performance of these lines in the hot-wet season, with and without rain shelter protection.

This experiment was conducted from May to October 2003. The main plot was shelter (with and with-

Table 97. *Performance of tomato, including nongrafted and grafted onto eggplant and tomato rootstocks in the hot-wet season.*[1]

Rootstock	Biomass: Leaf and stem (g/plant)	Biomass: Root (g/plant)	Biomass: Fruit (g/plant)	Biomass: Total (g/plant)	Fruit number (000/ha)	Yield (t/ha)	Avg fruit wt (g)	Bacterial wilt incidence (%)
Non-grafted	140.5 bcd[2]	8.9 ab	242.9	392.3 ab	4920 b-e	79.5 b-e	16.1 a	40.6 d
Eggplant rootstocks								
TS3	157.5 bc	8.2 abc	255.2	420.8 a	5917 abc	82.7 bcd	14.0 d	100.0 a
TS69	133.7 b-e	4.9 cd	175.6	314.3 a-e	4871 cde	71.8 cde	14.7 bc	93.8 ab
EG192	160.3 bc	9.1 ab	168.6	337.9 abc	4803 de	73.1 cde	15.3 bc	100.0 a
EG195	183.9 ab	8.7 ab	147.5	340.0 abc	5798 a-d	84.2 a-d	14.6 cd	92.2 abc
EG203	119.2 c-f	5.6 bcd	231.5	356.4 abc	4883 cde	73.5 cde	15.0 cd	100.0 a
EG219	138.9 bcd	7.7 a-d	165.5	312.1 a-e	4795 de	68.6 de	14.3 cd	95.3 ab
S. sisymbrifolium	214.3 a	8.7 ab	203.3	426.3 a	5746 a-d	87.3abc	15.2 a	84.4 bc
Tomato rootstocks								
TS56B	124.0 c-f	5.0 cd	184.3	313.3 a-e	4176 e	63.2 e	15.2 c	96.9 ab
H7996	61.5 g	4.2 d	154.3	220.0 de	5019 b-e	83.1 bcd	16.6 ab	87.5 abc
CRA-66	75.0 fg	7.1 a-d	195.1	277.2 b-e	5757 a-d	94.3 ab	16.4 a	79.7 c
BF101	56.6 g	6.7 a-d	144.9	208.1 e	4870 cde	79.4 b-e	16.3 bc	89.1 abc
H7996 × CRA66	99.3 d-g	7.7 a-d	219.9	326.9 a-d	6012 a	100.5 a	16.7 a	87.5 abc
H7996 × BF101	90.5 d-g	8.0 abc	177.8	276.2 b-e	5484 a-d	92.6 ab	16.9 a	96.9 ab
CRA66 × BF101	78.7 efg	9.6 a	165.2	253.5 cde	5963 ab	101.1 a	17.0 a	87.5 abc
Mean	122.2	7.3	188.8	318.4	5268	82.3	15.6	88.8

[1]Transplanted 2 June 2003 at AVRDC.

[2]Mean separation using Duncan's multiple range test, $P \leq 0.01$.

out), and subplots consisted of tomato scions CHT501, TLCV15, and FMTT847 non-grafted and grafted onto eggplant EG203 rootstocks. Plants were managed using AVRDC standard practices for summer tomato production.

The effects of treatments were obvious and dramatic. AVRDC's tomato scions FMTT847 and TLCV15 were highly resistant to ToLCV, whereas every CHT501 plant was damaged (Table 98). All nongrafted plants died from bacterial wilt (BW); whereas all grafted plants were symptomless for this disease. Due to their survival against BW, grafted plants outyielded nongrafted plants by 233% in the open field and 143% under shelters.

Grafted plants produced significantly smaller fruits than nongrafted plants and had a tenfold higher incidence of blossom end rot (Table 98). This problem has been reported in the past and can be reduced by making sure there are adequate levels of calcium and moisture in the soil.

Average yields for plants under shelters was 29.8 t/ha, slightly less than yields in the open field, 30.6 t/ha.This difference is nonsignificant and likely due to the lack of rain that fell during the experiment (only 878 mm). Similar results were found in previous years; that is, no benefits were found during the dry summer of 2002 (786 mm fell that season), but significant benefits of shelters were detected during the rainy summer of 2001 (1537 mm).

We conclude that FMTT847 and TLCV15 are well-suited for grafted tomato production during the hot-wet season. The benefits of rain shelters is entirely dependent upon rainfall levels, as would be expected.

Effects of protective structures on yield of summer tomato and sweet pepper

Low yields during the hot-wet season greatly limit summer tomato and sweet pepper production in the lowland tropics. Grafting tomato and sweet pepper lines onto rootstocks that resist both flooding and soil-borne diseases is a proven strategy to overcome these constraints. Protective structures may be another useful technology since they can protect crops from insect pests and the physical pounding of heavy rains. The objectives of this study were to test the most advanced grafted plant materials under different protective structures in order to evaluate the relative advantage of combining these technologies.

Three AVRDC tomato lines were grafted onto eggplant rootstock, EG 203, which possesses resistance to flooding and soil-borne diseases. The grafted determinate tomato hybrid PT4723, with ToLCV resistance, was transplanted on 29 May 2003. The grafted cherry tomato hybrid CHT501, a semi-determinate type, and the grafted indeterminate tomato CL 5915-206D, which is immune to tomato mosaic virus (ToMV) and shows partial resistance to bacteria wilt (BW), both were transplanted to the field on 2 July 2003. A heat-resistant sweet pepper hybrid, Blue Star, was grafted onto a chili rootstock, Toom, which possesses resistance to flooding. The grafted sweet pepper plants were transplanted to the field on 3 June 2003.

Plots consisted of raised beds that were 30 cm high, 2 m wide, and 5 m long. The determinate tomato lines were transplanted in triple rows using spacing of 40 cm between rows and 50 cm between plants in the row; each plot had 29 plants. The indeterminate to-

Table 98. *Effects of rain shelter and scions on yield and disorders for grafted[1] and nongrafted plants grown in the hot-wet season, 2003.[2,3]*

		Marketable yield (t/ha)		BER damage (t/ha)		BW incidence (%)		ToLCV incidence (%)	
Shelter	Scion	Grafted	Nongrafted	Grafted	Nongrafted	Grafted	Nongrafted	Grafted	Nongrafted
Rain shelter	TLCV15	47.9 a[4]	16.9 ab	5.9 a	0.2	0	100	0 b	0 b
	FMTT847	48.2 a	29.4 ab	5.1 a	1.3	0	100	1 b	2.1 b
	CHT501	30.6 b	5.9 b	0.8 b	0.1	0	100	100 a	100 a
Open field	TLCV15	52.8 a	27.7 a	7.8 a	1.2	0	100	0 b	0 b
	FMTT847	53.8 a	5.7 b	8.9 a	0.2	0	100	1 b	0 b
	CHT501	34.4 b	8.8 b	3.2 b	0.2	0	100	100 a	100 a

[1]Scions grafted onto EG 203 eggplant rootstocks.
[2]Transplanted 28 May 2003 at AVRDC.
[3]BER = blossom end rot, BW = bacterial wilt, and ToLCV = tomato leaf curl virus.
[4]Mean separation in columns within shelter treatments by Duncan's multiple range test, $P \leq 0.01$.

mato was transplanted using 20 plants per plot in double rows with spacing of 80 cm between rows and 50 cm between plants in the row. Twenty four plants of sweet pepper were transplanted per plot in double rows with spacing of 80 cm between rows and 40 cm between plants in the row.

There were three shelter treatments, i.e., plastic-covered shelter with open sides, plastic-covered shelter with sides enclosed by 60-mesh 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-diameter galvanized pipe. Ultraviolet-resistant clear polyethylene film was used as covering material for each shelter.

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

Unusually dry and hot weather during the cropping duration (29 May to 31 October) retarded growth of all entries. Cumulative rainfall during this period was only 875 mm (normal is 1419 mm), most of which occurred in June (496 mm). There was a single rainfall of 221 mm on 7 June, and 142 mm on 4 August during which the field was flooded over the bed, but no obvious damage was evident on these grafted plants. The mean air temperatures were particularly high: 28.6ºC in June, 30.9ºC in July, 30.0ºC in August, 29.5ºC in September, and 26.6ºC in October.

The determinate tomato line PT4723F1 was harvested from 24 July to 30 October. This line is not heat-tolerant and all plants produced low yields (Table 99). The enclosed shelters excluded ToLCV-transmitting whiteflies, but since this line is genetically resistant to ToLCV, there was no real benefit for using such an enclosed shelter.

The indeterminate lines, CLN5915-206D and CHT501, were harvested from 4 September to 11 December. Both lines are more heat tolerant than PT4723 F1; however, both lines are susceptible to ToLCV and plants exposed to whiteflies produced significantly lower yields than plants grown in the enclosed shelters. CHT501 is especially heat tolerant and consistently produced the highest yields among tomato lines.

The sweet pepper plots were harvested from 18 July to 11 December. Plants in the enclosed shelter produced significantly higher yields, again due to protection from virus transmission.

This trial showed the benefits of grafting technology for producing reliable yields in the hot-wet season. Tomato and sweet pepper plants are very sensitive to flooding, but the grafted plants in this trial survived flooding during the season.

The effects of shelter treatment and scion selection were clearly evident. For shelters, their cost-effectiveness is debatable, especially for the target clientele of AVRDC (ie. small-scale farmers), but yields of ToLCV-susceptible lines were clearly enhanced by the use of enclosed shelters.

The open-sided shelters could not protect against ToLCV infection, but provided relief against the rains, although this summer was a relatively dry one. Average yields of lines grown under the open-sided shelters were 20–42% higher than average yields in the open field, but yields were variable and these differences were statistically nonsignificant.

As for scions, the benefits of genetic resistance to ToLCV and tolerance to heat were evident in this trial. Selecting varieties with such qualities are likely to be a more cost-effective technology than using enclosed shelters. AVRDC is actively developing such lines and results from other studies indicate they show great potential for hot-wet season production.

Table 99. *Yields of sweet pepper, fresh market tomato and cherry tomato lines under rain shelters (RS) and in open field during hot-wet season of 2003.*[1]

Shelter	Swt. pepper Blue Star (t/ha)	Det. tom. PT4723 (t/ha)	Ind. tom. CLN5915 (t/ha)	Semidet. cherry CHT 501 (t/ha)
RS+Net[2]	64.7 a[3]	11.7 a	21.9 a	76.4a
RS	35.1 b	13.8 a	12.1 b	46.2 b
Open	23.7 c	10.8 a	8.5 b	38.5 b
Mean	41.2	12.1	14.2 b	53.7
CV (%)	12.6	19.5	17.7	10.6

[1]Date transplanted: sweet pepper on 3 June; tomato (PT4723) on 29 May; other tomato on 2 July 2003.

[2]RS = open-sided shelter covered with plastic roof; RS+Net = shelter covered with plastic roof and enclosed using 60-mesh netting along sides.

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

Commercialization of improved vegetable production technologies in Manila

The AVRDC peri-urban vegetable project in the Philippines is designed to stabilize the supply of nutritious vegetables to metro Manila. The following report describes activities in 2003, the last year of this 5-year project. Emphasis in 2003 was on the commercialization of technologies developed by AVRDC and partner researchers from 1998 to 2002.

Commercialization of grafted tomato technology

The grafted tomato technology developed by AVRDC effectively increased tomato yield, often twofold, during the hot-wet season in Central Luzon, Philippines. In the final months of the project, 1 April to 31 December 2003, resources were focused on commercialization of the grafted tomato technology among farmers previously trained in the provinces of Nueva Ecija, Bulacan, Tarlac, and Laguna. Here commercialization is measured by money invested by farmers to construct rain shelters and purchase materials such as grafted seedlings, fertilizers, pesticides, and pay for labor; whereas prior to 2003, materials were provided by the project to farmers receiving training.

Among 41 farmers in the provinces of Bulacan, Tarlac, and Nueva Ecija who invested in grafted tomato in 2003, the mean cost to construct a shelter was 8087PHP, but the mean amount invested by farmers was 3804PHP. The mean unpaid balance for shelters was 4282PHP and mean cash income was 4403PHP. Many farmers, therefore, did not recoup the cost of shelters in a single cropping season, which was expected. If properly stored, materials used to construct shelters can be used for multiple seasons, so a thorough economic analysis would pro-rate the cost of materials over several years, the annual pro-rated cost for a shelter would be less than cited above. However, materials costs are incurred upon delivery and farmers must pay immediately. They do not have the luxury of time-deferred payments. So, returns from a single season appear to paint a rather bleak picture for grafted tomato production, but beginning in season two, many farmers may show a net positive income.

At the end of the project, no farmers had adopted the technology because the investment needed to grow grafted tomato was beyond the means of most, if not all, farmers who received training. The implications are clear: 1) currently the technology is only for farmer-investors and not for resource-poor farmers, and 2) the cost of facilities to produce grafted seedlings and to rear grafted transplants must be reduced before the technology is adopted by a clientele that would benefit the most from off-season production, i.e. resource-poor farmers.

Central Luzon State University, Bureau of Plant Industry (BPI)-Los Baños, and Tarlac College of Agriculture (TCA) are uniquely positioned to foster adoption of the grafted tomato technology among farmer-investors. High-technology grafting chambers were constructed on the campus of CLSU and in the Municipality of San Ildefonso, Bulacan; low-tech chambers are located at BPI, and TCA. These facilities are capable of producing several thousand grafted seedlings each season.

Commercialization of improved practices for pak-choi

Previous studies showed the use of net tunnels and raised beds in pak-choi production could reduce crop damage and increase marketable yields by up to 500%. In training exercises conducted with farmers from 1998 to 2002, netting for net tunnels was provided to participants. The effort in 2003 was designed to encourage farmers themselves to purchase netting and other inputs. Personal investment would be a measure of the appeal, and therefore potential sustainability, of improved practices among farmers after the project terminates and funding ceases.

From among 16 potential investors, 5 purchased netting and other inputs. Net income among investors ranged from –4768 to 6646PHP. Two investors lost money with one crop but made money the second because cost of netting was subtracted from gross income for Crop 1 and price/kg was higher for Crop 2 than for Crop 1 by 42 to 100%. Positive net income occurred when yields were 17 to 29 t/ha; whereas, negative net income occurred when yields were 9 to 11 t/ha. Clearly, yield and price/kg are critical variables that affect net income, and as farmers became more accustomed to the proper use of netting, their yields increased from a range of 8–17 to 9–18 t/ha from their first crop to the next.

IPM fact sheets for pak-choi pests and diseases, flash cards with photos of insect pests and diseases and posters describing pest management tactics were distributed among the 16 potential investors. As well, large posters were given to the governmental institu-

tions, namely Bureau of Plant Industry and Tarlac College of Agriculture, and to the private seed companies, namely East-West Seeds, Ramgo, and Harbest Agribusiness Corporation. Only one of five farmer-investors claimed that the materials were needed to improve their management skills.

We found that pak-choi farmers were reluctant to invest in practices shown to effectively shield their crop from insect damage. That is, they will use net tunnels, but only if the netting is free. Demonstrations and training in the proper use of netting and pest management were not persuasive means to promote adoption of improved practices for pak-choi.

Illegal pesticide residues are often reported on leafy vegetables, which are short-season crops. We found many farmers had difficulty producing attractive leafy vegetables while still waiting the required time interval between spraying and harvesting. The AVRDC technology package would reduce pesticide usage by about 75%, but this was not a major concern among farmers. The main reasons were: 1) unawareness on the problems of contaminated vegetables for human health; 2) markets do not provide price preferences for safer vegetables; and 3) farmers avoid the complexity of applying IPM measures in preference of over-spraying, as spraying is considered the most secure way to prevent harvest and income losses.

Market price was more important and less predictable than crop damage or food safety. Crop loss was a constant, predictable and often unavoidable, whereas, markets fluctuate wildly. Farmers therefore, were reluctant to invest in costly crop protection measures that may not always succeed.

Future research needs

Constraints persist to adoption by Filipino farmers of grafted tomato culture and improved IPM practices for pak-choi. Five years of continuous research has, indeed, answered some critical questions on methodology and management, but these answers have not persuaded farmers to invest in new technologies and practices. It is the capital requirement of shelters for the grafted tomato technology package and netting for the pak-choi IPM technology package that discourages farmers from investing to minimize their risk of crop failure. In the future, research is needed to reduce costs for production technologies and to commercialize new technologies among farmer-investors, not resource-poor farmers.

Comparison of IPM practices vs. farmer practices on pak-choi yield and pesticide residues in Central Luzon, Philippines

Vegetable production by most farmers in Central Luzon, Philippines is highly dependent on pesticides. Pak-choi (*Brassica rapa* L. cv. *pak-choi*) production is no exception. Pesticides are used to prevent insect infestation and therefore are commonly applied before pest species are correctly identified and pest intensity assessed; a practice which is not totally irrational given that infestation by the cabbage webworm (*Hellula undalis*) often occurs at plant emergence and young larvae are difficult to detect. Disease is attributed to excessive rain and sun; therefore, fungicides are not applied. Nevertheless, current pesticide practices can lead to as many as 19 insecticide applications per crop over 40–45 days. The common view among provincial agriculturalists is that pesticide use is excessive and leads to reduced pesticide efficacy and to human health problems. That litany is repeated often among consumers, although evidence is largely anecdotal, and therefore, not unbiased. The objectives of this study were to understand the crop protection practices of pak-choi farmers in Central Luzon and to assess pesticide residue levels on their crops.

Replicated trials were conducted with five farmers in San Leonardo. Farmer standard practices (FSP) were compared with researcher-managed IPM practices; these paired trials were arranged in a RCBD with two or three replications per site.

As for FSP, farmers in Central Luzon commonly seed pak-choi during the hot-wet season when irrigation is unnecessary. Seed is broadcast onto a cultivated seedbed at about 5.4 kg/ha. A complete fertilizer of 14–14–14 NPK at 60 kg/ha is applied as a basal treatment with 100 kg/ha urea added 7 days after plant emergence. Pesticide treatments begin immediately upon plant emergence and continue until harvest. It is not uncommon for some farmers to apply an insecticide on the day of harvest. Chlorpyrifos is a common insecticide used in Central Luzon even though it is not on the list of recommended pesticides for leafy vegetables. Some farmers report using carbofuran, which is not approved for pak-choi. Insecticides are usually applied as a mixture of two or three active ingredients with little or no attention to compatibility.

For the researcher-managed IPM plots, researchers from Central Luzon State University (CLSU), the

Bureau of Plant Industry (BPI), AVRDC, and Technische Universität München (TUM) worked alongside farmers and introduced them to improved practices for pest and disease management. Bed preparation and seeding was done by farmers following their standard practices. IPM fields were treated with 35 t/ha chicken manure or composted household waste prior to seeding, followed by 71 kg/ha of 14–14–14 NPK as a basal treatment. Later, fields were treated with 22 kg/ha of urea at one week and again at two weeks after plant emergence. IPM fields were monitored twice every week for pest and disease incidence and numbers formed the basis for pesticide treatment. Researchers applied pesticides in these plots.

After farmers were trained to recognize specific pests and diseases and to make treatment decisions based on pest severity, they were asked to conduct paired trials comparing their standard practices and researcher-advised/farmer-managed IPM. Researchers continued to provide input to decision-making, but farmers applied the pesticides. Initially these trials too, were replicated, but this was dropped in favor of paired but non-replicated trials because farmers were unwilling or unable to follow the experimental protocol.

Before training, farmers following their FSPs used 68% more insecticide but 31% less fungicide than researchers who followed IPM guidelines (Table 100). Researcher-managed plots generally suffered more damage from insect pests and less damage to web blight. By using IPM, researchers were able to reduce the number of pesticide treatments by 59% and quantity of pesticide used by 49% without sacrificing yield.

Following their own practices after training, insecticide use by farmers dropped dramatically from a mean of 5.68 L/ha ai to 0.52 L/ha ai. This decline was even lower than in those plots where farmers followed IPM recommendations, which used 1.33 L/ha ai. Farmers also used less fungicide than recommended in IPM, both before and after training. Following IPM, the number of pesticide treatments on average was reduced from 11.3 to 8.3 treatments, but the quantity of pesticide used increased by 80%. Yields under IPM increased by 41% (Table 100).

It soon became apparent that pesticides alone, either by following FSP or IPM, did not consistently prevent insects and disease from causing severe crop damage. In fact, many trials were destroyed by cabbage webworm, diamondback moth (*Plutella xylostella*), armyworm (*Spodoptera litura*), striped flea beetle (*Phyllotreta striolata)*, and web blight disease (*Rhizoctonia solani*), and had to be abandoned. As a consequence, farmers were trained to use 32-mesh netting (Fig. 32) supported over seedbeds by iron rods as a means to protect crops from damage by insect pests. Farmers were encouraged to monitor pest and disease populations as the net tunnels did not always prevent entry by pests (if there were holes in the netting or gaps between the net and seed bed) or exclude their presence as some species pupate in soil (e.g. striped flea beetle) and emerge in the enclosed tunnels.

A trial was conducted in which farmers evaluated the benefits of net tunnels under IPM. Mean numbers of pesticide applications by farmers using IPM alone and IPM plus net tunnels were 3.6 and 1.6, respectively; a significant reduction compared to the other trials. Quantities of pesticide used were also reduced, especially in plots with net tunnels. Net tunnels contributed to significantly higher yields in two of the five

Table 100. *Pesticide use and damage caused by pests and diseases in plots grown under different management regimes in Central Luzon, Philippines in 2002.*

Management practice	Pesticide applications (no.)	Insecticide ai (L/ha)	Fungicide ai (L/ha)	Total ai (L/ha)	Damaged plants[1] insects (%)	Damaged plants[1] web blight (%)	DBM/ plant[2] (no.)	CWW/ plant[2] (no.)	Yield (g/sq m)
Before training									
Farmer standard practice	13.5	5.68	1.12	6.81	27	37	0.02	0.01	536
Researcher-managed IPM	5.5	1.83	1.63	3.47	40	25	0.02	0.02	536
After training									
Farmer standard practice	11.3	0.52	0.08	0.61	53	38	0.19	0.00	485
Researcher/ farmer-managed IPM	8.3	1.33	1.72	3.06	42	14	0.19	0.00	802

[1,2]Measured at plant harvest and plant emergence, respectively. DBM = diamondback moth larvae; CWW = cabbage webworm larvae.

Fig. 32. *Pak-choi growing under net tunnels.*

trials, and on average increased yields from 991 to 1888 g/m2.

To test for pesticide residues, twelve 1-kg samples of pak-choi leaves were collected from both FSP and IPM plots over nine crops from 1999 to 2003. All samples were placed in labeled plastic bags at the time of collection and transported the same day in an ice chest (4 °C) to the BPI Analytical Laboratory in Manila. There, samples were immediately frozen before being analyzed by liquid gas chromatographic procedures for presence of selected pesticides. Standards were provided by BPI. Pesticide residue was detected in seven of nine fields sampled. In two, the amount detected exceeded maximum residue levels (MRL) established by ASEAN for chlorpyrifos and in one sample the amount exceeded the MRL for cypermethrin (Table 101). These three samples were from FSP plots. Companion samples from IPM plots did not exceed MRLs.

IPM training materials for pak-choi developed by TUM and AVRDC focused on pest identification and crop monitoring. Farmers at the training classes stated the materials were useful; however, only those farmers with minimal experience used the materials after training. Experienced farmers were already familiar with most pests and were not willing to monitor their crops for pest and disease incidence.

Our data supports claims that vegetables in the Philippines may be unsafe because of pesticide residue; however, the danger may be less acute than has been assumed. Residues in excess of ASEAN standards for maximum residue levels were found in one-third of the fields sampled. In two-thirds, levels were less than MRL standards or zero. It is encouraging to note, however, that where IPM was practiced no residue exceeded MRL standards.

Table 101. *Residue (ppm) of four insecticides detected in pak-choi taken from fields managed by farmers' standard practices (FSP) and IPM.*

	Chlorpyrifos[1]		Profenofos		Cypermethrin		Methamidophos	
Farm	FSP	IPM	FSP	IPM	FSP	IPM	FSP	IPM
1	**0.192**	0.038	-	-	0	0.133	0.833	0.406
2	-	-	0.001	0.018	0.037	0.346	0	0
3	0.011	0.012	0.378	1.526	-	-	-	-
4	**0.191**	0.011	0	0.151	-	-	0	0.037
5	0	0	0.946	0.021	-	-	-	-
6	0	0	-	-	-	-	-	-
7	0	0	0	0	-	-	-	-
8	-	-	0.994	0.724	-	-	-	-
9	-	-	-	-	**4.917**	0.102	-	-

[1]Maximum residue levels (MRLs) on vegetables as established by ASEAN: chlorpyrifos, 0.05 ppm; profenofos, not available; cypermethrin, 2 ppm; methamidophos, 1 ppm. Those plots which exceed MRLs are highlighted in bold.

In conclusion, pak-choi farmers in Central Luzon can reduce the number of insecticide treatments and quantity applied without placing their crops at added risk of crop loss, if they practice IPM. Moreover, an additional reduction in pesticide use can be achieved and yield increased when net tunnels are used. By far the least amount of pesticide used, the fewest pesticide applications, and the highest yields were obtained from pak-choi grown under net tunnels.

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Variation in antioxidant activities among 151 edible plants

Antioxidants have been used for a long time by the food industry for preservation of nutrition and taste qualities and to suppress lipid peroxidation leading to rancidity. With the research on the pathogenesis of free radicals in human diseases, antioxidants have gained broader interest in their role of inhibiting free radical reactions, which help protect the human body against damage by reactive oxygen species (ROS). Dietary antioxidants are critical especially when the human body is under oxidative stress due to the imbalance between generation of ROS and endogenous antioxidants. Vegetables are abundant in phytochemicals with antioxidant activities (AOA), and are regarded as good sources for dietary antioxidants. Little information is available on AOA of vegetables native to the tropics and subtropics. An appropriate selection of particular vegetables or groups of vegetables would help to increase the consumption of AO in diets.

In this study, a total of 151 edible plants including 28 species were either provided by Technology Promotion and Services Unit (TPSU) from the Indigenous Vegetable Display Garden of the AVRDC or collected from local markets of southern Taiwan in 2001 to 2003. Species included are popular and lesser-known plants consumed as vegetables, herbs and spices in tropical and subtropical areas of Asia. The AOA of their water and methanol extracts were measured with four methods, namely super oxide, ABTS (2,2-azino-bis (3-ethylbenz-thiazoline-6-sulfonic acid), DPPH (1,1-diphenyl-2-picryl-hydrazyl) radical scavenging assays, and inhibition of lipid peroxidation (ILP) assay. Superoxide dismutase (SOD), Trolox (a vitamin analogue) and vitamin C were used as antioxidant standards. The units of AOA were either SODE (SOD equivalent, 100U/g), or AE (ascorbate equivalent, μmol/g) or TE (Trolox equivalent, μmol/g) on a dry weight basis.

We classified the 151 entries into 6 AOA classes, ranging from VH (very high), High, M (moderate), Low, VL (very low) and None (no AOA) (Fig. 33). Distributions of entries for AOA were not continuous but very skewed; only 2–9 entries per method were classified as VH. The top ten highest species for AOA varied depending on the assays, but Chinese cedar (*Cedrela sinensis*), rosemary (*Rosmarinus officinalis*), Tree of Damocles (*Oroxylum indicum*), and sickle senna (*Cassia tora*) demonstrated very high AOA in most assays (Table 102). Among species, Chinese cedar produced the highest AOA value for SOS (1908 SODE), ABTS (1706 TE) and ILP (1167 TE) methods; rosemary had the highest AOA value (3979 TE) for the DPPH method.

This study included many edible plants that have been elements of diets for many years and have dual functions as food and medicines. Based on our AOA data, most of the very high AOA species are perennial and locally utilized vegetables. Rosemary, categorized as VH in our study, is a widely used herb and well-recognized for its high antioxidant capacity. We included it as a reference for comparison with the other vegetables. Other VH AOA species included Chinese cedar, Tree of Damocles, rue, cassod tree, sickle senna, and sweet potato leaves.

Chinese cedar originated from China and can be grown as a tree for food and landscaping. The tender leaves and sprouts are prized as a vegetable for its high nutrient density and unique flavor. Its stems and roots are used in traditional Chinese medicine to relieve pain, stop bleeding, and to treat dysentery and inflammation. Several types of phytochemicals, including flavonoids, limonoids, phytols, toosendanin, and cedrelone have been isolated from leaves and stems of Chinese cedar.

Tree of Damocles, also called swordfruit tree, originated from Southeast Asia. The young leaves and flowers are often cooked as a side dish with rice. Tree of Damocles contains several types of flavonoids in seeds, such as chrysin, oroxylin, baicalein and baicalein glycosides. The fruits showed strong anti-mutagenesis activity and were highly correlated to the high concentration of baicalein (5,6,7-trihydroxyflavone) in leaves.

Many *Ruta* species contain diverse classes of phytochemicals such as coumarins, flavonoids and alkaloids, and rue is a hardy green herb that has antibacterial and anti-fungal activities. Fresh leaves have a bitter taste due to the high rutin content, a polyphenolic flavonolone glycosid.

Cassod tree and sickle senna originated in the tropics and are used for food and medicinal purposes. The

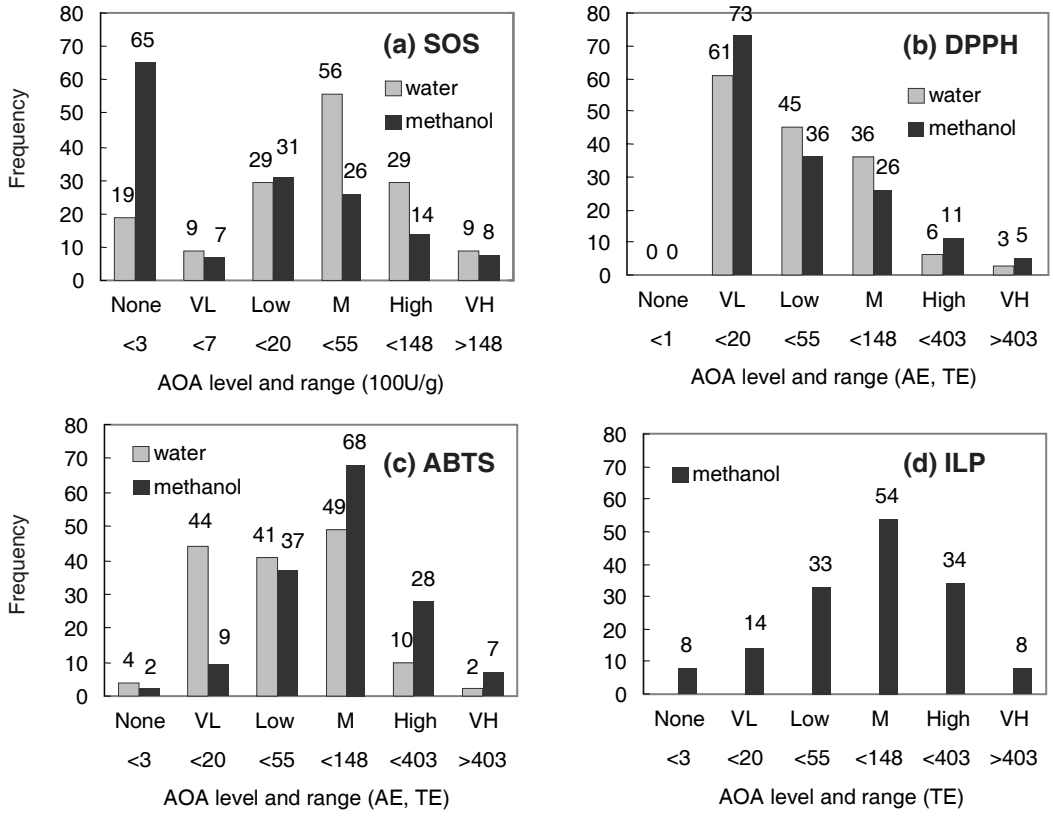


Fig. 33. *Frequency of entries by AOA levels.*

flowers of the cassod tree are eaten in curries and the young leaves and shoots of sickle senna are steamed as a potherb or cooked with rice. Several bioactive compounds such as bianthraquinones, luteolin, and emodin had been reported for these two plants.

Sweet potato leaves are eaten as a cooked leafy vegetable in many countries, and the leaves were reported to contain large amount of total phenolics (1.4–17g/100g dry wt), which are mostly caffeic acid and chlorogenic acid derivatives.

To increase AO consumption, the general public needs greater awareness of the species of very high AOA. Given the wide range of AOA among edible plants, there is great potential to increase antioxidant consumption. From the antioxidant density point of view, even a small quantity of intake of the high AO species would make significant differences in total consumption because their AOA can be 10–100 times higher than those of commonly consumed vegetables.

Table 102. *The top ten species highest in antioxidant activities[1] within 151 edible plants and ranked by ABTSm activity.*

No.	Scientific name	Common name (part)	DM (%)	SOSw SODE	SOSm SODE	DPPHw AE	DPPHm TE	ABTSw AE	ABTSm TE	ILPm TE
1	*Cedrela sinensis*	Chinese cedar (leaf)	36.5	(281)	(1098)	(1134)	(1716)	(1008)	(2105)	(1167)
2	*Rosmarinus officinalis*	Rosemary (leaf)	10.0	(147)	(444)	(547)	(3979)	(300)	(1446)	(650)
3	*Oroxylum indicum*	Tree of Damocles (shoot)	20.3	109	(695)	(293)	(548)	71	(1363)	(824)
4	*Cassia tora*	Sickle senna (leaf)	16.1	(258)	(369)	(291)	(357)	(228)	(662)	354
5	*Cassia siamea*	Cassod tree (shoot)	20.8	(389)	44	(564)	(565)	(573)	(642)	(418)
6	*Amaranthus* spp.	Amaranth (plant)	2.4	121	71	(165)	(425)	147	(578)	(416)
7	*Phyla nodiflora*	Frog fruit (shoot)	10.7	0	28	7	(323)	18	(498)	291
8	*Hibiscus sabdariffa*	Roselle (shoot)	10.7	(185)	(192)	119	167	153	(403)	(393)
9	*Wedelia triobata*	Wedelia (leaf)	11.5	27	52	92	(302)	114	(358)	354
10	*Ipomoea batatas*	Sweet potato (leaf)	9.1	48	(231)	133	(213)	(170)	(311)	361
11	*Lactuca sativa*	Leafy lettuce, pointed (plant)	8.0	40	60	39	(381)	24	293	(695)
12	*Brassica oleracea*	Red cabbage (plant)	7.0	62	78	(191)	205	93	287	(456)
13	*Cassia occidentalis*	Coffee senna (leaf)	11.8	68	0	60	61	(161)	252	220
14	*Ruta graveolens*	Rue (leaf)	26.2	(350)	15	117	128	(198)	252	180
15	*Zingiber officinale*	Ginger, old (stem)	6.1	94	(380)	105	101	(181)	251	145
16	*Lycium chinense*	Chinese boxthorn (leaf)	13.8	121	(138)	4	39	57	221	(617)
17	*Spinacia oleracea*	Spinach (plant)	5.0	113	0	(158)	105	102	206	244
18	*Cassia sophera*	Penghu senna (leaf)	17.8	74	12	128	76	(198)	175	241
19	*Pisum sativum*	Pea (shoot)	8.9	29	7	100	77	45	163	(401)
20	*Solanum melongena*	Eggplant (fruit)	5.4	62	(205)	24	77	70	132	303
21	*Abelmoschus esculentus*	Okra (fruit)	8.0	88	9	(247)	157	109	128	153
22	*Echeveria* sp.	Echeveria (leaf)	4.1	(223)	45	49	44	71	118	74
23	*Solanum indicum*	Indian nightshade (fruit)	16.6	(172)	83	26	27	39	97	54
24	*Blumea balsamifera*	Ngai camphor plant (leaf)	17.6	111	0	(148)	55	131	88	54
25	*Sphenoclea zeylanica*	Wedgewort (leaf)	10.3	(229)	93	64	31	79	84	83
26	*Lycopersicon esculentum*	Tomato (fruit)	4.3	54	(116)	23	19	75	80	149
27	*Sauropus androgynus*	Star gooseberry	23.7	88	15	75	36	(179)	58	94
28	*Solanum macrocarpon*	African eggplant	8.9	(190)	77	12	5	20	38	64

[1]AOA were measured by four antioxidant assays: SOS, DPPH, ABTS and ILP. The letter "w" and "m" represent water and methanol extract. The AOA units are given on a dry weight basis: SODE, superoxide dismutase equivalent, 100U/g; AE, ascorbate equivalent, µmol/g; and TE, Trolox equivalent, µmol/g. The AOA values of top ten highest entries within assays are enclosed in parentheses.

Antioxidants of Chinese cedar (*Cedrela sinensis*): temperature effects, processing properties and in vitro bioavailability

Chinese cedar, also called Chinese mahogany and Chinese toons (*Toona sinensis,* syn. *Cedrela sinensis*) is a perennial that originated from the forests of China. The tender leaves and sprouts of this tree have unique flavor and high nutrient values. The leaves, stem and root are used in traditional Chinese medicine to relieve pain, stop bleeding, and to treat dysentery and inflammation. Recent research indicates that leaf extracts exert a strong inhibition of several pathogenic bacteria such as *Staphylococcus aureas, Salmonella typhi* and *Shigella dysenteriae,* as well as show anti-cancer properties. Several types of phytochemicals, including flavonoids, limonoids, phytols, toosendanin, cedrelone had been isolated from Chinese cedar leaves and stems. In our study of 151 kinds of vegetables, we have found that the methanolic extract of Chinese cedar leaves demonstrate exceptionally strong antioxidant activities (AOA) in scavenging of free radicals (superoxide, ABTS, and DPPH) and inhibition of lipid peroxidation. Chinese cedar has great potential to be used as antioxidant supplements in addition to its nutritional and medicinal values. We report here on our investigations of Chinese cedar, including effects of various temperatures on AOA of leaves, monitored AOA changes during in vitro intestinal digestion and use of HPLC method to profile antioxidants.

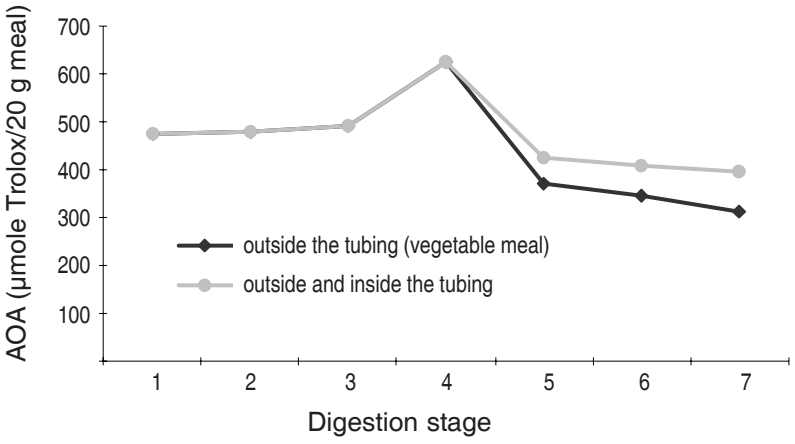
HPLC profiling of Chinese cedar antioxidants

About 2 kg of branches were harvested by the Technology Promotion and Services Unit from 5 one-year-old Chinese cedar plants in the AVRDC Indigenous Vegetable Display Garden. Tender brown-green and fully developed dark green leaves were detached from the branches; the senescent leaves were discarded. Antioxidants were extracted from 20 g of cut, fresh leaves in a homogenizer with methanol (1:5, w/v) and centrifuged. After acid hydrolysis to breakdown sugar and phenolic linkages, the extract was filtered and then subjected to HPLC analysis. This product was fractionated and collected every minute for 100 min, and then freeze-dried for further determination of ABTS scavenging activity. Vitamin antioxidants including β-carotene (HPLC method), α-tocopherol (HPLC method), ascorbate (colorimetric method) and total phenolics (Folin method) of fresh leaves were also measured. Fig. 34 presents the antioxidant profiles of Chinese cedar leaves before and after acid hydrolysis. Based on their optical absorption patterns, the major methanol extractable antioxidants were thought to be phenolics. With acid treatment, free phenolic acids such as gallic acid (7.12 mg/g) and flavonoids such as quercetin (3.42 mg/g) and kaempferol (0.78 mg/g) were detected. The contents are presented on a dry weight basis. Most of the phenolic compounds were conjugated with sugars in nature. Antioxidants at retention time from 25 min to 40 min are unknown and need identification. Ascorbate and α-tocopherol contents in Chinese cedar leaves were 8.3 mg/g and 2.4 mg/g on a dry weight basis and their AOA in ABTS scavenging were equivalent to 47 μmole and 5.6 μmole Trolox, which were thought to play a minor role in ABTS scavenging capacity. Total phenolic content was 335 mg/g, which was the major antioxidant contributing to ABTS activity.

Table 103. *Antioxidant activities of Chinese cedar.*

AO assays	Extraction	Unit[1]	Antioxidant activity	
			fresh weight basis	dry weight basis
SOS	Methanol	SODE, mg SOD protein/g	8.49	23.57
	Water	SODE, mg SOD protein/g	2.25	6.25
ILP	Methanol	TE, μmole Trolox/g	3.23	8.98
DPPH	Methanol	TE, μmole Trolox/g	558	1550
	Water	AE, μmole ascorbate/ g	199	550
ABTS	Methanol	TE, μmole Trolox/g	840	2330
	Water	AE, μmole ascorbate/g	425	1180

[1]SODE = superoxide dismutase equivalent, TE = Trolox equivalent, and AE = ascorbate equivalent.



Digestion stage

1. Fresh
2. Adjusted to pH 2
3. Addition of pepsin
4. Pepsin digestion for 2 h
5. Addition of dialysis tubing to increase pH value up to 6
6. Addition of pancreatine and bile salts
7. Pancreatine and bile salt digestion for 2 h

Fig. 34. *Changes in ABTS scavenging activity during in vitro digestion*

Temperature effects

Several 20-g samples of fresh leaves were soaked in 80 ml of prechilled/preheated water or methanol at 20°C, 25°C, 50°C and 100°C, respectively, for 10 min, and antioxidants were extracted and measured AOA by ABTS and superoxide scavenging (SOS) activities. Antioxidants with SOS and ABTS scavenging activity were stable at temperatures ranging from –20°C to 100°C (Fig. 35). Boiling had the effect of slightly increasing SOS activity for both methanol and water extracts. The results indicate that the common vegetable processing methods such as freezing, blanching, and boiling would not affect AOA of Chinese cedar.

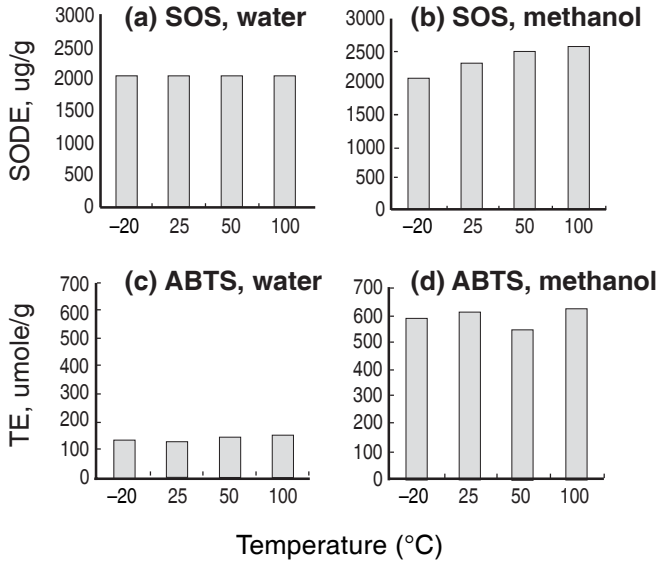


Fig. 35. *Temperature effects on AOA of Chinese cedar.*

AOA changes of Chinese cedar during in vitro intestinal digestion

The 5-h in vitro bioavailability assay of antioxidants was performed using fresh leaves with 5% dry matter prepared in water, followed by homogenization, pH 2 adjustment, 2 h of pepsin incubation, addition of dialysis tubing to increase the pH value > 6, and the final stage of 2 h digestion with intestinal enzymes (bile salts and pancreatine). ABTS scavenging activity of methanol extract from each stage was measured. Higher AOA was obtained with acidic conditions after pepsin incubation. The increase may be due to the unlocking of antioxidants from digested protein and the partial release of antioxidative phenolic compounds from their derivatives by acid hydrolysis. AOA dropped 10% at pH 6, which implied that the antioxidants were favored by acidic conditions such as in stomach rather than neutral pH such as found in the intestine. This is supported by the lower AOA found at pH 8 compared to that of 2, 4, and 5.5 (the pH value of Chinese cedar meal). About 21% of antioxidants were detected in the dialysis tubing, which means they were smaller molecules with molecular weights less than 6000 g/mole and may be easier to be undertaken by intestines due to the smaller molecular size comparing to antioxidants outside the tubing.

In summary, our study found that AOA in Chinese cedar leaves were not affected by freezing and boiling, and were resistant to intestinal digestion. In addition to the large amount of phenolic acids and flavonol derivatives, the species measured high in essential vitamin antioxidants, including β-carotene, ascorbic acid and α-tocopherol. Chinese cedar is an excellent source of dietary antioxidants.

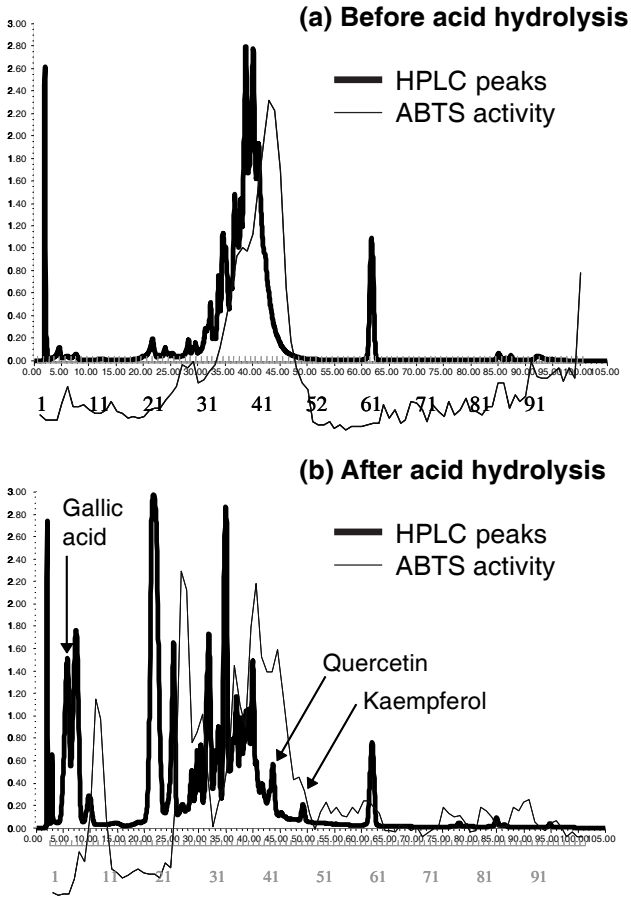


Fig. 36. *Antioxidant profiles of methanol extract of chinese cedar before (a) and after (b) acid hydrolysis.*

Nutrition values of vegetables harvested from the AVRDC Indigenous Vegetable Display Garden

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, vegetable species vary in their contents of nutrients. This work was conducted to measure nutrient contents of vegetables grown in the AVRDC Indigenous Vegetable Display Garden and to investigate their potential nutritional contribution.

Sixty-one entries from 55 species of vegetables were grown and harvested by the Technology Promotion and Services Unit in 2002 and 2003. Edible portions from 1–2 kg of raw materials were prepared for nutrient analyses by washing and cutting them into pieces, followed by thorough mixing, and oven-drying at 45 °C or freezing at –70 °C. Samples were analyzed for dry matter, crude fiber, sugar, protein, vitamins A, C and E, calcium (Ca), and iron (Fe). Analytical methods of the Association of Official Analytical Chemists (AOAC) were used with some modifications.

Nutrient values of 100 g fresh edible portions of the tested vegetables are presented in Table 104. The ranges of the values were wide due to various types of vegetables collected in this test, including leaves of perennial trees, leaves of herbaceous plants, herbaceous stems, flowers and fruits. We found that: 1) the high beta-carotene vegetables (>8 mg) included leaves of penghu senna (*Cassia sophera)*, jute mallow (*Corchorus olitorius*), Sickle senna (*Cassia tora*), mugwort (*Artemisia indica*), chinese mallow (*Malva verticillata*), and butterfly pea (*Clitoria ternatea*); penghu senna has an exceptional high content of about 20 mg; 2) iron contents >4 mg were only found in young leaves of Chinese mallow (9.4 mg) and water dropwort stem (*Oenanthe javanica*) (4.2mg); 3) high vitamin E (>5.9 mg) vegetables were penghu senna, rue (*Ruta graveolens*), star gooseberry (*Sauropus androgynus*), ivy gourd fruit (*Coccinia grandis*) and daylily (*Hemerocallis fulva*); 4) high vitamin C (>220 mg) species were coffee senna (*Cassia occidentalis*), penghu senna, rocket salad (*Eruca* spp.) and rue; and 5) young shoots of coffee senna, ivy gourd, weed passion flower (*Passiflora foetida*) and penghu senna demonstrated a high protein content (>40%) on a dry weight basis.

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Table 104. *Nutrition values of 100 g edible portions of vegetables harvested from the AVRDC Indigenous Vegetable Display Garden in 2002 and 2003.*

Scientific name	Common name	Part	Dry matter (g)	Protein (g)	ß-Carotene (mg)	Vit. C (mg)	Vit. E (mg)	Calcium (mg)	Iron (mg)
Abelmoschus manihot	Sunset hibiscus	Young shoots	12.3	3.60	5.11	82	4.51	163	1.29
Allium schoenoprasum	Chive	Leaf	10.0	2.46	1.51	21	1.25	92	0.50
Angelica keiskei	Ashitaba	Young shoots	8.7	1.37	1.85	43	-	55	0.50
Artemisia dracunculus	Estragon	Leaf	12.0	3.70	5.36	23	0.59	95	1.76
Artemisia indica	Mugwort	Leaf	20.0	5.16	9.21	31	3.04	21	2.43
Artemisia lactiflora	White mugwort	Young shoots	12.2	3.65	4.99	27	-	88	1.71
Asystasia gangetica	Chinese violet	Young shoots	15.6	4.99	4.80	53	1.54	201	1.70
Beta vulgaris	Swiss chard	Young leaves	8.6	2.27	1.54	12	0.35	68	0.80
Beta vulgaris	Swiss chard, dark green	Leaf	7.0	1.85	2.72	17	0.86	54	0.55
Beta vulgaris	Swiss chard, ighlt green	Leaf	6.0	1.29	1.38	6	1.05	52	0.55
Bidens bipinnata	Pilose beggarticks	Young shoots	10.0	3.22	4.29	43	2.35	104	1.41
Bidens pilosa	Hairy beggarticks	Young shoots	10.6	3.38	4.97	55	1.74	109	1.28
Brassica carinata	Ethiopian kale	Young shoots	9.6	2.85	1.50	137	0.50	133	0.78
Cassia occidentalis	Coffee senna	Young leaves	11.7	5.24	3.99	336	3.27	22	1.20
Cassia siamea	Cassod tree	Young shoots	20.8	4.89	2.65	108	2.28	50	1.41
Cassia sophera	Penghu senna	Leaf	18.0	7.17	19.83	291	11.85	273	2.88
Cassia tora	Sickle senna	Leaf	16.0	4.97	11.43	105	4.09	346	1.39
Chrysanthemum coronarium	Garland chrysanthemum	Young shoots	8.7	2.56	4.35	25	-	106	1.30
Cichorium endivia	Endive	Young shoots	9.3	1.71	2.69	25	-	61	0.83
Clitoria ternatea	Butterfly pea	Young shoot	12.0	4.51	8.52	117	2.27	23	1.34
Coccinia grandis	Ivy gourd	Immature fruit	25.0	4.43	0.40	17	-	60	1.55
Coccinia grandis	Ivy gourd	Fruit	32.0	5.44	1.40	5	6.00	105	2.06
Coccinia grandis	Ivy gourd	Young shoots	7.4	3.21	0.95	26	0.75	15	0.95
Colocasia esculenta	Taro	Stem	7.0	0.32	0.20	5	-	79	0.36
Corchorus olitorius	Jute mallow	Young leaves	12.0	3.69	3.15	61	1.74	138	1.12
Corchorus olitorius	Jute mallow	Leaf	18.0	5.96	11.94	72	3.02	198	2.36
Cucurbita moschata	Pumpkin	Young shoots	10.4	3.83	0.45	13	2.72	75	1.21
Curcuma aromatica	Aromatic turmeric	Stem	30.0	7.39	0.02	0	0.20	20	1.85
Echeveria spp.	Echeveria	Leaf	4.0	0.32	0.46	10	-	338	0.20
Eruca spp.	Rocket salad	Young leaves	12.2	3.83	4.47	254	1.95	282	1.16
Eruca vesicaria	Rocket salad	Young leaves	13.7	4.38	3.78	276	0.17	359	1.64
Hemerocallis fulva	Daylily	Flower	12.4	2.35	0.58	39	5.89	16	0.57
Hibiscus sabdariffa	Roselle	Young shoot	11.0	2.62	4.40	25	2.49	217	1.26
Ipomoea batatas	Sweet potato	Young shoots	11.2	3.29	0.75	13	0.24	30	1.26
Lablab purpureus	Hyacinth bean	Mature fruit	8.9	1.93	0.05	14	0.09	22	0.60
Lagenaria siceraria	Bottle gourd	Fruit	5.0	0.58	0.02	5	-	7	0.30

Malva verticillata	Chinese mallow	Young leaves	17.0	5.39	8.81	100	3.95	243	9.38
Momordica cochinchinensis	Spiny bitter cucumber	Immature fruit	7.0	0.94	0.04	91	-	23	0.34
Ocimum basilicum	Basil	Young shoots	10.9	2.66	4.15	42	0.91	268	1.65
Oenanthe javanica	Water dropwort	Stem	8.0	1.81	3.52	19	-	194	4.23
Oroxylum indicum	Tree of Damocles	Young shoots	20.0	5.92	3.48	97	4.16	26	1.26
Passiflora foetida	Weed passion flower	Young shoots	12.8	5.47	3.45	97	3.71	63	1.50
Petroselium crispum	Parsley	Young leaves	9.6	1.58	2.08	63	-	94	0.87
Rumex acetosa	Sorrel	Young shoots	6.7	1.48	1.04	26	-	39	0.75
Ruta graveolens	Rue	Young leaves	26.2	4.64	4.66	228	9.56	332	3.26
Sauropus androgynus	Star gooseberry	Young shoots	23.7	6.68	7.70	172	6.24	330	2.87
Sesbania grandiflora	Sesbania (red)	Flower	12.1	2.03	0.08	45	0.25	24	0.71
Sesbania grandiflora	Sesbania (white)	Flower	4.8	0.72	0.09	40	0.11	10	0.36
Solanum ferox	Hairly nightshade	Young fruit	11.5	1.85	0.19	11	0.30	26	0.84
Solanum indicum	Indian nightshade	Fruit	17.0	2.39	0.60	1	-	135	1.18
Solanum macrocarpon	African eggplant	Fruit	9.0	1.23	0.03	11	-	7	0.36
Solanum melongena	Eggplant, purple	Fruit	7.0	0.96	0.05	4	-	7	0.30
Solanum torvum	Water nightshade	Young fruit	20.4	2.56	0.16	15	0.71	77	0.93
Solanum xanthocarpum	Nightshade, yellow-fruit	Fruit	16.0	2.24	0.07	20	1.26	11	0.65
Solanum xanthocarpum	Nightshade, yellow-fruit	Mature fruit	16.9	2.28	0.04	12	0.50	21	0.70
Sphenoclea zeylanica	Wedgewort	Leaf	10.0	2.72	5.36	65	-	115	1.61
Talinum paniculatum	Panicled fame-flower	Leaf	9.0	2.77	6.07	74	4.91	106	1.50
Telosma cordata	Fragrant telosma	Flower	11.0	3.13	0.74	52	-	19	0.92
Tetragonia tetragonioides	New Zealand spinach	Young leaves	7.2	1.63	1.54	36	1.43	56	0.75
Trichosathes cucumerina	Snake gourd	Young fruit	4.2	0.50	0.06	13	0.03	10	0.24
Zanthoxylum ailantoides	Ailanthus prickly-ash	Leaf	26.0	5.69	8.43	138	3.35	95	2.41

Socio-economics

Assessment of nutritional impact of mungbean research

Mungbeans for enhanced iron consumption

Earlier research at AVRDC has analyzed the impact of mungbean research on consumer and producer surplus in Pakistan and estimated a net present value (NPV) of approximately US$19.7 million. Since mungbean contributes an important component to the diets in South Asia, it is worth asking what additional impact research on this crop has had. Mungbean is a cost effective source both of protein and iron, and it provides an excellent source of iron in the vegetarian-based diets on the South Asian subcontinent. This is of particular interest, because iron deficiency continues to be the most prevalent micronutrient disorder worldwide. In South Asia, approximately 88% of all pregnant women and 63% of children between 5 and 14 years of age are believed to be anemic. Iron deficiency anemia in children is associated with impaired physical and cognitive development, which leads to a loss of human capital. In adults in general, iron deficiency anemia leads to weakness and fatigue, and therefore to lower productivity and reduced capacity for physical work. Huge human and economic losses for economies are thus consequences of iron deficiencies. Combating iron deficiency is therefore an important means to decrease poverty in developing countries.

The role of mungbean for enhancing iron intake has been well researched. Mungbean supplementation has been shown to increase blood hemoglobin values in a one-year feeding trial conducted among school children aged 10–12 in southern India. The following study attempts to quantify the impact that enhanced iron consumption through mungbeans has had on overall productivity of female workers in Pakistan.

Methodology

This quantification is based on a consumption survey among female piece-rate workers in Pakistan, estimating the effect of enhanced iron intake on overall productivity, and extrapolating based on secondary production and consumption data of mungbean between 1985 and 1995. The year 1995 was chosen as the final year of the assessment in order to make the value comparable to an earlier study conducted at AVRDC that estimates consumer and producer surplus of mungbean research.

Women were interviewed concerning their consumption patterns (based on a 7-day food recall), their health status (blood hemoglobin value, Body-Mass Index as well as the incidence of diseases) and their wage levels. The survey was repeated three times in order to smooth out seasonal variation in consumption and wages, and approximately 200 women participated in the survey from June 2001 through February 2002. Because observations on nutritional, anthropometric and other variables were missing for some women in the three survey rounds, models are estimated using the complete data on 187 women, resulting in 561 observations.

Pulses were found to be an important contributor to overall dietary iron intake, being the source of approximately 25% of all iron. The major two other sources were cereals (50%) and vegetables (20%). Four different varieties of pulses were found to be consumed, namely chickpea, lentils, mungbean and urdbean. Chickpea was most frequently consumed (approximately 3 kg per capita and annum), followed by mungbean and lentils (both at 1.2 kg per capita and annum), and urdbean (0.4 kg per capita and annum). This may be explained by the price of the different pulses, chickpea being the least expensive at 37 Rs/kg, followed by 45 Rs/kg for mungbean and lentils, and 58 Rs/kg for urdbean. Roughly one-third of all households had consumed mungbean the week preceding the survey. Total pulses consumption was 5.8 kg per capita and annum.

It is a relatively old idea that at low income levels there is a relationship between nutrition and labor productivity. This hypothesis is known as the Efficiency Wage Hypothesis. Leibenstein (1957) and later Mirlees (1975) and Stiglitz (1976) argued that an increase in caloric intake enables workers to perform more demanding tasks, expressed in a greater marginal productivity as measured by wages. Since iron is known to affect the productivity of individuals, because it transports oxygen from the lung to the cells, an increase in iron intake may also lead to an increase in productivity as measured by wages. If this is recognized by the market, i.e. local labor markets operate

relatively freely and higher productivity is rewarded with higher wages, then better nutrition should result in higher market earnings, since workers would either be paid more for a given time unit of work, or they would be able to work in particularly taxing and rewarding activities, or both. However, in estimating this relationship, a methodological pitfall occurs: the causality can run in both directions. Better-nourished workers should be more productive and hence earn higher wages, and higher income will probably be spent for more nutrients and make household members more healthy, so that they can earn higher wages. If this simultaneity is not accounted for, estimates will be biased and inconsistent.

In order to account for simultaneity involved in household decisions regarding food purchases and wages received, the endogeneity of both variables is controlled for. Ignoring simultaneity results in inconsistent overestimates of the coefficients and biased standard errors. To eliminate the potential problem of reverse causality, wages and iron intake are simultaneously predicted, employing a two-stage least-squares (2SLS) estimation procedure. The 2SLS procedure is defined as first regressing 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 OLS regression. The semi-log wage equation takes the following form:

$$\ln W_{it} = \alpha_i + \gamma_t + \beta \hat{fe}_{it} + \chi \hat{BMI}_{it} + \delta \hat{HB}_{it} + \varepsilon X_{it} + \varepsilon_{it} \quad (1)$$

Since the sample was collected over three rounds, a fixed effect model was estimated, where t indexes time and i indexes the group. In this model, α_i is the industry effect and γ_t is the time effect. Three variables are considered to be endogenous to the system: nutrient intake *N*, Body-Mass-Index *BMI*, as well as the blood iron level *HB*, which outcome depends on past investments. *X* is a vector of control variables (age, age squared, school years, and sick days reported) and ε is the error term. The instrumental variables that were used to estimate nutrient intake, BMI, and blood hemoglobin level included a dummy each for current pregnancy and breastfeeding, the number of all children ever born, household size, per capita income and per capita replacement value of assets, and a price index each for cereals, pulses, vegetables, and animal products.

The net present value (NPV) of enhanced productivity (△W) due to the enhanced iron content of a modern variety (MV) of any crop as opposed to iron consumption based on traditional varieties (TV) can then be estimated based on equation 2. The change in overall iron availability is given by the vector of iron consumption (*fe*) based on the quantity (*q*) of modern and traditional varieties consumed in a given year and difference to iron consumption of that particular crop in base year, and total iron consumption in base year, and multiplied by the iron intake elasticity on wages η_{fe} and wages *W*.

$$NPV(\Delta W) = \sum_{n=1}^{t=n} \frac{\left(\left(fe^{MV} \times q_t^{MV} \right) + \left(fe^{TV} \times q_t^{TV} \right) - \left(fe^{TV} \times q_0^{TV} \right) \Big/ fe_0^{TOT} \right) \times \eta_{fe} \times W_t}{(1+i)^t} \quad (2)$$

Relationship between iron intake and workers productivity

Iron intake was measured as intake of bioavailable iron. In the following equations, FeTOT indicates the total iron intake, and FeBIO indicates the bioavailable iron. Heme iron is assumed to constitute 40% of FeMFP. The enhancing factor (EF) for a meal is EF = (M + F + P) + AA where M, F and P are the edible quantities of MFP (in g), respectively, and AA is the intake of ascorbic acid (in mg). If EF is > 75, then EF is assumed to be 75. To take account of the inhibitory effects of phytates (PHY), a "correction term" (CT) (0 < CT < 1) is estimated that gives the proportion of FeBIO. For PHY < 2.88 mg, CT is defined as 1 (i.e., it is assumed that there are no inhibitory effects of phytate intake for such small values). For other values of PHY, CT is defined by $CT = 10^{[-0.2869 \log 10(PHY) + 0.1295]}$, where log10 is logarithm to the base 10. Assuming that body iron stores are 0, 250 and 500 mg, the FeBIO can be calculated, respectively, from the following three equations, $\log_n$ being the natural logarithm. See Table 105 for a summary of results).

A Lagrange Multiplier test indicated that a fixed effect model was favorable to the classical regression model. The model is highly significant and the R-square is 0.36. The results of a Hausman test indicate that the hypothesis, that women's iron intake and blood hemoglobin values are endogenously determined through women's wage level, cannot be dismissed. This does not hold true for the Body-Mass Index. Additionally, piece-rate wages of women are determined by their education and age, as well as through their health status (proxied by the days reported sick

in the month preceding the survey). Current intake of bioavailable iron had a positive impact on current productivity, significant at the 0.10% level. The Body-Mass Index, a proxy for household health investments made earlier, does not show a significant impact on the productivity level of women. However, it does have a negative sign, indicating that obesity (shown to affect nearly one-third of the sample) has a negative impact on productivity as measured in piece-rate wages.

The elasticity of bioavailable iron on productivity measured in wages is 0.056; the marginal effect is 9.17 Rs per additional mg of bioavailable iron consumed. The elasticity of blood hemoglobin level on productivity is higher at 2.347. In contrast to these high elasticities, at the sample mean one extra year of school education for women would only result in 0.7 and 0.8 Rs higher daily wages. This is not to say that education for women is not important, but the results also show that without substantial improvements in the health status, particularly as far as iron deficiency anemia is concerned, rises in income and overall wealth of nations will be difficult to achieve.

Table 105. *2SLS with fixed effects: determinants of wage level.*[1]

Determinant	Coefficient (t-value)	Marginal effect	Elasticity	Mean values
Hb level[2] (g/dl)	0.207*** (3.119)	6.76	2.347	11.34
Body Mass Index[3]	–0.002^{NS} (–0.402)	–0.07	–0.045	22.54
Iron intake[2] (mg)	0.281* (1.781)	9.17	0.056	0.20
School years	0.024*** (3.307)	0.80	0.035	1.43
Age	0.016^{NS} (1.578)	0.53	0.519	32.16
Age squared (*10^{-3})	–0.299** (–2.169)	–9.79	–0.350	1.17
Days reported sick	–0.018*** (-3.224)	–0.57	–0.033	1.87
Constant	0.885^{NS} (1.144)		32.68	
R^2	0.364^{NS}			
F value	23.090***			

[1]Dependent variable is log of daily wages.
[2]Endogenous variables, variables include food prices, household income and assets, household size, number of all children born, and dummies for current pregnancy and breastfeeding.
[3]Not treated as endogenous, because of results of Hausman Test. Expressed as kg/m^2.
^{NS},*, **, *** Nonsignificant or significant at $P \leq 0.10\%$, $\leq 0.05\%$, $\leq 0.01\%$, respectively.
Source: Based on survey conducted by PERI in cooperation with AVRDC (2001/02), N = 561.

Quantifying the nutritional impact of mungbean research

The success of the joint mungbean breeding efforts between national agricultural research institutes in Pakistan and AVRDC has been documented elsewhere. Over the years, mungbean production in Pakistan has increased sharply, with an average annual growth rate of 5.8% between 1984 and 2000. This has resulted in an increase of annual per capita availability of domestic mungbean from 453 g to 739 g (total consumption has increased from 1.08 kg in 1984/85 to 1.42 kg per capita and annum in 1998). Apart from improved productivity characteristics, the modern mungbean varieties also have another, hidden advantage. These varieties record 6.0 mg of iron per 100 g dry matter, as compared to 3.5 mg of iron for traditional varieties.

Based on equation 2 we can now calculate the benefits of modern mungbean varieties from enhanced nutrition. In order to make the estimation of the NPV comparable to an earlier study on producer and consumer benefit, the years 1985 (first release of new mungbean varieties) to 1995 are chosen for this analysis. The area under modern varieties has grown to 88% in 1995 (we assume linear annual increases of 8.8% per year). Total iron available from mungbean has increased from 16.64 g/annum in 1985 to 36.97 g/annum in 1995, as compared to 14.95 mg in the base year. Compared to total iron intake, the increase in total bioavailable iron has been 0.07% in 1985 and 1.1% in 1995, based on a total iron intake of 6.7 mg daily for women in the base year and the assumption that, on average, 5% of the iron intake in the diet are bioavailable. Using an elasticity estimate of 0.056, per capita productivity increases due to enhanced consumption of bioavailable iron grew from 0.2 PKR per capita and annum in 1985 to 9.8 PKR per capita and annum in 1995.

The total female workforce increased from 7.8 million in 1985 to 11.7 million in 1995. Given that effects of increased iron intake on productivity can only be observed among anemic individuals, we only consider the share of the workforce that is anemic. Estimations are in the range of 50 to 60%. We use wage

data provided by International Labour Organization for the textile industry (an important sector for women's work) and multiply with the annual additional income per woman. The sum of net present value of this additional income is in the range of US$3.1 to 4.2 million, depending on the number of anemic women in the workforce (Table 106).

This quantification does not include reductions in forfeited productivity due to deficient iron intake during childhood and youth, which could potentially be very large, nor productivity losses due to anemia among the male workforce. These benefits of mungbean research are in addition to the total consumer and producer benefit attributable to mungbean research that has been estimated at US$19.7 million. This analysis shows that the additional benefit of mungbean consumption in terms of enhanced human productivity are substantial and can well be compared to direct research impacts. This study has shown that nutritional impact of agricultural research, measured in productivity increases of population groups deficient in micronutrients, is substantial. In the case studied here, the impact amounted to between US$3.1 and 4.2 million, approximately one-fifth of total consumer and producer surplus estimated for the crop.

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Assessing indirect impact of enhanced soil fertility in India

The role of mungbeans in rice–wheat cropping patterns

The emergence of the rice–wheat cropping system in South Asia has greatly contributed to the reduction of malnutrition and hunger in the region. Yet, following the goal of food self-sufficiency, domestic prices were kept artificially high and excessive resources have been devoted to the production of rice and wheat. These were staple crops for which farmers received assured prices at subsidized input prices. Thus, there was no real incentive for farmers to diversify from the rice-wheat rotation, and production of pulses in India has been declining. As a result the productivity of the system is declining or at best stagnant. Crop diversification is thus crucial in order to reverse declining productivity. Mungbeans have advantages in this system due to their short-growth duration and their ability of fixing atmospheric nitrogen. Several modern mungbean varieties (SML 668, SML 134 and SML 32) have recently been introduced to farmers in Punjab, India, for inclusion into the fallow period between wheat and rice. A stratified random survey, covering approximately 200 farmers in four ecological distinct regions of Punjab, 75 of which had adopted the modern varieties, was conducted in late 2002. Production

Table 106. *Quantification of nutritional impact of mungbean research.*

Year	Per capita availability (g)	Area under MV (%)	Iron MV (mg)	Iron TV (mg)	Total iron (mg)	Total bioavail. iron (mg)	Change in iron avail. (%)	Productivity increase (PKR)	Wage rate (PKR)	Female workforce (000)	Additional income (000 PKR) (50% anemia)	Additional income (000 PKR) (60% anemia)	NPV (US$) (50% anemia)	NPV (US$) (60% anemia)
1985	470	8.8	2.5	14.2	16.6	0.8	0.070	0.2	437.9	7864	814	977	41.5	49.8
1986	501	17.6	5.3	13.6	18.9	0.9	0.165	0.5	477.1	8126	2148	2835	86.1	113.7
1987	553	26.4	8.8	13.4	22.2	1.1	0.301	1.0	515.7	8394	4374	5774	147.7	195.0
1988	422	35.2	8.9	9.0	17.9	0.9	0.124	0.4	496.5	8673	1792	2365	56.7	74.9
1989	390	44.0	10.3	7.2	17.5	0.9	0.107	0.4	593.3	8951	1905	2514	53.8	71.0
1990	528	52.8	16.7	8.2	24.9	1.2	0.415	2.7	954.6	9236	12281	16210	308.5	407.2
1991	511	61.6	18.9	6.5	25.4	1.3	0.432	2.8	954.6	9693	13428	17724	315.5	416.4
1992	448	70.4	18.9	4.4	23.3	1.2	0.347	2.2	954.6	10165	11305	14923	249.5	329.3
1993	533	79.2	25.3	3.7	29.0	1.5	0.583	3.5	891.6	10654	18600	24552	399.1	526.8
1994	580	88.0	30.6	2.3	32.9	1.6	0.746	4.3	866.4	11166	24252	32012	487.7	643.7
1995	651	88.0	34.4	2.6	37.0	1.8	0.913	9.8	1590.0	11693	57026	75275	1053.5	1390.6
Total													3199.5	4218.3

MV = modern varieties; TV = traditional varieties; total bioavailable iron = 120 mg; $\eta_P = 0.056$.
Data sources: Per capita availability of mungbean, NARC, 2002; wage rate, ILO LABORSTA (2003), women's wage assumed to be 60% of men; workforce, World Bank development indicators (2003); exchange rate PKR/ US$, ILO statistics.

information was covered for approximately 250 plots. Of these, 160 followed either a mungbean–rice–wheat rotation, or a fallow–rice–wheat rotation.

Methodology

For the analysis, productivity in plots including mungbean is compared against the productivity of plots based on a fallow rotation. The impact on productivity of the paddy crop was estimated using a Cobb-Douglas Production function (equation 3),

$$\ln Y_i = b_o + b_1 \ln X_{i1} + b_2 \ln X_{i2} + b_3 \ln X_{i3} + b_4 \ln X_{i4} + b_5 \ln X_{i5} + b_6 \ln X_{i6} + b_7 D_{i1} + b_8 D_{i2} + \varepsilon_i \quad (3)$$

where the subscript, *i*, indicates the *i*th plot in the sample (i = 1, 2, …158); ln represents the natural logarithm; Y represents the output of paddy (in kg/ha); X_1, X_2, …,X_6 represent seed input, urea (kg/ha), pesticide use (Rs/ha), herbicide use (Rs/ha), human labor (h/ha) and machine use (h/ha), respectively; D_1 represents the ecoregion dummy, which has value 1 for farmers in the Central Plains and 0 otherwise; and D_2 represents the dummy variable indicating whether the crop rotation on the plot included mungbean or not. The *b*s are unknown parameters to be estimated and ε_i is the random error. This analysis covers plots only under the fallow–rice–wheat and mungbean–rice–wheat systems and plots with other rotation patterns are not considered (another rotation frequently found was mungbean–rice–potato). The hypothesis under which the estimation was performed was that productivity of paddy rice should be higher on plots that followed a mungbean–rice–wheat rotation as compared to plots that followed a fallow–rice–wheat rotation.

The impact of mungbean on enhanced productivity of paddy rice and income

The estimates for the parameters of the Cobb-Douglas production function are given in Table 107. The model is highly significant, although only 25% of all variation is explained. Six out of the ten variables are significant at the 0.05% level or better. Among these, the dummy variable that indicates whether the plot is under mungbean rotation has the single largest effect on paddy productivity. On these plots, productivity of the subsequent paddy is nearly 8% higher than on crops that do not follow this rotation pattern. On average, the paddy yield on these plots is 450 kg/ha higher than on plots that follow the fallow rotational pattern.

Table 108 indicates the effect of the inclusion of summer mungbean into the cropping system on total income per plot. Gross return for paddy rice is approximately 2000 Rs higher in the rotation following mungbean, as opposed to the rotation based on fallow–rice–wheat. This is the effect of the higher yield of paddy rice in mungbean rotations. Note also the slightly higher yield of the subsequent wheat crop (however, not statistically significant). Gross return for the two different rotation schemes differs by approximately 18,500 Rs/ha. Total cost for the rotation including mungbean is approximately 7,500 Rs higher, leading to an overall difference in net return by 11,000 Rs (US$235)/ha. However, the benefit/cost ratio of the rotation including mungbean is slightly lower than the

Table 107. *Paddy response function (dependent variable: log yield per hectare).*

Variables	Coefficient	T value	Mean	Marginal effect
Seed (kg/ha)	–0.034	–0.879	13.1	–14.881
Urea (kg/ha)	0.042	1.352	255.5	0.954
Pesticide (Rs/ha)	0.031	1.391	999.8	0.180
Herbicide (Rs/ha)	–0.072***	–2.560	506.8	–0.818
Labor (h/ha)	0.099**	2.222	317.9	1.813
Machine (h/ha)	–0.132***	–2.859	13.8	–55.308
Total land cultivated (ha)	0.016	1.388	6.5	14.265
Central Plains (dummy[%])	0.071***	3.647	33.2	410.708
Rotation includes mungbean (dummy[%])	0.077***	3.199	20.2	448.778
Intercept (kg/ha)	8.390***	22.073	5798.0	
R^2	0.247			
F value	5.397***			

*, **, *** Significant at $P \leq 0.10$, $\leq 0.05\%$, and $\leq 0.01\%$ respectively.
Source: Based on survey conducted by Punjab Agricultural University in cooperation with AVRDC (2002), N = 159 plots.

Table 108. *Cost/benefit analysis of fallow–rice–wheat vs. mungbean–rice–wheat production.*

Item	Fallow–Paddy–Wheat			Mungbean–Rice–Wheat				Difference
	Rice	Wheat	Total	Mungbean	Rice	Wheat	Total	
Yield (kg/ha)	5581	4656		901	5962	4803		
Return for main crop (Rs/ha)	31116	28804	59921	15301	33182	29193	77675	17754
Value of by-product (Rs/ha)	0	509	509	209	0	1107	1316	808
Gross return (Rs/ha)	31116	29313	60430	15510	33182	30300	78992	18562
Total variable cost (Rs/ha)	5111	4964	10075	2393	5483	4831	12707	2632
Total fixed cost (Rs/ha)	5670	4162	9832	4758	5482	4400	14641	4809
Total cost (Rs/ha)	10781	9126	19907	7151	10966	9231	27348	7441
Net return (Rs/ha)	20335	20187	40523	8359	22216	21069	51644	11122
Benefit/cost ratio	1.9	2.2	2.0	1.2	2.0	2.3	1.9	–0.1

Source: Based on survey conducted by Punjab Agricultural University in cooperation with AVRDC (2002), N = 159 plots.

rotation based on fallow. The net income for plots under mungbean rotation (including returns to labor) is 27% higher as the income of plots under fallow–rice–wheat.

In India, mungbean is a pulse crop with relatively high price and income elasticities. As the Indian economy continues to grow, demand for pulses is expected to further increase. Since current production in India is approximately 1 million tons, production would have to double within 10 years in order to meet local demand. If plans to grow mungbeans on 1 million ha of fallow land succeed, this would provide the added advantage of approximately 450,000 additional tons of rice production, adding to the increased income that farmers would receive from mungbean production.

In conclusion, mungbean production in Asia has seen a rapid increase after the 1980s, mainly due to the availability of high yielding, short duration varieties with uniform maturity and resistance/tolerance to diseases. The rise in production has been associated with a number of positive impacts, past studies showing large consumer and producer surplus, estimated at US$15–18 million in Thailand, and US$19.7 million in Pakistan. For China, the producer and consumer surplus has been shown to be especially large. It has been estimated to equal US$98 million in NPV, with an internal rate of return of 108%.

However, as this and other research studies have shown, development impact of crop research can take many other forms and be just as substantial. This study shows that the soil enriching effects of mungbeans can improve overall productivity and incomes of farmers.

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Multi-objective programming model for Manila's peri-urban production system

The complexity of the peri-urban system requires careful planning on how the resources available to the farmers may best be used. The inadequacy of the resources available as well as presence of multiple objectives that farmers seek to optimize make the multiple-objective programming (MOP) model an appropriate tool to guide decision makers in such a situation. Unlike Linear Programming (LP) for instance, where a single optimal solution to the problem is derived, the MOP solutions consist of a set of alternative efficient solutions, each of which are considered equivalent in the absence of further information regarding the relative importance of each of the objectives in the solution vectors. Hence the decision makers (DM) are confronted with an efficient solution set, from which the closest to the ideal solution (termed as the best compromise solution) should be chosen. It is within this context that this study was undertaken. Its general objective was to design and develop a multi-objective model to help understand the peri-urban vegetable production system and to apply this model as an economic decision tool within the system.

Four conflicting objectives were considered in this study, namely maximization of farm income, minimization of employment of hired labor, minimization of price-induced risk to total income, and minimization of yield-induced risk to total income. The best compromise solution was determined by first solving the MOP using constraint methods to generate the Pareto efficient solutions. The Pareto efficient solutions were reduced to the desired number by subjecting them to cluster analysis procedure. Then compromise programming (CP) was performed to determine the range where

the best compromise solution set lies.

Table 109 summarizes the results of the various analyses carried out. As can be seen, the alternative solutions vary substantially with respect to values of the objective functions. Options O2 and O5, for instance, are characterized by high income and high employment of hired labor with higher risk (total variance of income). At the other extreme, options O17 and O20 are characterized by low income with lower income variability or risk. Using the results of CP, the best compromise solution set is provided by option O10. Under this plan, the allocation of land resource is as follows: eggplant, 0.11 ha, string beans, 0.16 ha, squash, 0.50 ha, and shallot onion, 0.22 ha. This allocation gives a net income of PhP93,837; hired labor use of 86 man-days; and price- and yield-induced income variances of 3.52×10^8 (SD = PhP18,760) and 0.53×10^8 (SD = PhP7,300), respectively.

Potential for tomato production

The various representative solutions in Table 109 reveal that tomato is not part of the efficient solution vectors. This result suggests that even if it is possible to produce tomato during the hot-wet season, given the current production technology employed by farmers, tomato cannot compete with other alternative crops. If tomato production system can be improved through specific technological changes, there should be a possibility for tomato to become part of the efficient cropping system. Since its inception 30 years ago, the AVRDC has been developing technology for hot-wet season production of tomato. Recently developed technologies include the use of grafted tomato planted in raised beds and under rain shelters. This technology package is part of the AVRDC Peri-urban Project in Metro Manila.

As shown in Table 110, the entry of the technological improvement (specifically that of cultivation of grafted tomato under rain shelter) in the best compromise solution increased farmer's income from PhP93,837 to PhP1143,541. This corresponds to an increase of 53% per hectare, with relatively the same number of hired labor employed. Risk, however, substantially increased. Specifically, the price-induced variability to income has increased by 192% while yield-induced risk increased by 35%. These results

Table 109. *Representative efficient solutions from cluster analysis and range of compromise solutions from compromise programming (CP).*[1]

	Option						CP Metric	
Item	O2	O5	**O10**	O14	O17	O20	L1	Linf
Income	112,530	105,729	**93,837**	85,609	63,442	53,249	88,452	93,877
Hired labor	175	141	**86**	82	86	91	71	86
VarP	6.94	5.66	**3.52**	3.09	0.87	0.71	1.91	3.59
VarY	0.79	1.58	**0.53**	0.05	0.56	1.51	0.17	0.56
Crop								
Tomato FP (X1)	-	-	**-**	-	-	-	-	-
Pak-choi FP (X2)	-	-	**-**	0.23	-	-	-	-
Bitter gourd (X3)	0.08	-	**-**	-	-	-	-	-
Bottle gourd (X4)	-	-	**-**	0.19	0.19	0.08	-	-
Sponge gourd (X5)	0.00	-	**-**	0.02	0.07	-	0.19	-
Eggplant (X6)	0.11	0.26	**0.11**	-	-	-	0.01	0.11
String beans (X7)	0.02	0.09	**0.16**	0.07	0.02	-	0.11	0.16
Okra (X8)	-	-	**-**	0.03	0.11	0.17	-	-
Squash (X9)	0.42	0.50	**0.50**	0.30	-	-	0.31	0.50
Radish (X10)	-	-	**-**	0.02	0.19	0.25	0.07	-
Mustard (X11)	-	-	**-**	0.07	0.17	-	0.16	-
Semi-hot pepper (X12)	0.30	0.04	**0.00**	0.02	-	-	0.06	0.01
Red onion (X13)	-	-	**-**	0.01	-	-	-	-
Shallot onion (X14)	0.06	0.11	**0.22**	0.02	0.26	0.50	0.07	0.22
Yellow onion (X15)	-	-	**-**	0.02	-	-	0.01	-

[1]O = option; L = distance metrics; FP = farmer's practice; VarP refers to price-induced variability in income while VarY is yield-induced variability in income. Highlighted option is the best compromise solution set.

indicate that given the existing price trends, the higher income potentially available from expensive technology would only be acceptable if the farmers are willing to take on the higher variability in income. Even if the technology has a stable high yield during the hot-wet season, the historical price variability makes the best compromise solution risky. This risk was largely due to entry of tomato in the basic solution and the observed high variability in time series prices of tomato.

Capital constraints to technology adoption

One of the most often cited constraints to increased adoption of technological innovations is the lack of capital. Hence, it is a classic recommendation to provide credit to farmers. A scenario simulating this condition is included into the formulated MOP. The goal is to assess whether provision of capital will be sufficient incentive for farmers' increased adoption of the technology. Results are presented in Table 111.

Consistent with expectations, the provision of capital (i.e. removal of this constraint in the model) resulted in higher net income. Taking the best compromise solutions, C12 and T13, for instance, one could see that the area devoted to high-income crops like bitter gourd, string beans, eggplant, semi-hot pepper, and tomato have increased dramatically. This caused income to increase by about PhP40,000 (28%). However, there was also a significant increase in the variance of total income of the farmers (86% increase in price-induced risk). Note also that while one would expect the area devoted to tomato to increase significantly, relative to other crops in the model, the farmer opted to diversify to other crops in the system. This decision could indicate the risk aversion of farmers; they would shy away from technological innovations, like the AVRDC Peri-urban Project-espoused technology on tomato production, which is considered risky. To repeat, for risk-averse farmers, providing enough capital will not guarantee adoption of a capital-intensive, but risky, technology.

Another notable result in this scenario is that squash, which used to dominate almost all the alternative solutions when constraints on farm resources are imposed, practically disappeared in all the solutions when there is no capital restriction. This result suggests that

Table 110. *Best compromise solution vectors under existing technologies and with technological improvement in tomato production.*[1]

	Existing technology			With technological improvement		
Item	O10	L_1	$L\infty$	T13	L_1	$L\infty$
Income	93,837	88,452	93,877	143,541	93,746	143,546
Hired labor	86	71	86	87	60	87
VarP	3.52	1.91	3.59	10.29	3.53	10.29
VarY	0.53	0.17	0.56	0.72	0.25	0.72
Crop						
Tomato PE (X1)	-	-	-	0.12	0.03	0.12
Pak-choi PE (X2)	-	-	-	-	-	-
Bitter gourd (X3)	-	-	-	-	-	-
Bottle gourd (X4)	-	-	-	-	-	-
Sponge gourd (X5)	-	0.19	-	0.01	0.02	0.01
Eggplant (X6)	0.11	0.01	0.11	-	-	-
String beans (X7)	0.16	0.11	0.16	0.13	0.13	0.13
Okra (X8)	-	-	-	-	-	-
Squash (X9)	0.50	0.31	0.50	0.49	0.48	0.49
Radish (X10)	-	0.07	-	-	0.06	-
Mustard (X11)	-	0.16	-	-	0.19	-
Semi-hot pepper (X12)	0.00	0.06	0.01	0.07	0.01	0.07
Red onion (X13)	-	-	-	-	-	-
Shallot onion (X14)	0.22	0.07	0.22	0.18	0.07	0.18
Yellow onion (X15)	-	0.01	-	-	-	-

[1]O = options; T = options using technological improvements; L = distance metrics; VarP refers to price-induced variability in income while VarY is yield-induced variability in income. O10 and T13 are best compromise solutions obtained under existing and with technological improvement.

in the study site, squash production is not a major positive activity, but rather a coping mechanism of the farmers to the present capital availability. Further, results also show that the effect of relaxing capital constraint is not a linear or additive expansion of the original plan. Rather, farmers tend to diversity or modify their crop mix, given more resources on hand. The disappearance of squash in the crop mix is an evidence of this case. Similar examples are found in the cases of bitter gourd, semi-hot pepper and eggplant. These crops have very little importance in previous plan but had become the major income-contributing crops when capital is not limiting.

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Table 111. *Alternative solution vectors and range of compromise solutions obtained when capital constraint is relaxed.*[1]

	Option					CP Metric		
Particular	C1	C7	**C12**	C16	C24	L_1	L∞	**T13**
Income	251,420	218,794	**183,937**	98,562	61,454	177,402	204,080	**143,561**
VarP	51.26	27.56	**19.13**	1.54	0.71	8.19	13.30	**10.29**
VarY	9.53	1.65	**0.92**	0.13	1.58	0.67	1.41	**0.72**
Crop								
Tomato PE (X1)	0.20	0.18	**0.15**	0.09	0.04	0.14	0.16	**0.12**
Pak-choi PE (X2)	-	-	**-**	0.23	-	-	-	**-**
Bittter gourd (X3)	0.50	0.34	**0.28**	0.10	-	0.23	0.30	**-**
Bottle gourd (X4)	-	-	**-**	-	0.06	-	-	**-**
Sponge gourd (X5)	-	0.05	**-**	0.02	-	0.14	0.13	**0.01**
Eggplant (X6)	0.30	0.13	**0.15**	-	-	0.15	0.15	**-**
String beans (X7)	-	0.16	**0.17**	0.07	-	0.16	0.14	**0.13**
Okra (X8)	-	-	**-**	0.07	0.18	-	-	**-**
Squash (X9)	-	-	**-**	0.29	-	-	-	**0.49**
Radish (X10)	-	-	**-**	0.02	0.26	-	-	**-**
Mustard (X11)	-	-	**-**	0.07	-	-	-	**-**
Semi-hot pepper (X12)	-	0.14	**0.25**	0.02	-	0.18	0.12	**0.07**
Red onion (X13)	-	-	**-**	-	-	-	-	**-**
Shallot onion (X14)	-	-	**-**	0.02	0.46	-	-	**0.18**
Yellow onion (X15)	-	-	**-**	-	-	-	-	**-**

[1]C = compromise solutions, T = options using technological improvements; L = distance metrics; VarP refers to price-induced variability in income while VarY is yield-induced variability in income; PE = project-espoused technologies. Highlighted values indicate the best compromise solution vector. T13 is the best compromise solution from Table 110.

Technology Promotion

Regional yield trials of AVRDC promising breeding materials

AVRDC cooperates with the Taiwan national agricultural research and extension system (NARES) to evaluate promising AVRDC lines under a wide range of locations in different seasons. The goal is to identify superior lines for release in Taiwan and other countries with similar environmental conditions.

ToLCV-resistant fresh market tomato

This trial was conducted to identify promising fresh market hybrids with tomato leaf curl virus (ToLCV) resistance for summer production in the lowlands. Eight AVRDC hybrids were evaluated along with check varieties, Hualien-ASVEG No. 5, Taoyuan-ASVEG No. 9, Taichung-ASVEG No. 10, and Farmers 301 (of Known-You Seed Co.), during 30 July 2003 to 12 January 2004 (mean day/night air temperatures at 30.4/21.1°C, 372 mm rainfall) at AVRDC headquarters. The experimental design was randomized complete block design (RCBD) with four replications. Plants were set in twin rows spaced 75 cm apart on raised beds with plants spaced 50 cm apart. Plot size was 5 m × 3 m. Applications of 90N–38.7P–74.7K–13.7Mg kg/ha of inorganic and 80N–34.4P–66.4K kg/ha of an organic fertilizer with organic matter content of 60% were applied by basal dressing during land preparation. Applications of 30N–12.9P–24.9K inorganic fertilizer were sidedressed two weeks after transplanting, one month after transplanting, and then again every month after that.

Large-fruited lines FMTT955, FMTT904 and FMTT965 gave the highest yields at 58.3, 56.2 and 56.1 t/ha, respectively; these three lines significantly outyielded the check varieties Taichung-ASVEG No. 10 (46.6 t/ha) and Farmers 301 (29.6 t/ha) (Table 112). Heat-tolerant lines FMTT904, FMTT906, FMTT907 and FMTT934 had higher fruit setting rates than the other four ToLCV-resistant lines, but their yields were lower due to smaller fruit size. The incidence of ToLCV for the FMTT lines was very low (1.5–6.0%), whereas 30.8–64.5% of check varieties were infected.

These ToLCV-resistant lines were also evaluated at Taoyuan District Agricultural Improvement Station (DAIS); the Ilan branch of Hualien DAIS, and the

Table 112. *Regional yield trial of ToLCV-resistant fresh market tomato hybrids grown at AVRDC.*[1]

Lines	Days to maturity	Fruit set (%)	Fruit wt (g/fruit)	Mkt. yield (t/ha)	ToLCV (%)	Solids (°Brix)	Acid[2] (%)	Solids/ acid	Color[3] (a/b)
FMTT904	105.6	66.8	113.1	56.2	1.5	4.60	0.38	12.11	1.87
FMTT906	106.7	65.5	110.9	53.1	3.0	4.55	0.36	12.64	1.81
FMTT907	106.4	63.7	119.5	52.0	5.5	4.55	0.36	12.64	1.74
FMTT934	106.5	67.1	116.2	55.6	3.5	4.50	0.36	12.50	1.88
FMTT955	118.8	58.9	134.3	58.3	6.0	4.48	0.41	10.93	1.70
FMTT957	119.1	58.0	124.0	52.9	4.5	4.65	0.43	10.81	1.79
FMTT962	113.0	59.0	141.4	49.1	3.5	4.50	0.49	9.18	1.75
FMTT965	112.4	56.2	123.4	56.1	4.0	4.53	0.45	10.07	1.64
Hualien-ASVEG No. 5 (ck)	114.0	58.1	121.3	59.7	30.8	4.38	0.36	12.17	1.58
Taoyuan-ASVEG No. 9 (ck)	115.2	59.3	109.9	59.1	36.3	4.40	0.37	11.89	1.33
Taichung-ASVEG No. 10 (ck)	116.2	56.2	141.2	46.6	32.8	4.45	0.38	11.71	1.50
Farmers 301 (ck)	120.0	45.9	131.1	29.6	64.5	4.80	0.39	12.31	1.16
Mean	112.8	59.6	123.9	52.3	16.3	4.53	0.40	11.65	1.64
LSD (5%)	3.5	4.5	10.6	7.3	15.7	0.35	0.06	1.79	0.27

[1]Lines sown on 30 July, transplanted on 27 August, and harvested from 6 November to 12 January 2004.

[2]Equivalent of citric acid.

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

Pingtung branch of the Seed Improvement and Propagation Station (SIPS) in 2003 (data not shown). Cooperating farmers preferred FMTT906 due to its early maturity and high yields. Based on the results obtained, FMTT904 and FMTT906 (both light green shoulder types), and FMTT 957 and FMTT965 (dark green shoulder types) were selected for further evaluation.

ToLCV-resistant cherry tomato

This trial aimed to select promising cherry tomato hybrids for summer production. Five ToLCV-resistant red cherry tomato hybrids, CHT1312, CHT1313, CHT1372, CHT1374 and CHT1358, and check variety Tainan-ASVEG No. 6 were evaluated at four locations (AVRDC, Annan, Luenbey, and Sueishan; the latter three are within a 30-km radius from AVRDC) from 5 March to 21 July 2003 (mean day/night air temperatures at 31.1/22.8°C, 640 mm rainfall). The experimental design was RCBD with four replications. Plots consisted of twin rows spaced 75 cm apart; plants were spaced 50 cm apart. Plot size was 5 m × 3 m, and 75 cm between rows. Applications of 90N–38.7P–74.7K–13.7Mg kg/ha of inorganic and 80N–34.4P–66.4K kg/ha of an organic fertilizer with organic matter content of 60% were applied by basal dressing during land preparation. Applications of 30N–12.9P–24.9K inorganic fertilizer were sidedressed two weeks after transplanting, one month after transplanting, and then again every month after that.

The CHT lines outyielded the check variety by 295–441% at AVRDC, 138–227% at Annan, 51–93% at Luenbey, and 375–466% at Sueishan (Table 113). Mean yield levels at AVRDC were much lower than at Luenbey and Sueishan due to high rainfall (369 mm) and subsequent flooding during the flowering period of 6–13 June. Lines CHT 1312 and CHT1374 had higher survival rates, 65.6 and 64.1%, respectively, after flooding. Because of its proximity to the seacoast, about 15 km, plants in Annan may have suffered salt injury due to brine flooding on 10–13 June. Most of plants at this location died after only a few harvests. The incidence of ToLCV for the CHT lines was low (below 11%) at three locations, whereas 86.5–100% of the check variety plants were infected.

The fruits of CHT1312 were smaller but longer, and had more favorable color and solids/acid values than other ToLCV-resistant lines (Table 114). The collaborating farmers in Luenbey and Sueishan liked this new line due to its longer fruit shape, which consumers prefer. RYTs for these five CHT lines will be further evaluated for stability of ToLCV resistance and yield in 2004 at the same locations.

Table 114. *Fruit quality analysis of cherry tomato hybrids tested in regional yield trials across four locations in southern Taiwan during summer of 2003.*

Lines	Fruit wt (g/fruit)	Solids (°Brix)	Acid[1] (%)	Solids/ acid	Color[2] (a/b)
CHT1312	10.95	7.92	0.62	12.72	1.37
CHT1313	12.29	7.75	0.68	11.62	1.29
CHT1372	12.80	7.93	0.67	11.83	1.30
CHT1374	11.88	7.79	0.65	11.90	1.26
CHT1358	11.95	8.06	0.68	11.83	1.34
Tainan-ASVEG No. 6 (ck)	8.84	7.57	0.50	15.01	1.19
Mean	11.45	7.84	0.63	12.49	1.29
LSD (5%)	1.28	0.44	0.09	1.42	0.41

[1]Equivalent of citric acid.

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

Table 113. *Incidence of tomato leaf curl virus and fruit yields of cherry tomato hybrids evaluated at locations in southern Taiwan.*[1]

	AVRDC		Annan		Luenbey		Sueishan	
Lines	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)	Incidence (%)	Yield (t/ha)
CHT1312	4.7	24.0	-	12.4	4.5	52.9	7.8	73.6
CHT1313	5.7	27.1	-	12.9	8.3	51.5	9.9	62.3
CHT1372	6.3	25.7	-	17.0	3.0	65.3	7.8	61.8
CHT1374	5.2	31.4	-	12.6	4.5	51.3	10.9	69.9
CHT1358	6.3	22.9	-	13.1	2.5	64.9	8.4	70.2
Tainan-ASVEG No. 6 (check)	96.4	5.8	-	5.2	86.5	33.9	100.0	13.0
LSD (5%)	5.4	8.0	-	9.6	6.8	2.2	6.8	7.7

[1]Lines were sown on 5 March, transplanted on 1 April, and harvested from 3 June to 21 July 2003.

Cherry tomato hybrid released in Taiwan

Based on the results of RYTs, ROC's Council of Agriculture released cherry tomato hybrid CHT1200 developed by AVRDC. It is officially named as Hualien-ASVEG No. 13. This is the ninth AVRDC improved tomato line released by the host country since the Center's inception. The fruits of CHT1200 are orange, rich in β-carotene (2.8 mg/100 g), oval-shaped, firm, and resistant to cracking (Fig. 37). The vines are resistant to ToMV and Fusarium wilt races 1 and 2.

Fig. 37. *Fruits of high β-carotene line CHT1200.*

High quality vegetable soybean

Ten vegetable soybean lines, including two from AVRDC, three from Tainan DAIS, and five from Kaohsiung DAIS, were evaluated in RYTs at AVRDC in spring of 2003 (January 29–April 30, mean day/night air temperatures at 27.5/18.3°C, 88 mm rainfall), and autumn of 2003 (September 1–November 14; mean day/night air temperatures at 32.0/23.2°C, 81 mm rainfall). The experimental design was RCBD with four replications. Plot size was 5 m × 3 m, and spacing was 50 cm between rows and 10 cm between plants.

In spring, KVS1175 and TS88-04V produced the highest yields of graded pods, and significantly outyielded all check varieties, KS#1, KS#2, and KS#5 (Table 115). The pods of check varieties, however, had higher percentages of sugar compared to the experimental lines. Among the new lines, pods of GC95004-2-3-1, TS88-31V and KVS1312 had the highest percentages of sugar. One of highest yielding lines, TS88-04V, produced the darkest green pods (Table 116).

In autumn, KVS1312 produced the highest yield at 9.8 t/ha, significantly outyielding check varieties by 45–82% (Table 117). The 100-seed weight and shelled bean ratio values of KVS1312 were similar to those of KS5, and its yield was stable across seasons. The

Table 115. *Yield and horticultural characteristics of vegetable soybeans tested at AVRDC during spring of 2003.*[1]

Lines	Days to maturity	Pod no./ 500 g	100-fresh seed wt (g)	Pod length[2] (cm)	Pod width[2] (cm)	Graded yield (t/ha)
KVS1175	92	134.3	87.3	4.8	1.4	10.45
KVS1194	92	140.0	75.3	5.0	1.4	8.43
KVS1209	92	142.8	78.3	4.7	1.3	9.48
KVS1249	91	147.8	72.5	4.8	1.4	9.10
KVS1312	91	138.0	82.5	5.2	1.4	9.48
TS88-04V	85	130.8	72.3	5.4	1.5	10.45
TS88-31V	91	118.8	84.8	5.5	1.4	7.85
TS88-57V	85	135.8	74.3	4.9	1.4	7.50
GC95004-2-3-1-1	90	129.3	90.5	5.3	1.4	8.00
GC95016-6	90	110.0	100.5	5.9	1.6	7.88
KS#1 (check)	78	144.3	68.8	4.9	1.4	6.58
KS#5 (check)	85	136.5	88.5	5.0	1.4	7.35
KS#6 (check)	83	132.5	71.0	5.1	1.4	6.98
Mean	88	133.9	80.5	5.1	1.4	8.42
LSD (5%)	4	8.4	5.2	0.3	0.1	1.63

[1]Lines sown on 29 January and harvested 16–30 April 2003.

[2]Measured from double-seeded pods.

second highest yielder was KVS1175 (8.39 t/ha). Although its 100-seed weight and shelled bean ratio values were lower than KVS1312, its podding height and plant height were higher.

The highest yielding line overall was KVS1175. Yields of GC95004-2-3-1-1 were stable across seasons (8.00 t/ha in spring and 8.30 t/ha in autumn) and its podding height, plant height, 100-seed weight and shelled bean ratio values were intermediate between KVS1312 and KVS1175. AVRDC's GC95004-2-3-1-1 also had the highest percentage of soluble solids among all new lines (Table 116).

Table 116. *Quality analysis of vegetable soybeans tested at AVRDC.*

	Spring			Autumn		
Lines	Protein (%)	Sugar (%)	Color[1] (grade)	Protein (%)	Sugar (%)	Color[1] (grade)
KVS1175	42.55	6.55	4.00	40.27	7.61	3.85
KVS1194	43.66	6.22	5.02	41.16	7.35	4.95
KVS1209	42.02	6.99	4.61	39.69	7.48	4.14
KVS1249	43.63	7.18	4.80	41.12	7.48	4.56
KVS1312	41.36	7.81	4.72	39.96	8.02	4.07
TS88-04V	40.85	7.43	3.35	38.15	8.19	3.60
TS88-31V	44.27	7.86	4.15	40.12	8.08	3.53
TS88-57V	43.96	5.62	3.85	41.73	6.98	5.31
GC95004-2-3-1-1	40.97	8.01	4.84	36.97	8.77	4.30
GC95016-6	43.03	6.91	4.99	38.58	8.28	4.68
KS#1 (check)	39.51	10.27	3.94	35.10	9.17	4.02
KS#5 (check)	42.87	8.79	3.50	39.52	8.22	4.19
KS#6 (check)	38.55	10.70	3.61	34.92	10.34	3.61
Mean	42.09	7.72	4.26	39.02	8.15	4.22
LSD (5%)	1.41	0.84	0.28	0.66	0.48	0.23

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

Table 117. *Yield and horticultural characteristics of vegetable soybeans tested at AVRDC during autumn of 2003[1].*

Lines	Days to maturity	Pod no./ 500g	100-fresh seed wt (g)	Pod length[2] (cm)	Pod width[2] (cm)	Graded yield (t/ha)
KVS1175	75.0	185	68.8	4.15	1.30	8.39
KVS1194	75.0	178	71.0	4.30	1.33	8.10
KVS1209	74.0	191	64.8	4.68	1.33	7.95
KVS1249	74.0	178	66.5	4.95	1.45	8.23
KVS1312	74.0	168	70.8	5.30	1.45	9.80
TS88-04V	72.3	170	65.0	4.60	1.33	7.75
TS88-31V	73.0	186	64.3	4.85	1.25	8.18
TS88-57V	72.8	163	76.0	4.60	1.30	7.85
GC95004-2-3-1-1	71.8	167	69.0	4.72	1.30	8.30
GC95016-6	71.8	159	81.3	5.18	1.30	6.65
KS#1 (check)	66.0	184	53.5	4.53	1.35	5.38
KS#5 (check)	71.5	182	75.0	4.50	1.33	6.33
KS#6 (check)	66.0	169	58.0	4.55	1.35	6.77
Mean	72.1	175	68.0	4.68	1.33	7.67
LSD (5%)	0.4	10	6.4	0.15	0.09	1.16

[1]Lines sown on 1 September and harvested 5–14 November 2003.

[2]Measured from double-seeded pods.

In an adjacent trial, six promising lines of taro-flavor vegetable soybean were evaluated at AVRDC in spring and autumn of 2003. In spring, KVS7 produced the highest graded pod yield and significantly outyielded the check varieties, Shon-gi and Black-5-leaf by 77% and 62%, respectively (Table 118). In autumn, KVS8 gave the highest yield at 8.65 t/ha, which outyielded check varieties by 82% and 67%, respectively (Table 119). Quality analyses show that TS85-21V had the highest percentage of soluble solids among the new lines during spring and autumn. KVS3 and KVS6 produced the darkest green pods (Table 120). Further RYTs will be conducted to evaluate the stability of yield and pod qualities.

Table 118. *Yield and horticultural characteristics of taro-flavor vegetable soybeans tested at AVRDC during spring of 2003.*[1]

Lines	Days to maturity	Pod no./ 500g	100-fresh seed wt (g)	Pod length[2] (cm)	Pod width[2] (cm)	Graded yield (t/ha)
KVS2	87	151.5	84.5	4.6	1.38	4.1
KVS3	96	166.0	81.3	5.1	1.40	3.5
KVS7	84	130.1	60.3	4.4	1.30	9.9
KVS8	87	170.5	62.0	4.3	1.30	8.1
KVS6	87	134.8	78.8	5.0	1.43	2.0
TS85-21V	79	153.0	61.8	4.4	1.35	8.4
Shon-gi (check)	79	166.5	64.0	4.4	1.34	5.6
Black-5-leaf (check)	84	133.3	75.3	4.8	1.45	
Mean	85.0	150.7	70.97	4.62	1.37	5.95
LSD (5%)		40.91	6.59	0.21	0.06	0.82

[1]Lines sown on 29 January and harvested 17 April–1 May 2003.
[2]Measured from double-seeded pods.

Table 119. *Yield and horticultural characteristics of taro-flavor vegetable soybeans tested at AVRDC during autumn of 2003.*[1]

Lines	Days to maturity	Pod no./ 500 g	100-fresh seed wt (g)	Pod length[2] (cm)	Pod width[2] (cm)	Graded yield (t/ha)
KVS2	65	196	64.0	4.60	1.30	4.53
KVS3	75	201	66.3	4.53	1.30	7.50
KVS7	65	221	49.0	4.55	1.23	7.20
KVS8	68	198	60.0	4.05	1.30	8.65
KVS6	68	142	81.0	4.88	1.40	4.13
TS85-21V	61	208	62.3	4.13	1.35	5.00
Shon-gi (check)	61	209	65.8	3.80	1.28	4.75
Black-5-leaf (check)	61	181	69.3	4.53	1.30	5.18
Mean	65.5	195	64.7	4.38	1.31	5.86
LSD (5%)	0	14.91	6.84	0.14	0.06	1.34

[1]Lines sown on 1 September and harvested 31 October–14 November 2003.
[2]Measured from double-seeded pods.

Table 120. *Quality analysis of taro-flavor vegetable soybeans tested at AVRDC.*

Lines	Spring			Autumn		
	Protein (%)	Sugar (%)	Color[1] (grade)	Protein (%)	Sugar (%)	Color[1] (grade)
KVS2	39.91	7.47	2.20	36.77	7.94	3.86
KVS3	43.64	5.69	3.53	40.46	6.54	2.91
KVS7	41.70	7.42	3.87	38.12	7.37	3.75
KVS8	41.73	7.75	4.03	38.58	9.24	3.64
KVS6	42.82	6.69	3.05	40.25	9.30	2.68
TS85-21V	40.14	10.21	4.37	36.25	10.95	4.42
Shon-gi (check)	40.49	10.27	4.58	36.65	10.94	4.95
Black-5-leaf (check)	43.98	9.08	4.42	37.94	11.78	3.61
Mean	41.80	8.07	4.13	38.13	9.26	3.73
LSD (5%)	0.86	0.69	0.43	0.99	0.67	0.25

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

Effects of staking on yield of ivy gourd

Ivy gourd (*Coccinia grandis*) is a climbing, herbaceous perennial plant with tuberous roots. Its young shoots and leaves are consumed in different forms in South and Southeast Asia. The leaves are a good source of protein, minerals and vitamins, particularly vitamin A. Young shoots are harvested either for home consumption and/or bundled for sale at local markets. Despite its high nutritive value, there is little information on production methods for this vegetable. The objective of this study was to evaluate the productivity of ivy gourd by staking and non-staking methods.

Seeds were sown on 4 July 2003 and seedlings transplanted to the field three weeks later. A RCBD with three replications was used comparing two treatments, staking and non-staking. The two-row bed was 25 cm in height, 1.5 m in width, and 6 m in length. The spacing was 2 m between beds, 75 cm between rows, and 50 cm between plants. There were two beds in each plot. Vines were staked on bamboo sticks, 2 m in length, secured with plastic ties. Plants were tip pruned three days after transplanting. Young shoots (15 cm or more in length) were harvested twice a week from 8 August 2003 to 8 March 2004. Weights of leaves, stems and tendrils were measured respectively in each bed by random sampling of 30 young shoots and replicated three times, right after harvesting on 21 August. Flowers and young fruits were removed while harvesting young shoots in order to encourage vegetative growth. The protein and β-carotene contents of leaves, stems and tendrils were analyzed.

Staking had no effect on the yield of the first ten harvests, but thereafter reduced yields (Table 121). The yield increased with harvesting time and increasing temperature. From the 51st to 60th harvest, the average yield per harvest of non-staked plants was 13.99 t/ha compared to 12.29 t/ha for staked plants. Although staking reduced yields, the support system made farming operations much easier.

The results showed that the main edible portion of the ivy gourd young shoots was stems, followed by leaves and tendrils (Table 122). The leaves of ivy gourd are rich with protein and β-carotene content, 6.7 g and 4.2 mg per 100 g fresh weight, respectively, and higher than the nutrient contribution of stems and tendrils. This study was conducted from July 2003 to March 2004, and could be harvested year-round if maintained. Ivy gourd displayed that it can be a valuable vegetable in the tropics especially where vitamin A deficiency is of concern.

Table 121. *Yield of ivy gourd young shoots by non-staking and staking methods at different harvesting times.*

Harvest[1]	Yield (t/ha)			Mean day/night air temp. (°C), rainfall (mm)
	Non-staking	Staking	LSD (5%)	
1st -10th	2.78	2.70	0.44	33.8/25.9, 83
11th -20th	9.48	8.51	0.68	33.4/25.1, 64
21st -30th	18.65	15.87	2.02	30.2/20.4, 0
31st -40th	36.16	31.39	2.17	25.9/15.6, 3
41st -50th	70.04	61.29	3.71	24.1/13.5, 5
51st -60th	139.88	122.88	8.52	24.4/14.9, 0

[1]Harvest: 1st–10th (7 August–8 September 2003), 11th–20th (12 September–13 October), 21st–30th (16 October–17 November), 31st–40th (20 November–22 December), 41st–50th (24 December 2003–2 February 2004), and 51st–60th (6 February–8 March).

Table 122. *Nutrient contribution of different portions of young* Coccinia grandis *shoots.*

	Leaves	Stems	Tendrils
Shoot fresh weight (g)	30.4	62.2	7.4
Protein (g/100 g)[1]	6.7	2.9	2.6
ß-carotene (mg/100 g)[1]	4.2	0.8	0.5

[1]Based on fresh weight.

Growth analysis of okra

Okra is an herbaceous, annual vegetable crop native to the African and Asian tropics. It sets fruits on nodes of developing stems, beginning with the third to sixth node. As vegetative growth and fruiting proceed simultaneously for an extended period, the plant maintains a balance in the partitioning of assimilate between vegetative and reproductive parts. Research on okra production has been confined to a few management studies; thus, there is a significant void in information concerning the vegetable's growth and development in relation to yield. In this study, growth rates of six promising okra accessions were studied along with check varieties Lucky Five and Red Pod.

Seeds were sown on 20 June 2003 in seedling flats, 28 cm in width and 53 cm in length. Seedlings with 2–3 true leaves (about 18 days after sowing) were transplanted on 9 July in raised beds covered with plastic mulch. The experimental design was RCBD with three replications. Plants were set in twin rows on 25 cm beds with plants spaced 50 cm apart. Plot size was 7 m × 1.5 m, 75 cm between rows, and 30 cm between beds. A plant was sampled from each bed during transplanting, and then 2, 4, 6, and 8 weeks after transplanting (WAT) for growth analysis (from 9 July to 3 September, mean day/night air temperatures at 34.4/26.4°C, 305 mm rainfall). Data of plant height, leaf number and dry weights of different plant parts were taken. Crop growth rate (CGR) was calculated using the formula: $CGR = W_2 - W_1/SA\ (t_2 - t_1)$, where W_1 and W_2 are crop dry weight at beginning and end of the interval, t_1 and t_2 are corresponding days, and SA is the soil area occupied by the plants at each sampling.

The growth analysis of this particular experiment was conducted up to the first 8 WAT. During the interval of 4 to 8 WAT, plant heights of TOT0581, TOT4242 and TOT5864 were significantly higher than other tested lines (Fig. 38). Eight weeks after transplanting, plant heights of these lines ranged from 167 to 175 cm, whereas heights of other entries were only 92 to 115 cm.

The days to 50% flowering of TOT0581, TOT4242 and TOT5864 were 36, 44 and 46, respectively, much earlier than the 55–70 days required for other entries.

CGRs were low in the early growth stages but increased with time for all lines, with the exception of Red Pod, whose CGR peaked after 6 WAT (Fig. 39). After 8 WAT, CGRs of TOT1496 and TOT 2191 were highest, apparently due to their high Leaf Area Index values.

Among the eight entries, TOT0581 has the highest total fruit yield 14 WAT (data not shown), but its CGR had already began tapering off at 6 WAT. This implies that higher CGR may not necessarily translate into higher yield. When harvest index (HI) was measured

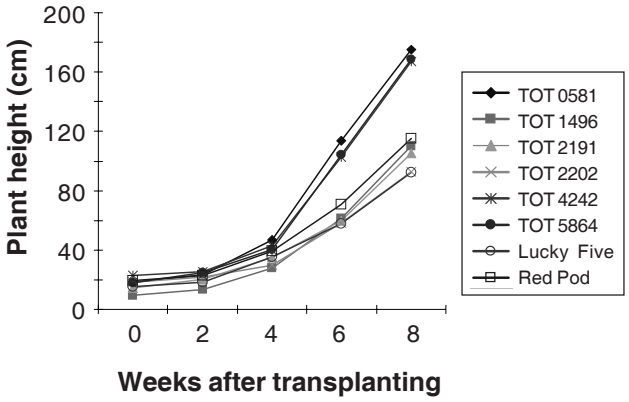

Fig. 38. *Changes in plant height of okra accessions at different time intervals.*

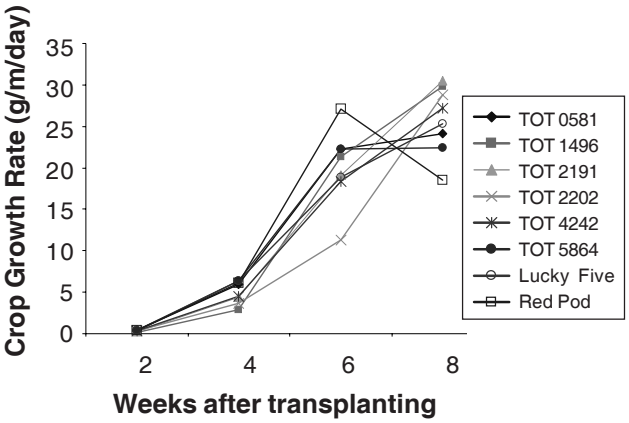

Fig. 39. *Crop growth rate of okra accessions at different time intervals.*

at 8 WAT, TOT0581 had higher HI values than other entries. This might due to its early maturity. High HI values of TOT1496 and TOT2191 indicate that vegetative growth overpowers reproductive growth, resulting in late maturity and low yield. To verify the above assumptions, growth analyses throughout the whole growing duration are being planned.

Besides growth and development as related to fruit yield, fruit characteristics are also important determinants for growers to accept new okra lines. Among the six TOT lines in this study, fruits of TOT0281, TOT4242 and TOT5864 produce five-ridged pods, and TOT2202, TOT2191 and TOT1496 produce smooth-sided pods. This factor will be taken into consideration in the next round of analysis.

Evaluation of flooding tolerance in four indigenous vegetables

Heavy rainfall and subsequent flooding during the hot-wet season in the lowland tropics restricts vegetable production. Growers can either develop management practices that reduce flooding damage in the field (e.g., using rain shelters and raised beds) or grow vegetables that tolerate flooding. The objective of this study was to evaluate the level of flooding tolerance of four indigenous vegetables, which have been previously identified as promising new vegetables.

Ten accessions of four species (Table 123) were selected for testing. The date of sowing, transplanting, flooding, and max./min. temperatures before and during flooding are listed in Table 124.

About 120 seeds were sown for each accession in seedling flats. After 2–3 weeks, 80 seedlings of uniform size (about 6 cm in height) with four true leaves were transplanted into plastic pots (9 cm diameter × 9 cm depth), one seedling per peat-containing pot, and placed in the screenhouse. Twenty pots were placed into a plastic tub (49 cm length × 32 cm width × 7 cm height). Before initiation of flooding, seedlings were allowed to grow in the screenhouse and maintained under well-aerated soil conditions for 7 days.

Table 123. *Materials for evaluation of flooding tolerance.*

Vegetable	Entry	Origin
Coffee senna (*Cassia occidentalis*)	TOT5820	Taiwan
Jute mallow (*Corchorus olitorius*)	TOT4312	Bangladesh
Ivy gourd (*Coccinia grandis*)	-	Thailand
Okra (*Abelmoschus esculentus*)	TOT0581	Bangladesh
	TOT1496	Philippines
	TOT2191	Philippines
	TOT2202	Philippines
	TOT4242	Bangladesh
	Lucky Five	Taiwan
	Red Pod	USA

Seven days after transplanting, a RCBD with three replications was employed for the experiment. Every block contained two plots. Each plot (10 plants) was randomly assigned to either flooding or non-flooding (control) treatment. Flooding was imposed by placing pots into larger plastic tubs (60 cm length × 18 cm width × 16 cm height) filled with tap water. Pots were flooded up to 1 cm above the soil surface for 3 days, and then drained. Water levels were maintained at the target levels by replacing evapotranspiration losses with tap water daily.

Leaf number and plant height were measured before flooding, and then 3 days, 1 week and 2 weeks after flooding. Analysis of all samples was performed in three replications, and made on a subset of five replicate plants per treatment per block. In the period of flooding, effects such as chlorosis, senescence and abscission of lower leaves were recorded. Two weeks after flooding, plants were carefully removed from the pots. Fresh and dry weights of stems, leaves, and roots were measured by sampling two plants per treatment (plot). Roots were washed well in tap water and gently blotted dry by paper towel. After fresh weight was recorded, plant samples were dried at 70 °C for 72 h.

After three days of flooding, lower leaves of *Abelmoschus esculentus* exhibited chlorosis, and the original root systems stopped growing downwards. Flooding inhibited root penetration and leaf expansion. After flooding, all accessions of *A. esculentus* shed many lower leaves, especially in the case of TOT0581 and TOT2191. In Red Pod, TOT1496, TOT2191, and TOT2202, leaf number had come back to normal after two weeks of flooding. Soil flooding led to a significant reduction in total biomass of *A. esculentus*. Fourteen days after flooding, the root/shoot ratio in flooded plants was 85 to 100% of the control plants (Table 125). Average seedling height was also reduced in flooding plants (Table 126).

Under flooded conditions, fresh weight and dry weight of *Cassia occidentalis* and *Corchorus olitorius* maintained or even increased biomass production. In the flooded plants of *C. occidentalis*, root

Table 124. *The date of sowing, transplanting, flooding, and max./min. temperatures before and during flooding.*

Group[1]	Date sowing	Date transplanting	Date flooding	Mean day/night temp. before flooding	Mean day/night temp. during flooding
I	08 July	7/22	29 July	29 ± 1°C / 26 ± 1°C	39 ± 2°C/ 27 ± 2°C
II	08 July	7/25	01 Aug.	29 ± 1°C / 26 ± 1°C	39 ± 2°C/ 27 ± 2°C

[1]Group I represent the accessions of TOT0581, TOT2202, TOT4242, Lucky Five and Red Pod; Group II represent the accessions of TOT1497, TOT2191, TOT4312, *Coccinia grandis* and *Cassia occidentalis*. *Coccinia grandis* was sown on 4 July 2003.

Table 125. *Yield ratio and survival rate of all entries under flooding stress.*

Entries	Yield ratio[1]	Ratio (flooded/non-flooded)			Survival rate (%)[2]
		Root	Stem	Leaf	
Cassia occidentalis	1.07	0.87	1.10	1.09	100
Coccinia grandis	0.53	0.49	0.53	0.54	80
Corchorus olitorius	1.08	1.07	1.08	1.08	100
Abelmoschus esculentus					
TOT0581	0.49	0.40	0.43	0.58	93
TOT1496	0.66	0.72	0.60	0.74	100
TOT2191	0.55	0.53	0.49	0.66	100
TOT2202	0.56	0.54	0.48	0.69	97
TOT4242	0.68	0.67	0.59	0.81	100
Lucky Five	0.55	0.48	0.52	0.58	100
Red Pod	0.60	0.65	0.54	0.73	100

[1]Ratio of final shoot biomass under flooded conditions to final shoot biomass under non-flooded conditions.
[2]Recorded 2 weeks after flooding.

biomass was 87% less than non-flooded plants and biomasses of stem and leaf were 10% and 9% less (Table 125).

After three days of flooding, the damage and death of many original root systems was observed in most flooded plants among all species. Two days after flooding, we observed the emergence of a few adventitious roots in *C. olitorius*, as well as the redirection to horizontal growth of existing roots. There were no adventitious roots present in the other species, but some protuberance was observed on the base of stem in *C. occidentalis*. No adventitious roots were found on the control plants in every species. *C. olitorius* showed significant growth under flooded conditions.

Based on this evaluation, *C. occidentalis*, *C. olitorius*, and two accessions of *A. esculentus,*TOT1496 and TOT4242, appeared most tolerant to flooding.

Table 126. *Effects of flooding on plant height growth of* Abelmoschus esculentus *entries.*

Treatment/Acc.	Range of plant height growth (cm)		
	Flooding	1 WAF[1]	2 WAF
Flooding			
TOT0581	2.0	5.0	5.0
TOT1496	2.2	3.5	3.5
TOT2191	1.6	2.9	3.2
TOT2202	0.9	3.3	3.3
TOT4242	0.9	4.6	3.8
Lucky Five	1.5	5.1	4.6
Red Pod	1.7	5.0	5.1
Control			
TOT0581	2.8	9.8	9.5
TOT1496	2.0	5.3	4.3
TOT2191	1.9	4.2	3.5
TOT2202	2.0	5.5	4.1
TOT4242	2.0	6.7	6.1
Lucky Five	2.1	6.7	5.0
Red Pod	2.1	7.1	5.9

[1]WAF = weeks after flooding.

Recipe development for promotion of promising indigenous vegetables

A total of 113 recipes for home cooking and culinary art were developed with 17 species of promising indigenous vegetables by the AVRDC staff and the faculty and students of Tainan Woman's College of Arts & Technology for promotion. Among them, 31 recipes were derived from indigenous vegetables with high β-carotene (*Coccinia grandis*, *Abelmoschus esculentus*, *Angelica keiskei*, *Corchorus olitorius*, *Asystasia gangetica*), 15 with high folate (*A. esculentus*, *A. keiskei*), 4 with high iron (*Oenanthe javanica*) and 3 with high calcium (*Hibiscus sabdariffa*). A calendar, *Calendar 2004 – Indigenous vegetables for healthy diets*, was well received within and outside Taiwan.

For more information, contact: George Kuo

Technical Services

Offering of technical services

AVRDC provided technical services to one private company and one public institution in 2003. The services included screening of resistance to Fusarium wilt races 1 and 2, tomato leaf curl virus, bacterial wilt and late blight in tomato, and resistance to bacterial wilt, late blight, tobacco mosaic virus, chilli veinal mosaic virus, and potato virus Y in pepper.

Seeds were produced of tomato lines Hualien-ASVEG No. 5, Taoyuan-ASVEG No. 9, Taichung-ASVEG No. 10, Tainan-ASVEG No. 11, and Hualien-ASVEG No. 13. In total, 132.28 kg of seeds were produced and distributed. In addition, Kagome Company contracted AVRDC to produce 2.5 kg each of processing tomato lines PT4732 and PT4734, which represented 50% of the tomato grown by the company in Taiwan.

Contract research projects

In 2003, AVRDC was granted US$1,200,000 for 24 contract research projects from the ROC Council of Agriculture and three from the National Science Council.

Increasing public awareness

AVRDC received 597 visitors, consisting of 435 from Taiwan, 24 from China, and 138 from other nations. AVRDC also helped arrange trips to introduce international visitors to small-scale farming and intensive crop production systems in Taiwan.

For more information, contact: George Kuo

Communications, Training and Information

Multimedia, electronic and print publications

The most extensive publication in 2003 was *AVRDC Report 2002*, which reported the research and development activities of the Center for that year. Another major publication was AVRDC's mid-term strategy plan, *AVRDC Mid-Term Plan 2003–2005.* This rolling plan highlighted successful projects, vegetable production and consumption trends, AVRDC's strategic approach, and our program goals for 2003–2005.

The booklet, *Vegetables for life: Confronting the crisis in Africa*, was produced for dissemination at the Annual General Meeting of the Consultative Group of International Agricultural Research, which was held in Africa for the first time. This booklet uses an illustrative format to describe AVRDC's strategy in Africa. It begins with an overview of problems in Sub-Saharan Africa, which include malnutrition, HIV/AIDS, and deteriorating soils. The importance of increasing vegetable production and consumption in the region is discussed, followed by a description of research and development initiatives.

AVRDC compiled the above three publications, a Powerpoint slide show on AVRDC, and the entire online Learning Center to develop an interactive CD-ROM, which was distributed to the participants at the Annual General Meeting.

Technical bulletins published in 2003 included *Development of an Integrated Pest Management Strategy for Eggplant Fruit and Shoot Borer in South Asia* and *Socio-economic Parameters of Eggplant Pest Control in Jessore District of Bangladesh*. The former is a summary of activities undertaken in a project that developed technologies to control eggplant fruit and shoot borer, the most severe pest of eggplant in Asia. The latter is an analysis of the use of pesticides in eggplant cultivation in a major vegetable production area in Bangladesh; this analysis includes an evaluation of socio-economic characteristics of farmers and an economic analysis of AVRDC's strategy to safely control the pest.

Brochures were written for extension specialists on eggplant pest control: *How to Control Eggplant Fruit and Shoot Borer* and *A Farmer's Guide to Harmful and Helpful Insects in Eggplant Fields*. Another brochure, *How to Grow Safer Leafy Vegetables in Nethouses and Net Tunnels*, describes a production strategy that allows for pesticide-free production of leafy vegetables.

Several publications related to the expanded use of AVRDC mungbean lines across Asia. *The Impact of Mungbean Research in China* examines the impact of this important legume crop on China, offering a detailed description of varietal improvement, agricultural policies related to its production, trends in nutrition and production, and economic analysis. The publication, *Enhanced bioavailability of iron from mungbeans and its effects on health of schoolchildren*, presents the findings of a feeding trial based on mungbean supplementation that was conducted among schoolchildren in southern India. A related publication, *High-Iron Mungbean Recipes for North India*, consists of nutritious and affordable recipes for families in the region, where most of the women and children suffer from iron deficiency anemia. A previously published work, *High-Iron Mungbean Recipes from South Asia*, was placed on-line for viewing and downloading in 2003.

International Cooperators' Guides were published on suggested cultural practices for bitter gourd, drumstick tree, jute mallow, amaranth, Malabar spinach, African eggplant, African nightshades, and spiderflower plant. Production guides for 19 vegetables are now on-line and available for downloading via the internet. Also, guides on grafting tomato and using rain shelters in the hot-wet season were published and placed on-line.

The proceedings of a workshop jointly conducted by AVRDC-RCA and FAO was published, entitled *Increasing the Consumption of Micronutrient-rich Foods Through Production and Promotion of Indigenous Foods*. This publication supports an AVRDC project that aims to improve the nutritional status of vulnerable communities in South Africa, Swaziland, Tanzania and Uganda. The proceedings includes a description of the project, country proposals, and recommendations for project activities.

Numerous scientific findings were published in refereed scientific journals. All AVRDC publications in 2002 are listed on page 188.

The Communications and Training Office mailing list currently contains over 1800 entries, including 623 libraries in 163 countries. The office printed more than a quarter of a million pages and handled more than 300 art requests from Center scientists. Over 10,000 photos were shot and processed.

AVRDC web site and Learning Center

As a research center with a global mandate and an immense number of clientele, information technology is an essential tool for AVRDC's communication and training activities. In 2003, AVRDC established a "virtual library" consisting of all of the Center's publications since 1997. This includes Annual Reports, books, bulletins, production guides, and over 100 fact sheets. Each month, approximately 10,000 persons from 120 countries download this information freely and instantly over the internet. In total, approximately 20,000 web pages from the AVRDC web site are downloaded every month.

Twelve computer-based tutorials were developed on major vegetable production topics. Approximately 6000 persons accessed these tutorials during 2003.

The Center's web site was transferred to a server in the USA, significantly increasing the speed of downloading. We added a simpler web address (www.avrdc.org), a vastly improved search engine, enhanced navigational components and streamlined access to electronic journals.

Collecting and sharing tropical vegetable information

This subproject is handled by the Center's library. In 2003, the library acquired over 175 new books and over 1786 serial publications. Subscriptions to 92 journals were renewed.

The library updated the Center's bibliographic databases to facilitate information storage and retrieval. A total of 216 books, 2743 crop documents, and 60 new serial titles were indexed and added to the library database. This in-house database, which now holds 40,920 bibliographic records and 3921 journal records, was placed on-line in 2003 and can be readily retrieved by staff and collaborators via computer. A total of 283 journal issues were bound; this hard-copy collection of journals now totals 15,715 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 2003. Thirty issues of SDI bulletins and three issues of recent AVRDC Library acquisitions were established on the library web site in 2003. A total of 535 users from 36 countries accessed the SDI services via the internet.

Library staff conducted 32 literature searches of CD-ROM databases and Tropical Vegetable Information Services databases for internal and external users. A total of 1224 documents were photocopied and delivered to 124 users in 75 libraries in 16 countries.

Training

In 2003, 76 scholars from 15 countries received training in vegetable research and development at AVRDC headquarters in Taiwan. These numbers are down from the record numbers of trainees in 2001 and 2002; this was due to the SARS health crisis in Taiwan, which discouraged persons coming to the island. A complete list of trainees can be found on page 183.

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 95% stated that they would like to come to AVRDC again for further training and 98% 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 3.53, the quality of their instruction from trainers at 3.98, and the assistance from the Communication and Training Office at 4.01.

ASEAN scholarship training

A multi-year scholarship program has been established 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 participated in this training program at AVRDC headquarters during 2003. The following information in this section is provided, in detail, to highlight examples of AVRDC training programs and their immediate impact:

Hai Thi Hong Truong, educator from Hue University of Agriculture and Forestry, completed a 6-month training program at AVRDC headquarters during 2003.

She subsequently was admitted for doctoral studies at the University of Hannover in Germany, and she continues her work at AVRDC today, which focuses on identifying molecular markers for tomato geminiviruses and other diseases.

Bounchanh Komboungnasith, agricultural technician from the Department of Agriculture in Laos, received 12 months of training on hot-wet season vegetable production technologies. He learned tomato grafting procedures, constructing grafting chambers, and screening tomato and eggplant rootstocks for diseases. After his training was completed, he returned to Laos and assists AVRDC staff in teaching grafting technologies to entrepreneur farmers.

Nguyen Ngoc Bau Chau, researcher from the National Center for Natural Science and Technology in Ho Chi Minh City, Vietnam, developed skills in gene transformation techniques. She learned Agrobacterium-mediated transformation of tomato with pest resistance protein-VrCRP. Ms. Nguyen is currently teaching gene transformation techniques to colleagues and students in her institute.

Chanthy Pol, researcher from the Cambodian Agricultural Research and Development Institute, evaluated attractants that attract eggplant fruit and shoot borer. The ultimate objective of this research is to develop eggplant varieties that are less attractive to this pest. He is currently using these techniques to develop new integrated pest management protocols in Cambodia.

Research internships, sabbatical scientists, and graduate students

A total of 23 researchers from 7 countries (Bhutan, China, Ethiopia, India, Indonesia, Korea, and Thailand) completed research internships and fellowships. In these 1 to 12-month training programs, researchers developed skills within the fields of biotechnology, genetic resource management, entomology, plant pathology, plant physiology, tomato breeding, pepper breeding, legume breeding, and nutrition.

A sabbatical scientist from the University of Virgin Islands, Dr. Manuel Palada, came to AVRDC and authored several production guides. Dr. Raymond Cerkauskas from Agriculture and Agri-Food Canada authored many fact sheets regarding disease management for tomato and pepper crops.

Among graduate students, Ms. Andrea Kuehn of University of Bonn analyzed economic impacts of tomato production in Taiwan as part of her doctoral research. Mr. Ramasamy Srinivasan of Tamil Nadu University in India studied host mediated behavior of tomato fruitworm for his doctoral research.

Summer program for undergraduates

AVRDC offers undergraduate training to support university studies and to provide valuable experiences to students who are deciding their futures in the life sciences.

For the 28th consecutive year, AVRDC hosted undergraduate students from universities in Taiwan. Twenty-nine students from 9 universities in Taiwan were trained in 2003. 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 Taiwanese students received training in the English language.

Thirteen students from the University of the Philippines at Los Baños came to AVRDC for training in genetic improvement, germplasm management, food science, and entomology. One student from Tokyo University of Agriculture learned vegetable seedling production techniques.

English language training English language training

A total of 32 university students, 20 research interns, and 24 AVRDC staff 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 20,000 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.

A total of 145 slide sets, 8 videos, and over 200 Vegetable Production Training Manuals were sold and disseminated upon request.

For more information, contact Tom Kalb

AVRDC-Asian Regional Center

The AVRDC-Asian Regional Center (AVRDC-ARC) serves as the link between AVRDC headquarters and the national partners in Asia. Originally established as the Thailand Outreach Program (TOP) in 1982, AVRDC-ARC was created in 1992 with the mandate to identify and address needs of vegetable research and development in the region.

AVRDC-ARC conducts applied research on a wide range of vegetables grown in the region, conducts regional and short-term training courses, and coordinates sub-regional networks and collaborative research and development programs.

AVRDC-ARC is implementing a project entitled "Collaborative Vegetable Research Network for Cambodia, Lao PDR and Vietnam, Phase II (CLVNET-II)" funded by the Asian Development Bank (ADB), which started in 2002 and will end in 2005. The objectives of the project are to increase vegetable production and to strengthen the capacity of national agricultural research and extension systems (NARES) in these countries, with emphasis on dissemination of mature technologies to farmers. In 2003, AVRDC-ARC started to implement Phase IV of the "Human Resource Development Project (HRDP-IV)" funded by the Swiss Agency for Development and Cooperation (SDC). This 4-year project promotes collaborative research and human resource development in the CLV countries as well as supports the regional training course on vegetable production, research and extension conducted every year at AVRDC-ARC.

Research

Inheritance of resistance to powdery mildew disease

The promising mungbean lines developed at ARC-AVRDC are showing increasing levels of resistance to powdery mildew. This experiment aimed to study the genes that control powdery mildew disease in the cross of VC 2778A × VC 6468-11-1A. In addition, the study hoped to find the type and magnitude of gene action for resistance to powdery mildew from resistant and susceptible inbred parents by determining the gene effect from generation mean analysis.

Six populations were made: susceptible parent VC 2778A (P_1), resistant parent VC 6468-11-1A (P_2), F_1 and F_2 generations of these parental lines, B_1 ($F_1 \times P_1$), and B_2 ($F_1 \times P_2$). The six populations were planted in randomized complete block design (RCBD) with six replications at the AVRDC-ARC experimental field in Nakhon Pathom. Each replication was surrounded with border rows of the susceptible variety, which were planted 30 days before the treatments, to spread the disease. Data were recorded on percent disease infected per plant (PIP) and per leaf (PIL) at 30 days after sowing date. PIP was rated on a 1–4 scale with 1 = < 10%, 2 = 10–30%, 3 = 31–60%, and 4 = >60% infected plants. PIL was rated on a 1–5 scale, with 1 = ≤ 5% or less, 2 = 6–10%, 3 = 11–25%, 4 = 26–50%, and 5 = > 50% infected leaves.

The genetic effects were analyzed from six parameters using Gamble's method (1962) that deals on mean (*m*) effects, additive (*a*) and dominance (*d*) gene effects, and three types of digenic epistatic effects (*aa, ad* and *dd*) for analysis gene controlling mungbean powdery mildew disease.

The results showed that both parents, VC 2778A and VC 6468-11-1A, had highly significant differences in PIP and PIL levels (Table 127). PIP levels for the parents were 2.38 and 1.25; PIL levels were 2.38 and 1.36. VC 6468-11-1A, the resistant parent, had a lower rate of disease development than the susceptible parent, VC 2778A. The F_1 and F_2 populations had levels

Table 127. *Mean of percent disease infected per plant and leaves in each mungbean generations.*

Generation	Infected plants (%)	Infected leaves (%)
P_1 (Susceptible)[1]	2.38 a[2]	2.62 a
P_2 (Resistant)	1.25 c	1.36 d
F_1 ($P_1 \times$ P2)	1.95 b	1.88 cd
F_2 (F_1 selfing)	1.83 b	1.98 bc
B_1 ($F_1 \times P_1$)	2.03 b	2.13 b
B_2 ($F_1 \times P_2$)	1.25 c	1.70 d
F-test	**	**
CV (%)	30.34	33.65

[1]P_1 = VC2778A, P_2 = VC6468-11-1A

[2]Means within columns separated by Duncan's multiple range test, $P \leq 0.05$.

**Significant at $P \leq 0.01$.

of disease infection of 1.95 and 1.83 for PIP, and 1.88 and 1.98 for PIL, respectively; these were near midparent values.

The progeny of the backcross to the susceptible parent showed levels of susceptibility similar to the susceptible parent. The progeny of the backcross to the resistant parent showed levels of resistance similar to the resistant parent. This indicates that resistance of powdery mildew disease in mungbean involves multiple genes. Gene effect analysis by generation mean analysis showed highly significant additive effects and nonsignificant dominant and epistatic effects (Table 128). Thus, epistatic effects were removed and an analysis was done only on the main three parameters. The results of this analysis showed that among the major gene effects, additive gene effects are important in this cross (Table 129). Therefore, breeders should follow methods that accumulate resistance genes for powdery mildew in one genotype and fix the resistant gene at the desired level.

Table 128. *Mean estimates of the six-parameter gene effects for powdery mildew disease on mungbean cross of VC2778A × VC6468-11-1A.*

Gene effects	Infected plants (%)	Infected plants t-test	Infected leaves (%)	Infected leaves t-test
m (mean)	1.83	13.02 **	1.98	12.20 **
a (additive)	0.53	2.81 **	0.43	2.12 *
d (dominance)	–0.17	–0.24 NS	–0.37	–0.48 NS
aa (addit. × addit.)	–0.26	–0.38 NS	–0.27	–0.35 NS
ad (addit. × domin.)	–0.08	–0.37 NS	–0.19	–0.35 NS
dd (domin. × domin.)	0.82	0.80 NS	0.35	0.31 NS

NS,*,**Nonsignificant, and significant at $P \leq 0.05$ asnd 0.01, respectively.

Table 129. *Mean estimates of the three-parameter gene effects for powdery mildew disease on mungbean cross of VC2778A × VC6468-11-1A.*[1]

Gene effects	Infected plants (%)	Infected plants t-test	Infected leaves (%)	Infected leaves t-test
m (mean)	2.12	3.09 **	2.26	3.00 **
d (additive)	0.61	5.50 **	0.62	5.05 **
d (dominance)	–0.99	–0.60 NS	–0.72	–0.40 NS

[1]Epistatic effects were nonsignificant and removed from this analysis.
NS,*,**Nonsignificant, and significant at $P \leq 0.05$ asnd 0.01, respectively.

Genetic studies on yield components and powdery mildew resistance

Powdery mildew (*Erysiphe polygoni*) is a serious disease problem of mungbean production in Asia. One of the thrusts in mungbean breeding at AVRDC-ARC is to develop advanced mungbean lines with improved levels of resistance to the disease. This study was conducted to establish estimates of direct and indirect correlation between powdery mildew resistance and seed yield. A collection of 16 released varieties were used for the study (Table 130).

Table 130. *Powdery mildew disease and yield components in sixteen mungbean lines.*

Line	Yield (t/ha)	Powdery mildew (%)	Pods per plant	Seeds per pod	1000-seed weight (g)
VC6468-11-1A	3.32	17.1	16.05	12.63	69.6
VC6469-12-2-6A	3.08	5.2	13.50	12.08	72.1
VC6469-12-1-1A	2.76	5.2	14.35	11.85	74.7
VC6465-8-5-2A	2.73	5.2	14.30	11.83	67.3
VC6467-10-3-1A	2.63	5.2	16.00	12.35	64.4
VC6465-8-1-2A	2.58	20.0	13.85	12.08	62.8
VC6469-12-1-4A	2.42	10.6	14.45	12.08	65.9
VC6469-12-3-4A	2.41	5.2	13.05	12.33	72.3
VC6464-7-3-1A	2.23	33.2	12.00	12.08	70.9
VC6372-45-8-1A	2.19	77.6	16.10	11.43	51.5
VC6368-46-40-4A	1.96	65.6	13.60	11.03	55.6
VC1628A (CN36)	2.60	77.0	14.50	12.05	68.2
VC1973A (KPS1)	2.54	74.5	13.25	12.00	65.4
VC2768A (PSU1)	2.28	80.0	12.30	12.18	66.6
NM 94	2.32	76.7	15.35	11.33	59.8
NM 92	1.91	70.0	16.25	9.83	51.4

Powdery mildew symptoms appeared during pod filling stage and continued through pod maturity, depending on variety. The results showed that seed yield was highly correlated to number of seeds per pod (r = 0.684*) and negatively correlated to powdery mildew (–0.589*)(Fig. 40). The direct effect of powdery mildew to seed yield, however, was very low (–0.028). The main components with high direct effects to seed yield were 1000-seed weight (0.659), number of pods per plant (0.558) and number of seeds per plant (0.359)(Table 131). The number of pods per plant was not significantly correlated but had high indirect effect to seed yield (0.501). The four components had a total coefficient of determination value of $R^2 = 76\%$ to mungbean yield.

Table 131. *Path coefficient analysis of mungbean yield through the incidence of powdery mildew disease, number of pods per plant, number of seeds per pod, and 1000-seed weight.*

No.	Correlation character	Path coefficient
1	Powdery mildew vs. seed yield	
	Direct effect of powdery mildew	–0.028
	Indirect effect of pods per plant	0.024
	Indirect effect of seeds per pod	–0.178
	Indirect effect of 1000-seed weight	–0.408
	Total correlation	–0.589 *
2	Pods per plant vs. seed yield	
	Direct effect of pods per plant	0.558
	Indirect effect of powdery mildew	–0.001
	Indirect effect of seeds per pod	–0.122
	Indirect effect of 1000-seed weight	–0.330
	Total correlation	0.105 NS
3	Seeds per pod vs. seed yield	
	Direct effect of seeds per pod	0.359
	Indirect effect of powdery mildew	0.014
	Indirect effect of pods per plant	–0.190
	Indirect effect of 1000-seed weight	0.501
	Total correlation	0.684 **
4	1000-seed weight vs. seed yield	
	Direct effect of 1000-seed weight	0.659
	Indirect effect of powdery mildew	0.017
	Indirect effect of pods per plant	–0.280
	Indirect effect of seeds per pod	0.273
	Total correlation	0.669 **
	$R^2 = 0.76$	

NS,*,**Nonsignificant, and significant at $P \leq 0.05$ asnd 0.01, respectively.

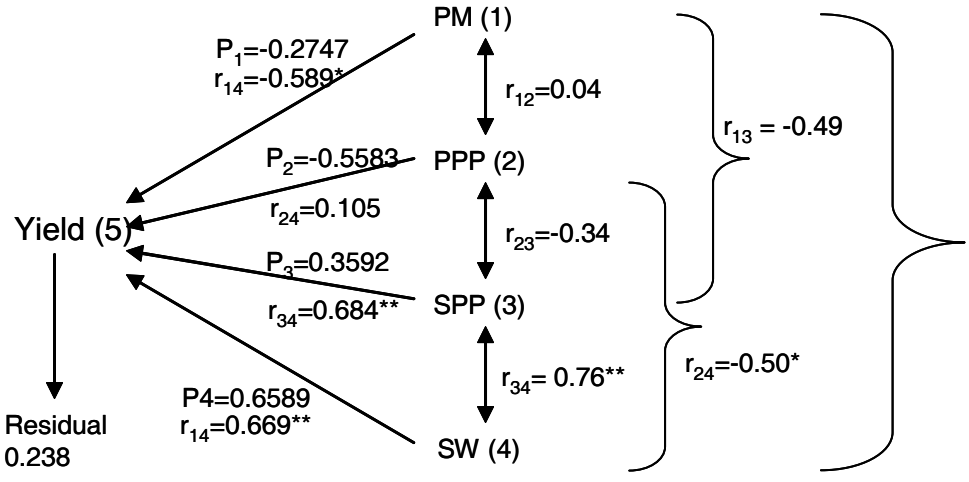

Fig. 40. *Diagram of path coefficient (P) and correlation (r) analysis for mungbean yield through powdery mildew disease (PM), pods per plant (PPP), seeds per pod (SPP) and 1000-seed weight (SW).*

*, **Significant at $P \leq 0.05$ and 0.01, respectively.

Effect of type and ratio of dehydrating material on storage of vegetable soybean seeds

One of the problems in vegetable soybean production in the tropics is the fast decrease in viability of seeds over time. Poor farmers cannot afford to have good facilities to store seeds so a simple storage technique needs to be developed. This experiment was conducted to evaluate eight vegetable soybean lines using different storage techniques. Lines AGS 190, AGS 292, AGS 328, AGS 370, AGS 372, AGS 373, AGS 375 and TN3 were each stored in a plastic box with different ratios of lime and ash (1:1 and 1:2) as dehydrating materials and different frequencies of changing the dehydrate (monthly and every two months). Seed germination and seed moisture content were tested monthly.

During the first month, AGS 190 and AGS 375 had high germination rates of 91.7 and 93.8%, respectively (Table 132). Seven months after storage, their germination rates were still high at 81.2 and 86.3%.

Lime was generally the best medium to control moisture and help maintain high seed germination (Table 133). The use of 1:1 or 1:2 ratio of seed-dehydrating materials resulted in similar germination rates. Changing the dehydrating material monthly or every two months did not increase seed germination rate compared to the control treatment (not changing the dehydrating material).

A comparison between the two best lines, AGS 190 and AGS 375, with AGS 292 on different dehydrating materials indicated the former two lines may not need any dehydrating material for at least eight months of storage, as their germination rates remained high for this period of time (Table 134). Proper sealing of the storage container itself may be sufficient to store seeds of these two lines. Further studies will be conducted on AGS 190 and AGS 375 to determine whether they can be stored for a much longer period of time.

Table 132. *Monthly change in germination percentage of vegetable soybean lines.*[1]

Line	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
AGS 375	91.7	93.8	86.3	82.3	81.7	86.0	80.2	86.3
AGS 190	92.5	91.7	86.2	86.2	83.7	86.9	75.8	81.2
AGS 370	80.0	81.0	59.6	46.2	48.5	55.6	36.9	39.4
AGS 373	83.3	69.6	60.0	51.0	44.2	53.7	39.0	38.3
AGS 328	75.0	66.0	41.3	26.3	22.9	29.4	11.5	16.3
KPS 292	83.3	55.0	31.7	25.8	17.3	27.1	14.6	13.8
AGS 372	78.3	59.0	46.0	45.8	41.7	40.6	27.9	-[2]

[1]Conducted at AVRDC-ARC, Kasetsart University, January–August 2003.
[2]Not enough seeds were available to test.

Table 133. *Monthly change in germination percentage of vegetable soybean by type of dehydrating material.*[1]

Dehydrating Material	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Lime	84.1	74.5	63.6	58.3	55.7	59.6	48.4	61.6
Ash	83.4	71.0	52.1	45.8	39.3	47.4	34.4	35.5
Control	80.0	86.1	69.6	50.0	61.8	65.0	37.1	43.2

[1]Conducted at AVRDC-ARC, Kasetsart University, January–August 2003.

Table 134. *Monthly change in germination percentage of selected vegetable soybean lines by type of dehydrating material.*[1]

Line and dehydrating material	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
AGS 190 in lime	92.5	90.4	83.8	81.3	82.5	84.6	87.5	81.7
AGS 190 in ash	92.5	93.3	88.3	90.0	85.0	89.2	67.5	80.0
AGS 190 alone	92.5	90.0	87.5	92.5	82.5	87.5	55.0	85.0
AGS 375 in lime	91.7	95.0	80.8	75.0	77.5	84.6	84.2	87.1
AGS 375 in ssh	91.7	93.3	90.4	88.3	86.7	88.8	77.1	83.8
AGS 375 alone	91.7	90.0	95.0	90.0	77.5	77.5	75.0	97.5
KPS 292 in lime	83.3	57.5	36.3	19.6	21.7	35.4	21.3	23.3
KPS 292 in ash	83.3	55.0	26.7	32.9	12.9	21.7	9.6	5.4
KPS 292 alone	83.3	40.0	35.0	20.0	17.5	10.0	5.0	7.5

[1]Conducted at AVRDC-ARC, Kasetsart University, January–August 2003.

Evaluation trial of AVRDC vegetable soybeans in Myanmar

In an attempt to introduce vegetable soybeans in Myanmar, 10 AVRDC vegetable soybean lines were evaluated in Yangon from November 2001 to March 2002 for yield and desirable pod characteristics. Plants were fertilized with a basal application of 25.5N–25.6P–49.4K kg/ha followed by sidedressings of 4.5N–0P–4.5K and 2.0N–0P–0K at 35 and 45 DAS. Staggered harvesting was done upon reaching the desired pod maturity.

The results showed that the average yield was lower than expected with a mean yield of only 2.72 t/ha (Table 135). AGS 381 and AGS 360 produced the highest yields and heaviest pods, but matured 9 days later than check variety AGS 292. This was the first attempt to evaluate vegetable soybean in Myanmar and efforts in the future will be made to generate higher yields.

Table 135. *Yield and related components of AVRDC soybean lines evaluated in Yangon, Myanmar.*[1]

Line	Total pod yield (t/ha)	Pod no./ 550 g	Pod no./ plant	Days to maturity
AGS 292	2.19 bc	251 b	11.9	75
AGS 335	1.63 c	370 a	14.2	85
AGS 346	2.65 bc	288 ab	19.9	92
AGS 360	3.31 ab	207 b	13.6	84
AGS 364	2.16 bc	281 ab	12.8	86
AGS 377	2.76 bc	223 b	11.7	84
AGS 378	2.35 bc	229 b	14.7	85
AGS 379	2.76 bc	259 b	9.5	84
AGS 380	2.94 bc	280 ab	13.9	75
AGS 381	4.42 a	222 b	12.7	84
Mean	2.72	259	13.5	-
F-test	**	*		
CV (%)	30.4	23.9		

[1]Trial conducted from November 2001 to March 2002.
*, ** Significant at $P \leq 0.05$ or 0.01, respectively.

Training

Regional training course

Fifteen participants supported by the Swiss Agency for Development and Cooperation (SDC) attended the 21st Regional Training Course in Vegetable Production, Research and Extension, held from 4 November 2002 to 4 April 2003. Four students were from Cambodia, three from China, three from Lao PDR, and five from Vietnam. Three slots were alloted for participants from Myanmar, but these persons cancelled at the last moment.

Certificates of recognition for exemplary academic performance were awarded to three training scholars during the course: Mr. Li Bin from China, Mr. Le Nhu Cuong from Vietnam, and Ms. Wang Rongqing from China. Awards were also given to two persons for outstanding presentations of research: Ms. Srun Khema of Cambodia for her paper on "Off-season production technology for tomato and eggplant through grafting" and Mr. Le Nhu Cuong for his paper on "Evaluation of powdery mildew resistance in mungbean populations."

The 22nd Regional Training Course started on 3 November 2003 with sixteen participants: two from Cambodia, two from Lao PDR, three from Myanmar, two from North Korea, and six from Vietnam. All trainees are supported by SDC. This is the first time AVRDC-ARC is training participants from North Korea.

Short-term training courses

In 2003, two short training courses were offered by AVRDC-ARC:

Seed Production Training Course. This six-week course, conducted from 6 January to 16 February provided information on varietal improvement and maintenance, hybrid seed production, seed drying and storage, seed moisture testing, germination testing, seed processing, seed sanitation, managing diseases and insect pests, and seedling evaluation. A total of 16 participants from Cambodia, India, Lao PDR, and Vietnam attended.

ISTA-Seed Testing Training Course. The course was conducted from 13 to 22 October 2003 in collaboration with the Asia & Pacific Seed Association (APSA) and the International Seed Testing Association (ISTA). The course was intended for seed specialists from APSA-member seed companies. A total of 17 staff from seed companies in China, India, Indonesia, Japan, Taiwan, Thailand, and Vietnam participated in the course. The lecturers included Dr. Michael Hill and Mrs. Karen Hill of the New Zealand Seed Technology Institute as well as scientists in seed testing at Kasetsart University, Thailand. The post-course evaluation by the participants showed they were impressed with the course content and the quality of lectures and practicals. All agreed that the information and techniques they learned from the course will be very helpful in their job.

In-country training courses

Eighteen in-country training courses and workshops were conducted by national partners in Cambodia, Lao PDR, Myanmar, and Vietnam (Table 136). Whenever possible, resource persons from AVRDC headquarters, AVRDC-ARC and other institutions were provided to assist in the training courses. The 689 participants included research and extension workers as well as lead farmers in the target areas of the CLVNET and HRD projects.

Germplasm collection, multiplication and exchange

Table 137 summarizes the distribution of vegetable seed packets through AVRDC-ARC.

Information and scientific exchange

The 18th AVRDC-ARC Training Report was published. The lay-outs of the 19th and 20th AVRDC-ARC Training Reports have been completed with publication slated for 2004.

A number of handouts were translated into local languages and printed for distribution to extension specialists and farmers. In Vietnam, publications were developed on nethouse construction, trellising techniques for vine crops, strategies for grafting tomato, cultivation techniques for numerous vegetables (lettuce, mustard, spring onion, cucumber, watermelon, hot pepper and onion), and management of major insect and diseases on vegetables. In Cambodia, publications were developed on home composting and on producing safe leafy vegetables inside nethouses and net tunnels.

Table 136. *Details of in-country training courses in the CLV countries for 2003.*

Course title	Location	Date	Participants
1. Vegetable seed production	Kandal, Cambodia	24–26 Nov.	30
2. Vegetable home gardening and composting	Kandal, Cambodia	13–15 Oct.	35
3. Seed production technology	Kandal, Cambodia	17–19 Nov.	30
4. Vegetable home gardening	Kandal, Cambodia	29–31 Dec.	30
5. General vegetable production	Sihanoukville, Cambodia	11–13 Nov.	30
6. Vegetable home gardening	Kandal, Cambodia	25–27 Dec.	30
7. Evaluation of beneficial insects	Vientiane Province, Lao PDR	3–5 June	8
8. Off-season vegetable production technology	Yangon, Myanmar	2–5 Sep.	25
9. Vegetable soybean and mungbean production	Yangon, Myanmar	2–5 Dec.	48
10. Vegetable seed production technology	Quang Binh, Vietnam	22–24 Nov.	35
11. Grafting tomatoes to control bacterial wilt	Ho Chi Minh, Vietnam	20–21 Oct.	53
12. Construction and development of nethouses for vegetables	Ho Chi Minh, Vietnam	15–16 and 22–23 Feb.	52
13. Nethouse construction and vegetable growing techniques	Quang Nam, Vietnam	28-29 Aug.	33
14. Off-season vegetable production	Hue, Vietnam	24-25 Dec.	40
15. Vegetable production technologies for lead farmers	Hoa Binh, Vietnam	5-7 Sep.	35
16. Vegetable production technologies for lead farmers	Pu Tho, Vietnam	19-21 Sep.	35
17. Improvement of extension skills of local staff	Nghe An, Vietnam	12-14 Oct.	35
18. Improvement of extension skills of local staff	Quang Binh, Vietnam	15-17 Oct.	35
Total			689

Table 137. *Distribution of vegetable seed germplasm sent to Asian countries in 2003.*

Crop	Cambodia	China	Lao PDR	Myanmar	Thailand	Vietnam	Total
Allium	-	-	15	-	-	-	15
Brassicas	-	6	8	-	-	-	14
Eggplant	-	-	4	-	-	-	4
Mungbean	-	-	6	5	616	16	643
Peppers	16	54	32	-	135	54	291
Soybean	-	1	25	38	95	115	274
Tomato	41	52	67	-	321	75	556
Others	39	-	-	-	5	8	52
Total	96	128	142	43	1172	268	1849

Web site development

Numerous additions were made to the AVRDC-ARC web site (www.arc-avrdc.org) in 2003. These included training reports of alumni who finished the five-month regional training course, highlights of in-country training activities in the CLV region, a description of selected varieties released by the Tropical Vegetable Research Center of Kasetsart University, and a database of garlic accessions collected by a collaborator in China.

For more information, contact: Masaaki Suzuki

Regional Center for Africa

Research and development at AVRDC-Regional Center for Africa focuses on AVRDC priority vegetables and African indigenous vegetables. During the year 2003, the following projects were implemented:

- Promote production and consumption of tomatoes and indigenous vegetables by introducing and developing technologies for better micronutrient uptake, health and income in southern African countries through the CONVERDS network.
- Promote multidisciplinary approaches to prevent vitamin A and other micronutrient malnutrition in southern Africa.
- Enhance production and utilization of African indigenous vegetables through sustainable seed production and distribution for better health, nutrition and small agribusiness in countries with membership in the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA).
- Collect, evaluate and improve germplasm of African leafy vegetables.
- Provide technical support to the International Plant Genetic Resources Institute (IPGRI) on conservation, capacity building, and regional characterization of African leafy vegetables.

A new project funded by BMZ/GTZ was initiated in March 2003 on the promotion of neglected indigenous leafy and legume vegetable crops for improved nutritional health in Eastern and Southern Africa.

AVRDC-RCA is committed to breaking the cycle of poverty in Africa by developing new disease-resistant lines of tomatoes; producing base seed stock of nutritious African indigenous vegetables; improving production technologies; and training researchers, non-governmental organization (NGO) personnel as well as farmers. In this regard, more than 700 kg of African indigenous vegetable crop seed have been produced and distributed to the national agricultural research and extension systems (NARES), NGOs and over 2000 farmers in various countries in Africa.

Research

F_8 and F_{10} late blight-resistant tomato lines

Late blight, caused by *Phytophthora infestans*, is increasingly becoming an important fungal disease of tomato (*Lycopersicon esculentum*) in the African highlands during the cool-wet season. In some cases, farmers lose the entire tomato crop when they do not spray in time. The objective of this trial was to evaluate F_{10} and F_8 late blight-resistant tomato lines for horticultural traits and compare the results to findings in previous studies.

Ten F_{10} and fourteen F_8 late blight-resistant tomato lines were tested along with three local checks: Tengeru 97, Marglobe and Money Maker. The experiment was laid out in randomized complete block design (RCBD) with three replications. Seedlings were transplanted on 4 July 2002. Each treatment was planted on raised beds in two rows at spacings of 0.6 m between plants and 0.75 m between rows. At transplanting, 20–4.3P–8.3K kg was incorporated in the planting holes. Sidedressings of 23N–0P–0K were applied three weeks later and then again three weeks after that. Furrow irrigation was carried out once or twice weekly, as needed, after transplanting until harvest. The field was weeded as needed. To control red spider mites, thrips, powdery mildew and tomato yellow leaf curl virus (TYLCV), the crop was sprayed a total of four times beginning two weeks after transplanting with a mixture of Ridomil and Actellic; the crop was also sprayed one month after transplanting with Selecron, and was sprayed later with Bayleton and Selecron in three-day intervals.

Results are presented in Tables 138 and 139. For the F_{10} lines, moderate yields in total fruit yield were obtained while marketable fruit yield did not significantly differ among the tested lines (Table 138). The top two lines were 19-1-10 and 81-8-10 with 45.9 and 45.1 t/ha of marketable fruit yield respectively. The lowest yield was obtained with line 81-1-10 with 27.7 t/ha. Line 19-1-10 had rather big fruit compared to line 81-8-10 (Table 138). None of the test lines had larger fruits than Marglobe (117.8 g); the smallest fruits were recorded with Money Maker (67.1 g).

Table 138. *Horticultural and yield traits of F_{10} late blight-resistant tomato lines.*[1]

Lines	Days to 50% flowering	Growth habit[2]	Plant height (cm)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Marketable yield (t/ha)	Total yield (t/ha)	TYLCV-incidence[2] (% plants)
19-1-10	22.0 cd[3]	ID	127.6 c	5.2 ab	7.0 a	114.8 a	45.9 a	51.4 abc	25.1 efg
80-1-10	20.6 d	ID	116.3 de	4.9 abc	5.7 de	71.8 bc	27.7 c	29.9 f	56.2 c
50-2-10	20.6 d	ID	123.0 cd	4.9 abc	6.8 ab	111.9 a	37.0 abc	50.1 abc	48.4 cd
80-3-10	20.6 d	ID	79.0 f	4.8 abc	6.2 b-e	107.1 a	40.0 abc	40.2 de	41.6 c-f
80-5-10	20.6 d	ID	123.3 cd	4.7 abc	6.4 abc	84.7 bc	42.9 ab	48.9 b-e	23.2 efg
81-1-10	22.0 cd	ID	111.6 e	4.9 abc	6.3 a-e	87.0 bc	38.5 abc	39.7 e	33.3d-g
81-3-10	22.0 cd	ID	111.3 e	4.9 abc	6.2 b-e	88.5 b	39.2 abc	49.7 b-e	24.4 efg
81-6-10	20.6 d	ID	126.0 c	4.6 bc	6.0 cde	73.4 bc	39.2 abc	59.2 a	43.5 cde
81-7-10	31.0 a	SD	160.6 a	4.8 abc	6.3 a-e	73.1 bc	34.8 abc	49.5 a-d	20.2 fg
81-8-10	24.0 bc	ID	135.0 b	4.5 bc	6.4 a-d	83.2 bc	45.1 a	55.2 ab	12.9 g
Tengeru 97 (ck)	24.6 b	ID	129.3 bc	4.2 c	5.9 cde	87.4 b	28.8 bc	43.9 cde	97.6 a
Marglobe (ck)	22.0 cd	ID	122.0 cd	5.4 a	6.8 ab	117.8 a	40.0 abc	51.3 abc	76.6 b
Money Maker (ck)	20.6 d	ID	58.3 g	4.3 c	5.6 e	67.1 c	40.7 abc	48 b-e	31.6 d-g
LSD (5%)	2.1		6.8	0.6	0.6	17.6	12.2	8.5	19.2
F-test	***		***	*	**	***	*	***	***
CV (%)	5.48		37	16.8	15.6	11.7	18.8	10.7	27.8

[1]Transplanted 4 July 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]ID = indeterminate, SD = semi-determinate, TYLCV = tomato leaf curl virus.
[3]Mean separation in columns by Duncan's range test at $P \leq 0.05$.
*, **, *** Significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 139. *Horticultural and yield traits of F_8 late blight-resistant tomato lines.*[1]

Lines	Days to 50% flowering	Growth habit[2]	Plant height (cm)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Marketable yield (t/ha)	Total yield (t/ha)	TYLCV-incidence[2] (% plants)
19-1-8	22.6 bcd[3]	ID	128.0 a	5.1 a-d	7.7 a	113.2 a	51.8 abc	66.4 a	11.8 a-d
27-1-8	24.0 bcd	ID	125.3 a	4.5 cde	5.8 ef	72.1 d	35.9 cd	45.7 de	4.8 d
21-2-8	32.0 a	ID	111.6 c	5.5 a	6.2 c-f	79.3 cd	33.8 d	41.3 e	3.4 d
38-2-8	24.0 bcd	ID	114.6 bc	4.6 b-e	5.8 ef	69.9 d	33.3 d	39.9 e	12.5 a-d
39-1-8	24.0 bcd	ID	94.0 d	4.3 de	5.9 def	71.3 d	41.0 cd	47.8 cde	11.1 a-d
41-1-8	22.6 bcd	ID	115.6 bc	5.2 abc	6.2 c-f	76.2 cd	44.9 bcd	55.0 a-e	18.0 ab
42-1-8	22.0 cd	ID	115.3 bc	4.9 a-e	6.3 c-f	78.5 cd	39.8 cd	46.7 cde	14.5 abc
44-1-8	24.0 bcd	SD	112.6 bc	5.6 a	6.1 c-f	81.7 cd	34.4 d	43.2 de	5.5 cd
44-2-8	23.3 bcd	D	117.3 bc	4.9 a-e	5.8 f	72.9 d	41.2 cd	49.6 b-e	20.1 a
50-2-8	22.0 cd	ID	120.3 ab	4.8 a-e	7.5 ab	88.6 bc	50.9 abc	58.2 a-e	11.8 a-d
80-1-8	23.3 bcd	ID	120.0 ab	5.0 a-e	6.9 a-e	94.5 b	50.3 abc	63.3 abc	15.9 ab
80-3-8	23.6 bcd	SD	74.0 e	5.4 ab	7.0 a-d	89.3 bc	40.4 cd	49.0 b-e	11.8 a-d
94-3-8	23.6 bcd	ID	75.3 e	4.2 e	6.0 c-f	73.4 d	57.4 ab	64.6 ab	9.7 bcd
110-3-8	24.3 bc	D	91.0 d	5.1 a-d	6.1 c-f	69.2 d	41.4 cd	50.6 b-e	3.5 d
Tengeru 97 (ck)	25.0 b	ID	128.0 a	5.0 a-e	7.1 abc	81.2 cd	40.2 cd	49.6 b-e	19.4 a
Marglobe (ck)	22.0 cd	ID	126.0 a	4.8 a-e	6.6 b-f	114.2 a	46.4 a-d	54.1 a-e	20.1 a
Money Maker (ck)	21.6 d	ID	57.3 f	4.8 a-e	6.2 c-f	70.7 d	61.1 a	66.8 a	4.8 d
LSD (5%)	2.1		7.2	0.6	0.9	11.7	13.5	13.5	7.8
F-test	***		***	**	**	***	**	**	***
CV (%)	5.4		4.04	8.3	8.9	8.6	18.5	15.4	40.3

[1]Transplanted 4 July 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]ID = indeterminate, SD = semi-determinate, TYLCV = tomato leaf curl virus.
[3]Mean separation in columns by Duncan's range test at $P \leq 0.05$.
, * Significant at $P \leq 0.01$ or 0.001, respectively.

Significant differences in days to 50% flowering were observed among the F_{10} lines (Table 138). Lines 81-1-10, 50-2-10, 80-3-10, 80-5-10, 81-6-10 and Money Maker flowered earlier at 20.6 days after transplanting while line 81-7-10 flowered last at 31 days.

The main diseases observed were TYLCV and powdery mildew. Nearly all Tengeru 97 plants were infected with TYLCV, while line 81-8-10 was the least affected (12.9% infected plants)(Table 138).

Among F_8 lines, there were highly significant differences in total and marketable yield among the check and the tested lines (Table 139). Money Maker had the highest marketable fruit yield (61.1 t/ha) followed by line 19-1-8 with (51.8 t/ha), while Tengeru 97 and Marglobe yielded 40.2 and 46.4 t/ha, respectively.

Highly significant differences in days to 50% flowering were observed among the F_8 lines. Line 42-1-8, 50-2-8 and Marglobe flowered 22 days after transplanting while line 29-2-8 flowered last. Line 19-1-8 had similar fruits size as Marglobe, 113.2 and 114.2 g, respectively, while the smallest fruits were recorded in line 110-3-8 (69.2 g) (Table 139).

Plant height differed significantly among the lines and the check varieties. The tallest were lines 19-1-8 and Tengeru 97, both 128 cm tall, and the shortest was Money Maker at 57.3 cm. Most lines and check varieties were affected by TYLCV. High TYLCV incidences (Table 139) were observed on line 44-2-8 (20.1% plants infected), Marglobe (20.14%) and Tengeru 97 (19.4%) while line 110-3-8 was only slightly affected (3.45%).

Yield and horticultural characteristics of onion lines

Onion is one of the most important and widely grown vegetables in the tropics, but yields in Africa are relatively low. There is an urgent need to select varieties well adapted to the different ecological conditions of the continent. This trial was conducted to evaluate 15 onion lines for yield adaptation at AVRDC-RCA in Arusha, Tanzania from July to December 2002.

The experiment was laid out in a RCBD with three replications. Seeds were sown on a nursery bed and transplanted on beds measuring 3 × 1 m. Spacing was 15 cm between rows and 10 cm between seedlings. A total of 81.6N–8.6P–16.6K kg/ha was applied in two split applications. The beds were irrigated twice a week during the initial stage of growth and once a week thereafter. Other cultural practices included weeding and spraying of insecticides, which were carried out as needed.

Results showed that CAL 606 was the fastest to mature while TA 364 A-A-N was the slowest (Table 140). Yield of the lines ranged from 32.2 t/ha (line TA 364 A-A-N) to 148.9 t/ha (line TA 368 A-A-N) and generally lines with yellow bulbs had higher yields than those with red bulbs (Table 140). High yield was also associated with larger bulb weight. Plant height at maturity ranged from 42 to 54.9 cm. Bulb doubling was negligible. All lines were susceptible to thrips.

Lines TA 368 A-A-N, CAL 606, AC 572 (A)-C, OC 175 (R) C-B and AC 691 (C) showed yields of more than 80.0 t/ha. The bulbs of these lines were all large, especially those of AC 572(A)-C, which weighed 413.3 g on average. These lines may be suitable for promotion provided that further testing confirms results obtained in this study.

Yield and horticultural characteristics of garlic lines

Garlic (*Allium sativum*) is grown by smallholders in Africa for income and personal consumption. Used as a flavorful addition to meals, garlic is a source of many vitamins and is reported to have medicinal properties. Continuous characterization and evaluation of varieties is necessary to select superior garlic lines adapted to different soil and climatic conditions. Most garlic lines grown today in Africa are unproductive, mature lately, and tend to split. There is a pressing need to develop early maturing and productive lines with resistance to pests and diseases. AVRDC routinely eliminates viruses through meristem tip culture and for the last four years, initial virus-free lines have been grown in the open field in Arusha, Tanzania to compare yield characteristics with a check entry (Kenya 2).

This experiment was conducted from July to November 2003 and was laid out in a RCBD with three replications. Plot sizes measured 1 × 5 m, each consisting of five rows spaced 15 cm apart with 10 cm between plants. A total of 50.7N–6.5P–12.5K kg/ha was applied 27 days after sowing. Another application at the rate of 20.7N–0P–0K was applied two weeks later. Thrips were controlled by spraying Diazinon, Decis, and Selecon every week. All beds were regularly weeded and furrow irrigation was carried out weekly, or as needed.

Results showed that line G98-6-1-1, had the highest bulb yield with 11.76 t/ha (Table 141). Line VFG

Table 140. *Yield and horticultural characteristics of onion lines.*[1]

Entry	Days to maturity	Bulb yield (t/ha)	Bulb weight (g)	Bulb color	Bulb shape	Bulb diam (length) (cm)	Bulb diam (equatorial) (cm)	Neck thickness (cm)	Plant height (cm)
Red Creole	92	53.3 de[2]	80.0 c	Red	Globe	7.46 ab	7.44 ab	5.76 a	54.9 a
OC 51-H-B	91	75.6 cd	113.3 bc	Yellow	High globe	6.83 abc	4.24 c	1.21 c	48.7 abc
AC 853 (H) N	92	48.9 de	73.3 c	Yellow	Spindle	1.68 d	6.98 ab	5.93 a	51.5 ab
TA 368 A-A-N	79	148.9 a	223.3 b	Yellow	High globe	6.73 bc	5.37 bc	1.06 c	51.6 ab
AC 319-C	92	55.5 de	83.3 c	Red	Globe	1.57 d	7.23 ab	5.22 a	52.2 ab
Texas Grano	78	75.6 cd	113.3 bc	Yellow	Globe	6.50 bc	6.13 bc	1.68 bc	52.4 ab
OC 175 (R) C-B	72	86.7 cd	130 bc	Yellow	High globe	6.50 bc	6.13 bc	2.23 bc	42.6 bc
OC 3-44 C-N	90	57.8 de	86.7 c	Yellow	Thick flat	1.37 d	1.37 d	1.20 c	47.9 abc
AC 731 (A) –C	69	48.9 de	73.3 c	Yellow	High globe	5.90 c	5.33 bc	1.69 bc	42.3 bc
CAL 606	62	135.0 ab	130.0 bc	Yellow	Globe	7.32 ab	8.76 a	2.93 b	47.9 abc
TA 377 (C)	74	46.7 de	70.0 c	Yellow	Globe	6.73 bc	5.13 bc	1.93 bc	38.3 c
AC 572 (A)-C	68	108.9 bc	413.3 a	Yellow	Thick flat	7.96 a	7.36 ab	2.33 bc	47.4 abc
TA 475 (A) A-N	79	57.8 de	86.7 c	White	High globe	5.69 c	5.43 bc	1.33 bc	46.7 abc
AC 691 (C)	79	86.7 cd	130.0 bc	Yellow	High globe	6.53 bcd	6.10 bc	1.31 bc	47.4 abc
TA 364 A-A-N	96	32.3 e	170.7 bc	Red	Flat globe	1.64 d	4.52 c	5.15 a	51.5 abc
LSD (5%)		34.9	99.5			1.06	2.09	1.41	9.3
F-test		***	***			***	***	***	***
CV (%)		28	25.1			11.9			11.6

[1]Trial was conducted from July to December 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
*** Significant at $P \leq 0.001$.

Table 141. *Yield and horticultural characteristics of garlic accessions grown in the open field.*[1]

Lines	Cloves/ bulb (no.)	Biomass (t/ha)	Bulb yield (t/ha)	Bulb weight (g)	Bulb color	Bulb shape	Bulb diam (length) (cm)	Bulb diam (equatorial) (cm)	Neck thickness (cm)
G98-6-1-1	13 b[2]	22.90 a	11.76 a	21.17 a	Mixed	Globe	3.95 a	4.10 a	1.46a
VFD180	15 b	19.80 a-d	10.80 ab	19.43 ab	Mixed	Globe	3.53 ab	3.82 ab	1.25 abc
VFG176	28 a	22.11 ab	10.55 ab	18.99 ab	Mixed	Globe	3.70 ab	3.81 ab	1.06 c
VFTA325	14 b	20.21 a-d	10.08 ab	18.15 ab	Mixed	Mixed	3.87 a	3.73 ab	1.19 abc
VFG34	13 b	18.34 b-e	9.40 ab	16.92 ab	Mixed	Flat globe	3.54 ab	3.71 ab	1.3 abc
G98-9	17 b	19.04 a-e	9.30 ab	16.74 ab	Mixed	Flat globe	3.80 a	3.73 ab	1.19 abc
G50-1-2-2	21 ab	16.58 de	8.88 b	15.98 b	Mixed	Flat globe	3.92 a	3.79 ab	1.39 ab
VFTA275	12 b	17.82 cde	8.87 b	15.97 b	Mixed	Flat globe	3.73 ab	3.61 b	1.12 bc
Kenya 2 (ck)	17 b	21.01 abc	8.81 b	15.85 b	Mixed	Mixture	3.13 b	3.70 ab	1.12 bc
VFTA158	14 b	15.57 e	8.35 b	15.03 bc	Mixed	Flat globe	3.47 ab	3.69 ab	1.05c
VFG173	22 ab	10.02 f	5.96 c	11.03 bc	Mixed	Globe	3.14 b	3.46 b	0.76 d
Mean	17	18.49	9.34	16.84			3.60	3.74	1.17
LSD (5%)	9.5	3.68	2.31	6.62			0.54	3.74	0.25
F-test	*	**	**	**			*	NS	**
CV (%)	32.9	11.69	14.54	14.5			8.75	5.6	12.7

[1]Trial was conducted from July to November 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

176 gave the highest number of cloves per bulb. Bulb shape varied among the lines, but line G98-6-1 produced the longest and widest bulbs, with the thickest necks (Table 141).

These results showed slight variations with results from previous experiments (*AVRDC Reports 2001, 2002*) conducted at RCA and indicate the influence of environmental differences on yield results in garlic.

Effects of intercropping spiderflower plant and Ethiopian mustard on pest and disease occurrence

Ethiopian mustard (*Brassica carinata*), also called Ethiopian kale, is a traditional leafy crucifer widely grown throughout Africa. Spiderflower plant (*Cleome gynandra*) is an erect annual herb with a wide range of habitats in both cultivated and waste lands. Along with *B. carinata*, it is commonly used as an "African spinach". Both vegetables are rich sources of vitamins A and C, calcium, and iron. Spiderflower plant has been reported as having the potential to be a companion crop in reducing the infestation of diamondback moth (*Plutella xylostella*) on cruciferous vegetables. This trial was therefore carried out at RCA from July to November 2002 to test this hypothesis.

Seeds of a local variety of spiderflower plant and two varieties of Ethiopian mustard, Mbeya Green and Mbeya Purple, were sown on ridges spaced 60 cm apart with 7 ridges per plot. Spiderflower plant seeds were directly sown and later thinned to 25 cm apart. Ethiopian mustard was also directly sown and later thinned to 40 cm between plants. For every two rows of Ethiopian mustard, there was one row of spiderflower plant. The plots were irrigated, fertilized and weeded, as needed. The experiments were laid out in a RCBD with three replications. Data were collected on several parameters including pest incidence, number of diamondback moth (DBM) larvae, severity of aphid attack, and incidence of turnip mosaic virus.

Results showed a higher mortality rate of the intercropped Ethiopian mustard plants over the two control treatments (Table 142). This could be attributed to the high infestation of spiderflower plants by aphids, which subsequently infested the nearby Ethiopian mustard plants. There was a constant uniform incidence of aphids in all four treatments. Results obtained also show that Mbeya Green was more susceptible to DBM than Mbeya Purple. The lower count of DBM larvae on the intercropped Ethiopian mustard was due to low surviving number of plants and not to any effect of the companion plant. There was no significant difference between the treatments for the number of DBM larvae.

It is recommended that further studies be carried out on other potential companion crops that might control aphids and DBM on Ethiopian mustard.

Table 142. *Effect of intercropping spiderflower on pest/disease incidence on Mbeya Green and Mbeya Purple varieties of Ethiopian mustard at AVRDC-RCA.*[1]

Treatment	Mortality rate (%)	Aphid incidence (% plants)	DBM larvae/ plant	TuMV severity[2]
Control (M. Green)	68.7 b[3]	100	6.7 a	4.0 b
Control (M. Purple)	83.0 ab	100	2.0 b	5.0 a
Intercropped (M. Green)	99.6 a	100	1.7 b	4.7 a
Intercropped (M. Purple)	100.0 a	100	0.0 b	5.0 a
LSD (5%)	21.4	0	2.6	0.6
F-test	*	NS	**	*
CV (%)	12.2	0	50.4	6.2

[1]Conducted July to November 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Turnip mosaic virus scored on 1 to 5 scale with 1 = no damage and 5 = severe damage.
[3]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
NS, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively.

Effects of harvesting time on leaf yield of Ethiopian mustard

Ethiopian mustard (*Brassica carinata*) belongs to the Cruciferae family and is a traditional leafy vegetable widely adapted to several African ecosystems. It is common in most parts of eastern and southern Africa and is believed to have originated from the Ethiopian highlands, hence its name. Ethiopian mustard is not commercially cultivated on a large scale but is mainly grown at the home garden level. Ethiopian mustard grows best during the cool period (10 to 15°C) of the year and at an altitude of 1200 to 1800 m. The leaf yield of Ethiopian mustard is low in tropical Africa due to poor production and post-harvest handling practices. The objective of the present study was to determine the appropriate time to start harvesting Ethiopian mustard leaves to obtain optimum yield.

The experiments were carried out at AVRDC-RCA from September to December 2002 and July to October 2003. Two Ethiopian mustard lines (Mbeya Green and Mbeya Purple) were tested; Mbeya Green was tested in 2002 and both lines were tested in 2003. Direct sowing was done on 25 September 2002 and 15 July 2003 in plots of size 60 × 40 cm. The experiments were laid out in RCBD with three replications. Four weeks later, plots were thinned to one plant per hill. A total of 46N–0P–0K kg/ha (5.2 g/plant) was applied in two splits starting 2 weeks after transplanting (WAT). Spraying against aphids and diamondback moth was

carried out once a week starting from 15 days after transplanting using Selecron and Polytrin. Harvesting of leaves was started 5 WAT as per treatment combination. Follow-up harvesting of treatments was carried out as needed after each harvest.

Results showed that Mbeya Green produced significantly larger leaves and higher yields than Mbeya Purple (Table 143). Both lines had the same number of leaves per plant (Table 143). Yields in terms of fresh and dry weight and number of leaves/plant all peaked when harvesting started 8 WAT, decreasing thereafter. The average leaf length and width reduced with delayed harvesting (Tables 143 and 144). At the later harvest periods, many leaves appeared to have started senescing. In summary, Mbeya Green was more promising than Mbeya Purple in terms of leaf yield characteristics and harvesting should begin 8 WAT in order to maximize yields.

Table 143. *The effects of harvesting time on leaf yield of* Brassica carinata *var.* Mbeya Green.[1]

Harvesting time (weeks after transplanting)	Leaf yield (g/plant)	Leaf yield (t/ha)
6	85.47[2]	3.56
7	143.03	5.96
8	131.67	5.48
8.4	109.00	4.54
LSD (5%)	68.08	2.84
F-test	NS	NS
CV (%)	29.05	29.08

[1]Conducted September to December 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
[NS]Nonsignificant at $P \leq 0.05$.

Table 144. *The effects of harvesting time on leaf yield of* Brassica carinata *lines.*[1]

Line	Fresh leaf yield (g/plant)	Fresh leaf yield (t/ha)	Dry leaf yield (g/plant)	Dry leaf yield (t/ha)	Leaves/plant (no.)	Avg leaf length (cm)	Avg leaf width (cm)
Lines							
Mbeya Green	287.4 a[2]	11.97 a	33.94 a	1.41 a	44.14	15.05 a	11.59 a
Mbeya Purple	196.4 b	8.18 b	22.45 b	0.94 b	43.37	12.72 b	10.13 b
LSD (5%)	29.7	1.23	2.99	0.12	5.21	0.42	0.43
Harvesting time (weeks after transplanting)							
5	241.4 b[2]	10.06 b	26.08 cd	1.09 cd	42.69 bc	14.64ab	11.31 bc
6	247.8 b	10.32 b	28.17 bcd	1.17 bcd	43.19bc	15.01 a	12.61 a
7	300.1 ab	12.50 ab	33.04ab	1.38 ab	46.64 b	14.76ab	11.62 ab
8	331.2 a	13.80 a	36.63 a	1.53 a	63.66 a	13.45cd	10.46 cde
9	255.9 b	10.66 b	30.76 bc	1.28 abc	37.00 bc	14.02c	10.77 cd
10	184.3 c	7.68 c	24.58 d	1.03 d	39.01 bc	12.44e	9.77 e
11	132.3 c	5.51 c	18.10 e	0.75 e	34.09 c	12.88e	9.95 de
LSD (5%)	55.6	2.32	5.59	0.23	9.75	0.79	0.81
F-Test	***	***	***	***	***	***	***
CV (%)	19.37	19.37	16.71	16.74	18.78	4.79	6.25

[1]Conducted from July to October 2003 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's range test at $P \leq 0.05$.
[***] Significant at $P \leq 0.001$.

Studies on African eggplant

African eggplant (*Solanum aethiopicum, S. macrocarpon,* and *S. anguivi*) is the most popular traditional vegetable in West and Central Africa. It is less important in East Africa, even though it is commonly found in the markets of Uganda and Tanzania. African eggplant can be cooked and served as a side dish for starchy foods and is a rich source of vitamins, minerals, carbohydrates and crude fiber. The productivity of this crop is still relatively low and there is a need to improve productivity in order to satisfy consumer demand. Several studies were carried out at AVRDC-RCA to determine the phenotypic variation, yield and horticultural characteristics of select African eggplant lines.

Plant population

The optimal plant population for a crop contributes to high yields, excellent vegetable quality, and maximum profits for farmers. Generally, yield increases with an increase in plant population, but this is only up to an optimal limit. Beyond this optimum, yield will not increase but rather decrease. The recommended spacing for eggplant depends on the variety. A spacing of 90 × 90 cm can be used for vigorous growing, strongly branched varieties and 90 × 60 cm or 75 × 60 cm for less vigorous ones. Most farmers use a spacing of 60 × 60 cm but this may enhance the development of fungal leaf diseases such as angular leaf spot (*Cercospora melongenae)*; which in turn, reduces the quantity of marketable fruit. An experiment was thus carried out to determine the ideal spacing requirements of different lines for optimum yield responses.

This trial was conducted at AVRDC-RCA in Arusha, Tanzania from July 2002 to March 2003 to determine the appropriate spacing for optimum yield of four promising African eggplant lines. The experiment was laid out in a RCBD in three replications using four spacing level treatments. To reflect diversity, the lines used were Tengeru White (*S. aethiopicum*), Toumbot (*S. anguivi*), UVPP (*S. macrocarpon*), and AB2 (*S. aethiopicum*). The aim of the selection of these lines was to determine the yield response of different species to planting density to help develop production package information. Four spacings of 30, 50, 70 and 90 cm between plants were tested. Inter-row spacing was maintained at 60 cm. The seedlings were transplanted on 15 July 2002. Three weeks after transplanting (WAT), 103N–17.2P–33.2K kg/ha of fertilizer was applied. At 6 and 9 WAT, applications of 23N–0P–0K was applied. Weeding was done four times before the full canopy was formed. The first harvesting was done 18 WAT. The fruits were weighed and graded into marketable and non-marketable categories. Ten fruits per treatment were used for length and width measurements and seeds were extracted accordingly.

Results showed significant differences between the four lines for all parameters assessed (Table 145). Toumbot had the highest number of fruits per plant (996.4) with the lowest number of seeds per fruit (34), while UVPP had the lowest number of fruit per plant (13.8) but showed the highest number of seed per plant (10,624). AB2 had the highest total fruit yield (113.9 t/ha) and Toumbot the lowest (46.4 t/ha). Seed yield was highest for Toumbot (1894 kg/ha) and lowest for UVPP (1531 kg/ha), which also had the highest 100-seed weight (Table 145).

Number of fruit per plant, fruit yield per plant, 100-seed weight, seed yield per plant, and seed yield per fruit were not affected by the different spacings (Table 145). The spacing of 30 cm resulted in more total fruit and seed yield probably due to the fact that it allows more plants per ha. Both fruit and seed yield decreased with an increase in spacing. However, up to the 70-cm spacing, an increase in spacing significantly increased the number of seeds per plant (Table 145). A decrease is then observed (Table 145), which was reflected in seed yield per fruit.

Tengeru White and AB2 gave high fruit and seed yields. Fruits for these accessions are also relatively big and sweet. This shows that these varieties have great potential for promotion.

Characterization and purification

Systematic characterization of crop varieties/lines using morphological traits is needed to fuel breeders' efforts in this species. This study was therefore conducted with the following objectives: 1) to provide clean seed of desirable lines that is true to type; and 2) to provide information on phenotypic characters for future plant selection and breeding purposes.

The trial was carried out at AVRDC-RCA in Arusha, Tanzania during the cool season from July 2002 to March 2003 on 24 African eggplant lines belonging to the species *S. aethiopicum, S. anguivi* and *S. macrocarpon*. The seedlings were transplanted on single beds of at least 10 m in length in scattered stations with an isolation distance of at least 30 m between stations. The plants were transplanted on 23 and 25 July 2002 at a spacing of 50 cm from plant to plant.

Table 145. *Study on horticultural characteristics of four African eggplant varieties/lines as affected by spacing.*[1]

Treatment	Fruit no./ plant	Fruit yield/plant (kg)	Fruit yield (t/ha)	100-seed weight (g)	Seed yield (g/plant)	Seed yield (kg/ha)	Seed no./ plant	Seed yield (g/fruit)	Seed no./ fruit
Line									
Tengeru White	78.6b[2]	3.3 b	106.3 a	0.24 c	51.8 ab	1731	22 226 b	0.67 b	287 b
UVPP	13.8 b	1.4 c	46.6 b	0.37 a	44.9 b	1531	132 267 a	3.35 a	10 624 a
Toumbot	996.4 a	1.5 c	46.4 b	0.20 d	63.9 a	1894	32 033 b	0.07 b	34 b
AB2	113.9 b	3.8 a	115.1 a	0.27 b	47.0 b	1575	18 215 b	0.42 b	164 b
LSD (5%)	129.0	0.5	17.2	0.02	12.7	537	39 053	0.58	2 177
Spacing (cm)									
30 × 60	348.9	2.42	134.3 a	0.26	54.3	2832 a	23 178 b	1.11	332 b
50 × 60	318.0	2.51	75.5 b	0.26	53.7	1789 b	22 642 b	1.14	370 b
70 × 60	285.8	2.45	57.6 c	0.27	50.3	1197 c	93 934 a	1.22	6 154 a
90 × 60	250.1	2.54	47.1 c	0.26	49.4	914 c	64 989 a	1.04	4 253 a
F-test	NS	NS	***	NS	NS	***	**	NS	***
LSD (5%)	129.0	0.49	17.2	0.02	12.6	537	39 053	0.58	2 177
CV (%)	15.1	10.60	26.2	10.32	29.2	38.3	31.5	21.79	24.0

[1]Conducted July 2002 to March 2003 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's range test at $P \leq 0.05$.
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

An application of 80N–17.2P–33.2K kg/ha was applied as a sidedressing one week after transplanting. Urea was applied at the rate of 150 kg N/ha in three equal splits, two, five, and nine weeks after transplanting. The experiment was irrigated using furrow irrigation twice a week during the first few weeks after transplanting and once a week later. Hand weeding was done three times. Selecron and Peropal were sprayed as necessary to control flea beetles, aphids and red spider mites.

Off-type plants were rogued before reaching the flowering stage. Characterization was carried out from the first flowering stage up to maturity stage using the descriptor list for African eggplant and eggplant (*Solanum melongena*) prepared by AVRDC. Characterization consisted of recording those characters or traits which are highly heritable or can be easily seen and expressed in all environments. Fruit length and width were obtained by longitudinal measurement on 10 dissected fruits per line. Twelve-member taste panels participated in evaluating the taste of each line in raw and cooked form. The taste ratings were: bitter, intermediate, or sweet. The data were analyzed and characters were documented.

Results indicated distinct variation in phenotypic characteristics among the three species studied. However, many similarities were common between *S. aethiopicum* and *S. anguivi* lines. All *S. anguivi* and many *S. aethiopicum* lines produced cream-color flowers, while most *S. macrocarpon* lines had light purple and large flowers (Table 146). The leaf size showed general similarities but with smaller leaf petiole in *S. macrocarpon* lines. Leaf angle was acute in *S. anguivi*, mainly intermediate in *S. aethiopicum*, and a combination of both in *S. macrocarpon*. *S. aethiopicum* had hairy leaves and the presence of spines on leaf veins and stems in some lines; whereas, leaves and stems of *S. macrocarpon* were glabrous and spineless.

Plant height and width varied from 57–114.5 cm among *S. aethiopicum* and *S. anguivi* lines, but only 11–41 cm for *S. macrocarpon* (Tables 147, 148). The stems and branches of *S. macrocarpon* were greenish-purple, but leaves of the other species were green.

Distinct variation was noticeable in fruit characteristics, both between and within species, depending on trait. *S. anguivi* had small-sized round fruits, while *S. aethiopicum* had medium to large-sized oval fruits (Table 147). *S. macrocarpon* lines had both the longest and shortest calyxes (Table 148). Tasting of the fruits indicated that fruits of *S. anguivi* were bitter, and *S. aethiopicum* were sweet or intermediate in bitterness whether raw or cooked. However, cooking of fruits generally improved taste.

Table 146. *Phenotypic characteristics for vegetative and floral characters of promising African eggplant lines.*[1]

Accession	Plant height (cm)	Leaf angle	Leaf hairiness	Flowers/ inflores. (no.)	Flower color	Corolla diam (mm)	Calyx				
							Total length (mm)	Base to sinus length (mm)	Lobe width (mm)	Tips (no.)	Lobe shape
S. aethiopicum											
AB2	65.3	Interm	Interm	3	Cream	21–28	26.7	2.3	6.9	10.8	Recurved
DB3	68.0	Interm	Many	3	Cream	17–20	26.7	3.4	3.5	6.8	Clasping
Manyire Green	104.0	Interm	Few	3	Cream	21–28	38.1	1.4	5.1	11.2	Clasping
N1	57.0	Acute	Interm	3	Cream	17–20	44.9		7.4	5.3	Recurved
N9	75.2	Interm	Many	3	Cream	17–20	30	8.8	10	11.6	Clasping
N12	97.2	Acute	Many	5+	Cream	17–20	16.8	1.7	3.5	5.7	Clasping
N18	60.4	Interm	Many	3	Cream	14–16	21.9	2.5	5.6	8.4	Clasping
N24	61.4	-	-	5+	Cream	17–20	18.7	2.6	4.2	7.4	Clasping
Tengeru White	71.6	Interm	Few	3	Cream	21–28	49.1	10.9	7	17.3	Recurved
S. anguivi											
024	68.8	Interm	Interm	5+	Cream	17–20	16.2	1.5	3.3	6	Clasping
11-05	67.9	Acute	Few	5+	Cream	17–20	16.3	1.7	3.5	5.7	Clasping
Fovembot	53.2	Acute	Few	5+	Cream	17–20	13.7	2.8	4.1	3.2	Recurved
N17	114.5	Acute	None	5+	Lt purple	21–28	28	2.4	5.4	8.5	Clasping
N19	76.9	Acute	None	5+	Cream	17–20	16.7	2.4	3.3	6	Clasping
Toumbot-A	85.0	Acute	Few	5+	Lt purple	17–-20	16.5	2.3	3.2	6.9	Recurved
Toumbot-B	79.2	Acute	None	5+	Lt purple	17–20	15.3	2.5	3.5	4.8	Clasping
Yambio S. Sudan	71.5	Interm	None	5+	Cream	17–-20	16.4	2.3	2.6	5.8	Clasping
S. macrocarpon											
CR001	41.0	Acute	Few	3	-	-	-	-	-	-	-
CR005	28.0	Interm	None	3	Lt purple	40+	85.7	16.7	9.0	28.7	Recurved
CR006	14.9	Interm	None	3	Lt purple	29–35	-	-	-	-	-
CR007	28.0	Acute	Many	3	Lt purple	40+	99.7	13.7	14.3	47.7	Clasping
CN008	64.1	Interm	None	3	Cream	17–20	36.6	1.8	5.9	15.2	Clasping
Mauritius	11.0	Acute	None	3	Lt purple	21–28	-	-	-	-	-
UVPP	32.1	Interm	None	3	White	40+	108.3	15.3	27.0	46.7	Free, straight

[1]Transplanted 23 and 25 July 2002 at AVRDC-RCA in Arusha, Tanzania.

Yield

Young seedlings were transplanted on 22 July 2002. The experiment was laid in RCBD with three replications on plots measuring 5 m long and 75 cm wide. Seedlings were transplanted in double rows at a spacing of 75 cm between rows and 50 cm between plants. The plants were sidedressed with 103N–17.2P–33.2K kg/ha three weeks after transplanting. Two more urea applications of 50 kg N/ha were applied twice at three-week intervals after the first application. Selecron and Perepal were sprayed to control pests.

Results showed highly significant differences between the lines for the number of fruits per cluster, and days to 50% flowering, fruiting and fruit maturity (Table 148). Line DB3 flowered earliest (48.0 days) while lines CR005 and UVPP were the latest to flower (77.0 days). Line 11-05 fruited earliest (52.6 days) while line Yambio-Sudan gave the shortest days to 50% fruit maturity (58.7 days). Line N19 had the highest number of fruit/flower cluster (9.3) (Table 148).

Significant differences were also observed with fruit and seed yields (Table 148). Manyire Green had the highest fruit yield (110.0 t/ha) while line N24 gave the highest seed yield (150.4 g/plant). Line N19 gave the highest number of fruit per plant.

This data confirm that Manyire Green, N24, AB2, Tengeru White, and DB3 are productive lines, each producing more than 70.0 t/ha. All these lines produce flavorful, bitter-free fruits that consumers prefer and all of these lines are well-suited for promotion.

Table 147. *Fruit characteristics of promising African eggplant lines.*[1]

Accessions	Fruits/cyme (no.)	Fruit shape	Fruit color at harvest	Fruit color at full maturity	Raw flavor	Cooked flavor
S. aethiopicum						
AB2	2	Oblate	Creamy white to light yellow	Light red	Intermediate	Sweet
DB3	2	Oval	Orange with green stripes	Orange	Intermediate	Sweet
Manyire Green	2	Round	Light green	Drk red	Sweet	Sweet
N1	1	Round	Green and yellow	Light red	Bitter	Intermediate
N9	2	Round	Orange with green stripes	-	Sweet	Sweet
N12	5	Round	Dark green	Light red	Intermediate	Sweet
N18	2	Round	Orange with green stripes	Orange	Sweet	Intermediate
N24	2	Oval	Light green	Light red	Sweet	Sweet
Tengeru White	2	Round	Half green, half white	Dark red	Intermediate	-
S. anguivi						
024	7	Round	Yellowish orange	-	Bitter	Light red
11-05	8	Round	Half green, half white	Orange	Bitter	Bitter
Fovembot	8	Round	Creamy white to light yellow	Light red	Intermediate	Bitter
N17	6	Round	Dark green	-	Intermediate	Intermediate
N19	7	Round	Light green	Smooth	Bitter	Intermediate
Toumbot	5	Round	Dark green	Light red	-	-
Yambio S. Sudan	10	Round	Light green	Light red	Intermediate	Intermediate
S. macrocarpon						
CR001	-	-	-	-	Sweet	Sweet
CR005	1	Round	-	-	Intermediate	Sweet
CR006	-	Round	-	-	-	-
CR007	2	-	-	-	Intermediate	Intermediate
CN008	1	Round	Dark green	Dark red	-	-
Mauritius	1	Oblate	-	-	-	-
UVPP	1	Round	-	-	-	-

[1]Transplanted 23 and 25 July at AVRDC-RCA in Arusha, Tanzania.

Table 148. *Yield characteristics of promising African eggplant lines.*[1]

Accessions	Days to 50% flowering	Days to 50% fruiting	Flowers/ cluster (no.)	Fruits/ plant (no.)	Fruit yield (kg/plant)	Fruit yield (t/ha)	100-seed weight (g)	Seed yield (g/plant)	Seeds/ fruit (no.)	Seed yield (g/fruit)
S. aethiopicum										
AB2	53.0 hi[2]	62.0 def	2.0 f	83 c	2.95 bc	76.7 abc	0.26 d-h	40.2 def	188 cde	0.49 c-f
DB3	48.0 i	58.3 efg	2.3 ef	63 c	2.6 b-e	70.1 bcd	0.27 c-g	38.7 d-g	240 b-e	0.64 c-f
Manyire Green	50.0 i	57.0 fg	9.0 bc	67 c	4.1 a	110.0 a	0.20 jk	58.0 cd	435 abc	0.94 a-e
N1	65.3 b-e	67.0 cd	2.3 ef	50 c	1.5 d-j	40.5 d-h	0.24 g-j	33.4 d-h	277 b-e	0.66 c-f
N9	62.0 d-g	71.0 abc	2.0 f	35 c	1.7 d-h	44.6 c-g	0.29 a-e	27.7 e-i	287 b-e	0.82 b-f
N12	65.3 b-e	69.6 bcd	2.3 et	485 b	1.6 d-i	42.5 d-g	0.21 ijk	91.5 b	106 de	1.2 def
N18	60.6 fgh	66.3 cde	4.3 def	77 c	1.7 d-h	44.2 c-g	0.19 k	39.6 def	281 b-e	0.52 c-f
N24	48.3 i[1]	57.3 fg	2.3 ef	910 a	3.7 ab	99.7 ab	0.24 g-j	150.4 a	78 de	0.18 ef
Tengeru White	50.0 i	62.0 def	4.6 de	79 c	2.7 bcd	71.6 bcd	0.20 jk	45.9 def	299 bcd	0.59 c-f
S. anguivi										
024	55.0 ghi	66.3 cde	9.3 bc	503 b	0.9 g-k	23.3 e-h	0.21 jk	29.0 e-i	29 e	0.06 f
11-05	49.6 i	52.6 g	3.0 def	450 b	0.99 f-k	26.4 e-h	0.25 e-i	59.8 cd	61 de	0.16 ef
Fovembot	55.6 f-i	66.3 cde	12.3 a	494 b	0.83 g-k	22.1 e-h	0.21 jk	36.4 d-h	35 e	0.07 f
N17	56.0 f-i	65.6 cde	11.0 ab	160 c	1.8 d-g	47.6 c-f	0.25 e-h	53.2 cde	135 de	0.34 c-f
N19	52.3 hi	57.3 fg	8.6 c	1032 a	2.1 c-f	56.3 cde	0.23 g-j	75.7 bc	34 e	0.08 ef
Toumbot	64.6 c-f	66.3 cde	2.0 f	885 a	1.2 f-k	31.3 e-h	0.20 jk	58.2 cd	40 de	0.08 ef
Yambio-S. Sudan	60.3 e-h	66.0 cde	2.3 ef	591 b	1.2 f-k	31.8 e-h	0.22 h-k	44.3 def	35 de	0.08 ef
S. macrocarpon										
CR001	73.6 abc	78.0 a	3.0 def	6 c	0.4 ijk	10.7 gh	0.28 b-f	8.3 hi	636 a	1.76 a
CR005	77.0 a	76.3 ab	5.3 d	4 c	0.3 jk	8.4 gh	0.27 c-g	8.8 hi	621 a	1.68 a
CR006	72.0 abc	78.0 a	3.3 def	19 c	0.4 ijk	9.7 gh	0.3 a-d	20.5 f-i	252 b-e	1.06 abc
CR007	70.3 a-d	76.3 ab	2.0 f	7 c	0.5 hijk	13.4 fgh	0.31 ab	10.4 hi	484 ab	1.48 ab
CN008	55.3 ghi	62.6 c-f	3.3 def	28 c	1.5 e-j	39.6 d-h	0.24 f-j	29.0 e-i	425 abc	1.04 a-d
Mauritius	74.0 ab	78.0 a	2.3 ef	8 c	0.2 k	5.6 h	0.30 abc	3.5 i	188 cde	0.59 c-f
UVPP	77.0 a	78.0 a	2.6 ef	6 c	0.4 ijk	48.4 c-f	0.33 a	11.3 ghi	594 a	1.66 a
LSD (5%)	8.1	6.5	18.6	226	1.0	30.7	0.07	24.1	220	0.72
F-test	***	***	***	***	***	***	***	***	***	***
CV (%)				22	21.5	23.9	9.11	14.6	23	26.17

[1]Transplanted 22 July at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
*** Significant at $P \leq 0.001$.

Effects of harvesting time on yield of vegetable cowpea leaves

Cowpea (*Vigna unguiculata*) is the most important pulse crop in tropical Africa, especially in arid and semi-arid areas, where it is deeply rooted and tolerant to drought. Cowpea is indigenous to several African countries and has been cultivated for centuries. Numerous varieties are known to be used for their seeds, but varieties with leaves having long vines are mainly used for their leaves (and occasionally for their young green pods). The leaves can be eaten fresh or dry. Besides being a nutritious food source, cowpea fixes nitrogen efficiently and is an excellent green manure crop. Lack of knowledge on the optimum time to start harvesting leaves to realize high yields is one of the most important constraints in increasing leaf yield in vegetable cowpea production. The objective of this study was to evaluate the effect of harvesting time on leaf yield of two promising cultivars of vegetable cowpea.

The experiment was conducted from July to November 2002. Harvesting periods of 8, 9, 10, 11, and 12 weeks after sowing (WAS) were tested using a

RCBD with three replications. Each plot was 6 m long and 0.12 m wide. Sowing was done in double rows on raised beds spaced 60 cm apart and a spacing between plants of 20 cm. A total of three hand-weedings were carried out and Selecron (15 ml per 20 L) was sprayed to control aphids, leafhoppers, African bollworm, and cowpea leaf beetle. No fertilizer was applied. The experiment was irrigated twice weekly during the early crop stage and weekly thereafter using furrow irrigation. Harvesting was done by hand-picking the leaves every week for five consecutive weeks. Harvested leaves were weighed while fresh. Data was analyzed using COSTAT computer software.

The line Fahari produced 5.26 t/ha, significantly more than Dakawa's yield of 3.21 t/ha (Table 141). Highly significant differences for total leaf yield with regard to the time to start harvesting were observed. The earliest harvest (8 WAS) gave the lowest yields of 0.04 kg/plant and 3.40 t/ha, while the last harvest (12 WAS) gave the highest yields of 0.06 kg/plant and 5.22 t/ha (Table 141). This shows that, in general, the later the harvesting time was started, the higher the yield. For promotional purposes, Fahari has shown more promising results than Dakawa; while harvesting starting at 12 WAS should be recommended.

Table 149. *Varietal effect and time to harvest on leaf yield of vegetable cowpea.*[1]

Treatment	Leaf yield (kg/plant)	Leaf yield (t/ha)
Lines		
Dakawa	0.039 b[2]	3.215 b
Fahari	0.063 a	5.258 a
LSD (5%)	0.004	0.36
Time to harvest (weeks after sowing)		
8	0.041 c	3.398 c
9	0.045 c	3.722 c
10	0.053 b	4.403 b
11	0.053 b	4.438 b
12	0.063 a	5.222 a
LSD (5%)	0.007	0.361
F-test	***	***
CV (%)	10.82	10.93

[1]Trial conducted from July to November 2002 at AVRDC-RCA in Arusha, Tanzania.

[2]Mean separation in columns by Duncan's range test at $P \leq 0.05$.

*** Significant at $P \leq 0.001$.

Incorporation of vegetable cowpea and vegetable soybean as organic manure in production of amaranth as a model crop

Intensive agricultural systems involving high inputs of chemical fertilizers and synthetic pesticides are not affordable to many small-scale farmers in developing countries. These cropping systems may also damage soil and water resources as well as the health of farmers.

The application of green manure crops into the soil can improve soil fertility in a sustainable manner that is affordable to farmers. Green manure crops are grown and then incorporated into the soil before sowing cash crops. Grasses, legumes or a mixture of both can be used as green manure. Grasses are good at adding organic matter and stimulating earthworms while legumes are good at adding nitrogen. Green manure plants absorb nutrients that might be washed away from the soil and then slowly release the nutrients back to the soil as the plant decays.

The amount of nitrogen fixed depends on the rhizobial strain (which is host-specific), the host plant, and the environmental conditions. Cowpea can fix about 100 kg/ha of N and soybean 112 kg/ha N, with clover going up to 561 kg/ha N from experiments done in New Zealand. Time needed for complete decomposition depends on the material, quantity, environmental factors, and soil status. Soybean straw produces about 105 kg/ha nitrogen, 20 kg/ha phosphorus, 73 kg/ha potassium, 12 kg/ha magnesium and 17 kg/ha sulfur. This trial was conducted to evaluate vegetable soybean and cowpea as green manure crops.

Experiments were carried out at AVRDC-RCA, Arusha, Tanzania from July to December in 2002 and 2003. A 3 × 3 factorial experiment in split-plot design with three replications was used. The main plots had three plots each measuring 3 m wide and 5 m long. Each plot had 5 ridges spaced 60 cm apart. There were three main treatments: no green manure (control), vegetable soybean, and vegetable cowpea. Vegetable soybean and vegetable cowpea were sown on both sides of the bed in respective plots at an in-row spacing of 10 cm with two seeds per hole. The plots were watered once a week using furrow irrigation from sowing date to two days before incorporation into the soil. Incorporation of cowpea and soybean into the soil was carried out two months after sowing and just at the beginning of flower formation. The main plots were then divided into three sunken bed plots each measur-

ing 0.6 m wide and 5 m long, separated by a 40-cm path. Three *Amaranthus* lines from two species (*A. hypochondriatus* and *A. cruentus*) were randomly assigned to the three beds in each plot. Amaranth was broadcasted on the prepared sunken beds starting one week after the green manure treatment had been incorporated into the soil. A total of 50 g of each amaranth line was broadcast on each plot as per the treatment. The beds were mulched with grass and watered three times a week. Weeding was done by hand. No pesticides or chemical fertilizers were applied. Harvesting of amaranth lines was done three weeks after sowing, by uprooting the whole crop and weighing the biological (whole plant) and economic yields (whole plant minus roots). A second sowing of amaranth was done immediately after removing the first crop to make sure that the soil nutrients were utilized efficiently. Each succeeding crop was harvested three weeks after broadcasting. A two-way analysis of variance was performed using COSTAT software.

Results obtained show mainly significant differences among the three lines of amaranth tested as affected by green manure; although there were no marked variations in yield with succeeding crops. *A. hypochondriatus* gave significantly higher yields than the two *A. cruentus* lines (Table 150).

The effect of green manure on amaranth yield was not fully conclusive although the trend showed an increase in yield with the second crop which subsequently declined with succeeding crops. Amaranth yields per ha on control plots initially were higher than plots with green manures incorporated in the soil; although the yields per plant were lower (Table 150).

Our data indicate that the best time to sow a crop for maximum utilization of nutrients from a green manure is about three weeks after incorporation of the green manure in the soil. In general, vegetable soybean seems to be slightly more effective than vegetable cowpea as a green manure. Additional research should be conducted to verify these results and to determine how much nutrients both crops add to the soil.

Table 150. *Effects of vegetable cowpea and vegetable soybean as green manure on yield of* Amaranthus *lines.*[1]

	2002					2003			
	Biomass[2] (t/ha)			Yield[3] (t/ha)		Biomass[2] (t/ha)			
Treatment	1st	2nd	3rd	1st	2nd	1st	2nd	3rd	4th
Green manure									
Vegetable cowpea	5.5 b[4]	6.9 a	2.5 b	4.7 ab	6.0 b	1.8 b	5.3	0.8 b	4.3
Vegetable soybean	7.3 ab	8.4 a	3.5 b	3.6 b	7.4 a	1.2 b	4.1	1.8 a	2.9
None	10.7 a	3.2 b	6.3 a	6.4 a	2.8 c	4.4 a	4.7	1.5 a	2.0
LSD (5%)	3.8	1.8	2.2	2.1	1.2	0.1	1.3	0.6	2.3
F-test	*	*	**	*	***	***	NS	**	NS
CV (%)	15.3	9.5	22.0	9.5	7.6	25.6	26.2	43.8	76.8
Amaranth									
NL (*A. cruentus*)	5.7 b[3]	5.7 b	4.3	3.5 b	4.7 b	1.2 c	5.4 a	0.8 b	2.7
ZIM (*A. cruentus*)	6.4 b	4.2 b	4.0	4.0 b	3.6 b	1.9 b	3.5 b	1.2 b	3.3
MX (*A. hypochondriatus)*	11.4 a	8.6 a	4.1	7.1 a	7.9 a	4.3 a	5.2 a	2.0 a	3.1
LSD (5%)	3.8	1.8	2.2	2.1	1.2	0.1	1.3	0.6	2.3
F-test	*	***	NS	**	***	***	*	**	NS
CV (%)	15.3	9.5	22.0	14.2	7.6	25.6	26.2	43.8	76.8

[1]Trial conducted from July to December in both 2002 and 2003 at AVRDC-RCA in Arusha, Tanzania.
[2,3]Plant mass with and without roots, respectively.
[4]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Spacing recommendations for leaf and seed yield of sunn hemp

Many legumes are used as vegetables, including African species *Crotalaria ochroleuca and C. brevidens*, often called sunn hemp. *C. ochroleuca* can be found throughout Africa and is cultivated at altitudes of 1000–1200 m from the shores of Lake Victoria to Mount Elgon and into the semi-arid zones of Northern Uganda. The crop can be grown as monocrop or intercropped with a range of other crops that benefit from its capacity to fix nitrogen and reduce nematode populations.

Other than being used as vegetable, sunn hemp leaves are used as fodder, and its seeds can be used to feed poultry. Oil extracted from the seeds is sometimes used as an insect repellent. Flowers and young pods are highly valued for use in soups. Sunn hemp contains protein, β-carotene, vitamin C, calcium and iron. Thus, it provides an important contribution to the human diet. Little is known about the production practices of *Crotalaria* species. The objective of this study was to evaluate the best spacing for leaf and seed yields.

The experiment was conducted at AVRDC-RCA, Arusha Tanzania from August 2002 to February 2003. The experimental design was RCBD with 3 replications. Seeds were drilled in rows and thinned later to achieve the desired spacing of 20 × 20, 40 × 40, 60 × 60, and 80 × 80 cm between plants and between rows. Weeding was done as needed. Furrow irrigation was done before drilling and after emergence of plants and continued on a weekly basis. The first leaf harvest was done 69 days after sowing by plucking leaves, and the tips of the plants were pinched to accelerate shoot regeneration. Half of the plants in each row were harvested for leaf yield and the other half for seed yield assessment.

The results showed no significance differences for 1000-seed weight and the number of seeds per pod (Table 151). The closest spacing (20 × 20 cm) was found to be most effective in increasing total leaf and seed yields per ha, while the widest spacing (80 × 80 cm) was more effective in enhancing seed and leaf yields per plant (Table 151). Further testing is recommended for at least two seasons to verify these preliminary results.

Effects of spacing and nitrogen fertilizer on leaf and seed yield of spiderflower plant

Spiderflower plant (*Cleome gynandra*) is an African indigenous vegetable that forms part of the daily diet in some rural households. It is still undomesticated in many countries of the region and some communities still gather the species from the forest. Over time, the production and consumption of this crop has gone down dramatically and the crop is under threat of genetic erosion if conservation measures are not strengthened.

The increase in consumption and utilization of this indigenous vegetable could lead to the diversification of food crops in Africa and thus contribute to food security in the region. However, the productivity of spiderflower plant is still very low and cannot meet the increasing demand from the population. Moreover, information on agronomic and seed production requirements for spiderflower plant is still very scant.

An evaluation trial was conducted at AVRDC-RCA in Arusha, Tanzania from July to December 2002 to assess the yield response and growth components of spiderflower plant to nitrogen and spacing. Two separate experiments on response to nitrogen and spacing

Table 151. *Spacing requirements on leaf and seed yield of sunn hemp.*[1]

Spacing (cm)	Leaf yield/ plant (g)	Leaf yield (t/ha)	Seed yield/plant (g)	Seed yield (kg/ha)	1000-seed weight (g)	Seed no./ pod	Seed no./ plant	Pod no./ plant
20 × 20	112 b[2]	28.0 a	21.7 c	5422 a	6.2	33.3	3505 c	105.3 c
40 × 40	168 ab	10.5 b	31.6 c	1972 b	6.3	36.7	4989 c	137.7 c
60 × 60	246 ab	6.8 bc	57.2 b	1589 b	6.6	28.0	8717 b	322.3 b
80 × 80	316	4.9 c	91.1 a	1424 b	6.3	31.0	14553 a	483.3 a
LSD (5%)	173	3.7	15.3	1029	0.4	13.6	2444	103.6
F-test	*	***	***	***	NS	NS	***	***
CV (%)	21.1	14.6	15.2	19.81	2.79	21.08	15.41	19.78

[1]Trial conducted from August 2002 to February 2003 at AVRDC-RCA in Arusha, Tanzania.

[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

were carried out. The experiments were laid out in a RCBD with three replications. The trial to evaluate spacing effects used four treatments (20 × 20, 40 × 40, 60 × 60, and 80 × 80 cm). The trial to evaluate nitrogen effects evaluated six levels of N (0, 60, 90, 120, 150 and 180 kg/ha), using urea as the nitrogen source. Seeds of a purple stem line were sown in double rows in plot sizes measuring 6 × 0.9 m. The field was irrigated and weeded as necessary. Aphids were controlled with Selecron.

Reducing spacing from 80 to 20 cm significantly increased leaf yields per hectare while the number of pods per plant increased with an increase in spacing from 20 to 40 cm. All the other parameters measured were not affected by spacing treatments (Table 152).

Significant differences were detected among N rates for leaf yields and numbers of pods per plant; the rate of 120 kg N/ha was optimum (Table 152). Other parameters measured did not show significant variations in their responses to urea. This study show that spiderflower plant performs best at a spacing of 20 cm and the optimum application of urea nitrogen is 120 kg N/ha. These findings confirm the results of previous studies carried out for three years at AVRDC-RCA in Arusha, Tanzania.

Effects of spacing and nitrogen fertilizer on leaf and seed yield of jute mallow

Jute mallow (*Corchorus olitorius*) is a nutritious leafy vegetable that prefers a warm, moist climate. Yields are usually low due to lack of improved varieties, poor seed quality, and poor production practices, including improper fertilization and spacing of plants. In Africa, Nigeria is one of the few countries that have given research priorities to the genetic improvement of jute mallow. Thus, a large number of local landraces have been characterized and improved.

Fertilizer trials indicate that the crop does not respond favorably to high nitrogen application, which may be evidence of its adaptation to low nitrogen conditions. Preliminary studies at AVRDC have shown that higher leaf yields can be obtained with the application of 90 kg N/ha of urea while spacing of 20 × 20 cm gave the highest leaf yield. The objectives of this study were 1) to verify the optimum spacing and fertilizer that maximizes leaf and seed yield; and 2) to show characteristics of selected *C. olitorius* accessions that can generate information for future breeding programs.

The study was conducted at AVRDC-RCA, in Arusha, Tanzania from July to November 2002; and

Table 152. *Response of spiderflower plant to spacing treatments and nitrogen application.*[1]

Treatment	Leaf yield (g/plant)	Leaf yield (t/ha)	No. of seeds/pod	No. of seeds/plant	Seed yield (g/plant)	Seed yield (kg/ha)	No. of pods/plant	200-seed wt (g)
Spacing (cm)								
20 × 20	667	166.7 a[2]	62.8	2835	4.03	1008	40.4 b	0.28
40 × 40	747	46.7 b	47.1	3097	3.81	238	71.6 ab	0.25
60 × 60	720	20.0 c	46.2	3273	4.27	357	72.8 a	0.26
80 × 80	863	13.5 c	42.6	2815	3.95	62	67.3 ab	0.28
LSD (5%)	193	22.9	42.9	2303	3.23	1070	30.5	0.36
F-test	NS	***	NS	NS	NS	NS	NS	NS
CV (%)	12.9	18.6	43.2	38.4	40.3	128.7	24.2	6.69
Nitrogen (kg/ha)								
0	327 b	13.6 b	66.5	4024	5.05	211	60.7 ab	0.25
60	530 ab	22.1 ab	68.1	3677	4.74	198	56.8 b	0.26
90	580 ab	24.2 ab	51.8	4360	4.71	196	81.4 a	0.23
120	670 a	27.9 a	67.6	5628	6.17	257	82.9 a	0.23
150	530 ab	22.1 ab	73.7	4517	6.24	260	60.2 ab	0.27
180	487 ab	20.3 ab	99.8	7442	9.17	382	68.4 ab	0.25
LSD (5%)	280	11.7	49.1	4480	5.38	224	20.9	0.06
F-test	*	*	NS	NS	NS	NS	*	NS
CV (%)	29.6	29.6	37.9	49.84	49.2	49.2	16.8	13.2

[1]Trial conducted from July to December 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

consisted of three separate experiments. The first experiment was laid out in a RCBD with four spacing levels of 20 × 20, 40 × 40, 60 × 60 and 80 × 80 cm, each replicated three times. Each experimental plot was 7 m long and the width varied according to the spacing between plants. The second experiment was also laid out in RCBD with three replications and seven urea fertilizer levels of 0, 60, 80, 90, 120, 150 and 180 kg N/ha. Each experimental plot had two ridges, which were each 7 m long and 1.8 m wide; spacing between ridges was 60 cm and spacing between plants was 40 cm. The third experiment consisted of sowing seven semi-purified jute mallow lines in seven separate stations separated by an isolation distance of at least 30 m. Each experimental plot had two to three ridges spaced 60 cm apart with plants spaced 50 cm apart. Plants were irrigated weekly using furrow irrigation, and weeding was done as needed. Topdressing was done with urea in two splits at a rate of 120 kg N/ha for the characterization and spacing experiments. In the N rates trial, topdressing with urea was done in two splits at the tested rates of 0, 60, 90, 120, 150 and 180 kg N/ha. Characterization was carried out based on descriptors developed by AVRDC.

Results confirmed that spacing of 20 × 20 cm produced the highest leaf and seed yields respectively (7.44 t/ha and 2,925 kg/ha) while the widest spacing (80 cm × 80 cm) gave the lowest yields (0.56 t/ha and 279 kg/ha respectively) (Table 153). Leaf and seed yield generally increased with increasing plant population. Applications of urea significantly improved seed yields compared to the control treatment (Table 153), but the N levels tested did not significantly affect leaf yields. For optimum leaf yield, we recommend a 20 × 20 spacing and 90 kg N/ha.

Variation in the number of days to seedling emergence, stem color and days to flowering showed interspecies variation in characteristics (Table 154). *C. olitorius* lines with horizontal stems germinated fastest (10 days) while Sud1 and Sud2 germinated slowest (15 days). A narrow variation was observed in the cotyledon color, flower size, plant height, leaf height and leaf width (Table 154). The variation in plant characters might be genetically linked.

Table 153. Effect of spacing and fertilizer application on yield characteristics of *Corchorus olitorius.*[1]

Treatment	Leaf yield (g/plant)	Leaf yield (t/ha)	Seeds/pod (no.)	Seeds/plant (no.)	Seed yield/plant (g)	Seed yield (kg/ha)	Pods/plant (no.)	500-seed weight (g)
Spacing								
20 x 20	29.8	7.44 a[2]	63.8	5 701	11.7	2925 a	90.8	1.03
40 x 40	44.6	2.79 b	70.8	7 803	16.1	1005 b	114.6	1.02
60 x 60	33.3	0.93 b	74.6	7 509	11.9	331 c	96.9	0.97
80 x 80	35.9	0.56 b	92.3	9 199	17.9	279 c	100.7	0.97
LSD (5%)	22.7	2.90	59.2	6 444	11.6	466	36.3	1.02
F-test	NS	**	NS	NS	NS	***	NS	NS
CV (%)	31.6	49.5	39.3	42.7	40.4	20.6	18.0	5.15
Nitrogen (kg/ha)								
0	38.4	1.60	134.0 b	8 232 b	16.9 b	704 b	64.2 b	1.03 c
60	44.1	1.84	224.4 a	14 639 a	31.1 a	1294 a	64.8 b	1.06 abc
90	63.1	2.63	169.5 ab	11 406 ab	23.8 ab	991 ab	71.3 ab	1.05 bc
120	54.5	2.27	137.8 b	10 340 ab	22.7 ab	944 ab	77.9 ab	1.09 ab
150	58.4	2.43	172.7 ab	14 881 a	30.9 a	1286 a	89.8 a	1.04 bc
180	62.2	2.59	120.2 b	9 741 ab	21.7 ab	904 ab	80.4 ab	1.11
LSD (5%)	23.2	0.97	78.9	4 855	9.7	406	19.4	0.05
F-test	NS	NS	*	*	*	*	*	*
CV (%)	23.8	23.8	27.2	23.1	21.9	21.9	14.3	2.56

[1]Trial conducted from July to November 2002 at AVRDC-RCA in Arusha, Tanzania.

[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 154. *Plant and morphological characters of selected* Corchorus olitorius *lines.*[1]

Acc.	Cotyledon color	Plant height[2] (cm)	Plant width[2] (cm)	Stem color	Leaf color	Leaf length[2] (cm)	Leaf width[2] (cm)	Fruit shape	Fruit color	Mat. pod length (cm)	Mat. pod weight (g)	Seed color	1000-sd weight (g)
Sud1	Green	166.4	109.0	Green	Green	12.30	4.04	Globule	Brown	4.40	0.95	Black	1.86
Sud2	Green	170.0	96.5	Green	Green	11.00	2.94	Long	Brown	5.10	0.79	Brown	2.00
Sud3	Green	-	-	Green	Green	9.08	2.75	Long	Green	5.38	0.69	Brown	1.86
Sud4	Green	200.5	136.0	Green	Dk grn	10.10	2.76	Long	Green	5.10	0.74	Black	2.00
Horizl[3]	Lt green	128.0	45.8	Red-purp	Lt grn	4.87	2.37	Long	Brown	7.50	0.68	Brown	2.21
Mix[4]	Lt green	116.0	141.0	Green	Green	5.27	1.92	Long	Brown	5.70	0.93	Green	2.16
Erect[3]	Purp-grn	-	-	Grn-red	Green	-	-	-	-	-	-	Green	2.30

[1]Trial conducted from July to November 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Assessed at 50% flowering stage.
[3,4]Semi-purified and nonpurified seed, respectively.

Effect of spacing on seed yield of okra

Okra (*Abelmochus esculentus*, *A. caillei,* and *A. manihot*) is one of the most widely grown vegetables in warm climates. Its distinctively ridged fruits can be consumed fresh when young or then grown to maturity and dried for processing into powders. The major constraint in okra production is yellow vein mosaic virus (YVMV). Improved cultivars can produce 24–28 fruits/plant and yield up to 17 t/ha under intense management. Little is known about fruit and yield performance of known varieties under African conditions. The objective of this study was to test okra seed yield response to variation in spacing.

An okra line highly tolerant to YVMV was used. Four spacing levels between rows (45, 60, 75 and 90 cm) and five spacing levels of plants within rows (10, 20, 30, 40 and 50 cm) were evaluated in split plot design with three replications. Row spacing constituted the main plots and in-row spacing formed the subplots. Sowing was done on 20 February 2002. Weeding and pest management practices were carried out as needed. Plants were topdressed with 80N–0P–0K kg/ha.

Results showed that seed yield per plant was not clearly influenced by spacing although seed yield per hectare significantly increased with a decrease in spacing between plants (Table 155). The experiment is being conducted again to validate these findings.

Table 155. *The effect of different spacings on seed yield in okra.*[1]

Spacing (cm)	Seed yield (g/plant)	Seed yield (kg/ha)	1000-seed weight (g)
45 × 10	11.10 cd[2]	2460 a	66.57 abc
45 × 20	17.70 a	1950 b	69.2 a
45 × 30	16.15 ab	1200 de	65.47 abc
45 × 40	13.75 abc	860 efg	65.80 abc
45 × 50	16.40 ab	463 g-j	64.77 abc
60 × 10	10.85 cd	1825 b	62.37 c
60 × 20	8.60 d	715 f-i	64.3 abc
60 × 30	9.70 cd	550 g-j	62.33 c
60 × 40	8.55 d	360 ij	65.90 abc
60 × 50	16.50 ab	550 g-j	62.20 c
75 × 10	12.50 bcd	1700 bc	67.93 ab
75 × 20	10.40 cd	825 e-h	66.40 abc
75 × 30	10.75 cd	475 g-j	65.53 abc
75 × 40	11.90 bcd	415 ij	66.03 abc
75 × 50	10.30 cd	300 j	65.57 abc
90 × 10	12.25 bcd	1365 cd	63.17 bc
90 × 20	18.10 a	1005 def	63.07 c
90 × 30	16.40 ab	650 f-j	68.40 ab
90 × 40	11.55 cd	425 hij	65.53 abc
90 × 50	10.85 cd	255 j	64.70 abc
LSD (5%)	4.07	355	4.63
F-test	***	***	*
CV (%)	15.30	18.47	4.29

[1]Trial conducted from February to July 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
*, **, *** Significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Effects of plant spacing on promising nightshade lines

Nightshade species *Solanum scabrum* and *S. villosum* are frequently grown in West and East Africa, while *S. americanum* is grown less extensively. Nightshade leaves are widely consumed as vegetables, and are reportedly rich in protein, calcium, and ascorbic acid. Nightshade requires cool climates and moist soils; otherwise, very few inputs are used to grow nightshade in most African countries. Like many other indigenous vegetables, there is little information available on the cultural practices required to optimize production of nightshades. Plant spacing is one of the most important cultural practices in leafy vegetable production, influencing both yield and quality.

This experiment was conducted on two nightshade species grown under four varying plant populations to assess the effects on seed and leaf yields. The trial was conducted during the cool-dry season at AVRDC-RCA in Arusha, Tanzania from July 2002 to February 2003. Thirty day-old seedlings of two promising lines of nightshade: SA (*S. americanum*) and SS-532 (*S. scabrum*), selected for their diversity in morphological characteristics were transplanted on 25 July 2002 in a 2 × 4 factorial experiment laid out in a RCBD with three replications. There were four rows of plants per plot with each plot having four ridges. The length of the plot size was about 6 m. Different spacings (30 × 30, 50 × 50, 70 × 70, and 90 × 90 cm) between plants were tested. Plants were fertilized with 114.5N–17.2P–33.2K kg/ha five days after transplanting, followed with an application of 34.5N–0P–0K eight days later. The plots were irrigated weekly using furrow irrigation. Weeding was done through hand hoeing as needed. Selecron was applied 21 days after transplanting to control aphids. Harvesting was done by hand-picking fresh leaves. The first harvest was carried out 43 days after transplanting and subsequent harvests carried out every two weeks to make a total of four harvests. Fruits were harvested when they were ripe. Seeds were extracted from the fruits, cleaned and dried under the sun. Data collected were then subjected to ANOVA analysis using COSTAT computer software.

Results showed that the two lines did not significantly differ for total leaf yield, number of fruit per plant, number of seed per plant, and the number of seed per fruit (Table 156). Significant differences were, however, observed for several characteristics including the leaf yield per plant, total seed yield per ha, and 100 seed weight. The data shows that SS52 produced more seeds than SA and the seeds of SS52 were also heavier (Table 156). Line SS-52 also produced more leaf yield per plant (768.1 g) than line SA.

Plant spacing results showed no significant differ-

Table 156. *Effects of plant spacing on leaf and seed yield characteristics of SS-52* (Solanum scabrum) *and SA (*S. americanum) nightshade lines.[1]

Treatment	Leaf yield (g/plant)	Leaf yield (t/ha)	Seed yield/ (g/plant)	Seed yield (kg/ha)	Fruits/plant (no.)	100-seed wt (g)	Seeds/plant (no.)	Seeds/fruit (no.)
Lines								
SS52	768 a[2]	36.5	128.4a	5120 a	2000	0.12 a	81 368	56.0
SA	616 b	29.1	24.3b	810 b	1482	0.03 b	1 032 645	53.0
LSD (5%)	144	7.5	27.2	2890	575	0.01	30 215	13.0
F-test	*	NS	***	**	NS	***	NS	NS
CV (%)	23.7	26.0	40.7	11.87	37.70	14.6	37.38	27.3
Spacing (cm)								
30 × 30	715	79.4 a	59.5	6610 a	1167 b	0.08	60 394 b	51.8
50 × 50	764	30.6 b	69.2	2290 b	1608 ab	0.08	86 255 ab	53.6
70 × 70	635	13.0 c	94.2	1920 b	2373 a	0.08	128 955 a	54.3
90 × 90	653	8.1 c	82.5	1020 b	1816 ab	0.08	93 662 ab	51.6
LSD (5%)	203	10.6	38.5	4	813	0.01	42 730	18.4
F-test	NS	***	NS	*	*	NS	*	NS
CV (%)	23.7	26.0	40.7	11.87	37.70	14.6	37.38	27.3

[1]Trial conducted from July 2002 to February 2003 at AVRDC-RCA in Arusha, Tanzania.

[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

ences on leaf yield per plant, number of seeds per plant, and the 100-seed yield. They also showed that the closer plant spacing was, the higher the yields per ha. The highest leaf yield (79.4 t/ha) was obtained with the 30-cm spacing and the lowest (8.0 t/ha) with 90-cm spacing. The 30-cm spacing also gave the highest seed yield (6.6 t/ha) with seed yield decreasing as plant spacing decreased (Table 156). The higher yield characteristics of line SS-52 may be attributed to its larger leaf morphology.

These results are being validated in a subsequent, on-going experiment. However, the preliminary information indicates that farmers can thus be advised to grow nightshade at a spacing of 30 cm between plants.

Characterization of nightshade lines

Nightshade (*Solanum scabrum*, *S. villosum* or *S. americanum*) is an important indigenous vegetable in many parts of Africa, although in other places it is considered as a weed. The centers of origin of the crop are considered to be in West Africa and tropical Asia. It is an annual branching herb that grows up to 90 cm, depending on variety. The nutritional value of the leaves is high and its tender shoots are edible. The crop requires cool climates and moist soil to grow well. Otherwise, nightshade requires very little input and could increasingly become an important cash crop to vegetable growers.

Nightshades are grown for both commercial and home garden purposes. However, little information is available on morphological characteristics of nightshade species. Preliminary information has shown that in most varieties, leaves are ovate and pointed while flowers are white and about 9 mm in diameter. The aim of this study was to characterize eight nightshade lines and assess their horticultural characters including yield. All these data will be useful in plant selection programs.

The trial was conducted from July to December 2002 at AVRDC-RCA, Arusha, Tanzania. The experiment was laid out in RCBD with three replications. Eight lines of nightshade were evaluated with seedlings transplanted in double ridges at a spacing of 75 cm between ridges and 40 cm between plants. Weeding was done four times and Selecron was applied as necessary to control aphids and other pests. Furrow irrigation was applied as needed. The leaves were harvested four times.

Result shows that the highest leaf yield/ha was obtained from line SS52 (22.0 t/ha) followed by line SS49, SS04.2, and SA as shown in Table 157. Line SV showed the lowest yields. Fruit flesh color was either green, purple or orange and great variations were observed in petiole, blade length, and blade leaf width (Table 158). All accessions had ovate or lanceolate green leaves with few hairs.

Plant height and width varied significantly. Ex-Hai Kilimanjaro was the tallest line, growing 93.4 cm high, while the shortest line, SS0.42, only grew 63.2 cm. Line SA showed the widest canopy while line SS04.2 was the most erect (data not shown). For all lines, the branching pattern was mainly primary and secondary; wings were present along the stem with few strong dents; petioles were winged in the upper half only; leaf apex acute; fruit attachments remain on the plant when fully ripe; and the type of hair was not easily established. Based on all parameters assessed in this study, it can be assumed that lines SS52 and SS49 are the most promising ones. These two lines produce broad leaves and high leaf yields.

Table 157. *Yield characteristics of promising Solanum lines.*[1]

Lines	Species	Leaf yield (g/plant)	Leaf yield (t/ha)
SS 52	*S. scabrum*	660 a[2]	22.0 a
SS 49	*S. scabrum*	584 ab	19.5 ab
SS 40	*S. scabrum*	324 cd	10.8 cd
SS0.42	*S. scabrum*	529 ab	17.6 ab
Ex-Hai Kilimanjaro	*S. scabrum*	289 cd	9.6 cd
SA	*S. americanum*	416 bc	13.9 bc
SS47	*S. scabrum*	298 cd	9.9 cd
SV	*S. villosum*	141 d	4.7 d
LSD (5%)		182	6.1
F-test		***	***
CV (%)		25.6	25.6

[1]Trial conducted from July to December 2002 at AVRDC-RCA in Arusha, Tanzania.
[2]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
*** Significant at $P \leq 0.001$.

Table 158. *Morphological characteristics of promising African nightshade lines.*[1]

Lines[2]	Bloom on fruit	Fruit flesh color	Petiole length (mm)	Blade length (mm)	Blade width (mm)	Leaf shape	Plant height (cm)	Plant width (cm)	Stem color	Stem hairs
SS52	Present	Green	41.2	169.9	120.4	Ovate	74.4	81.85	Lt purple	Few
SS49	Present	Green	74.8	157.0	118.0	Ovate	84.3	66.1	Lt purple	Few
SS40	Present	Purple	53.1	161.8	99.7	Lanceolate	83.46	80.8	Lt purple	Few
SS0.42	Present	Purple	58.1	159.9	102.1	Ovate	63.2	53.5	Lt purple	Few
SS Ex-Hai Kilimanjaro	Present	Purple	57.3	152.6	111.5	Ovate	93.46	83.8	Green	Few
SA	Absent	Green	20.0	74.2	45.3	Ovate	72.0	102.4	Lt purple	None
SS 47	Present	Purple	72.4	142.0	106.0	Ovate	68.2	71.2	Green	Few
SV	Present	Orange	38.2	106.1	98.5	Ovate	63.87	55.66	Green	Few

[1]Trial conducted from July to December 2002 at AVRDC-RCA in Arusha, Tanzania.

Effects of seed priming on nightshade and African eggplant

Seed priming is a physiological pre-plant seed enhancement treatment in which seeds are allowed to imbibe water and go through the first stages of germination, but does not allow actual radical protrusion through the seed coat to occur. The seeds are then dried back to their original dry state. The basis for seed quality enhancement in vegetable crops is to achieve rapid and uniform field emergence, so as to increase yield, quality and ultimately improve stand establishment. Uniformity, rate and percentage of seedling emergence in vegetable crops have a great impact on final yield and quality.

The germination of nightshade and African eggplant is slow and erratic. It is possible that the delay in germination of seeds of these species may be due to dormancy and that seed priming may be used to reduce dormancy. There is no simple recipe for determining the best priming treatment for a particular species. Priming techniques must be determined empirically.

The objective of this study was to enhance the seed quality and the germination potential of nightshade and African eggplant seeds, following a range of priming treatments with water (hydropriming) and field soil (solid matrix priming). The trial was conducted at AVRDC-RCA in Arusha, Tanzania from September to December 2002. The experiment was conducted both in the laboratory for priming processes, and in the field for seedling tests. The experiment was conducted by preparing seed samples for priming treatments on 7 September 2002. For hydropriming experiments, 2.5-g and 5-g seed samples of SS49 (*S. scabrum*) and UVPP (*Solanum macrocarpon*), respectively, were prepared. One and 1.5 ml of water for nightshade and African eggplant, respectively, were added to the seeds in a sealable plastic bag with the optimum seed to water ratio having been determined in earlier preliminary experiments. Plastic bags were placed in a refrigerator set at 11–14°C. The samples were interchanged daily between room temperature for 10 h (22–27°C) and refrigerator for 14 h throughout the priming duration. Different priming durations of 3, 5, 7, 9, and 11 days were tested. At the end of the priming period, the primed seeds were dried back to normal moisture content. Seed drying was carried out in a desiccator filled with silica gel for five days to attain a moisture content of 6–8%. The dry primed seeds were then sown under field conditions in trays filled with sterilized medium (3 parts soil, 1 part sand, and 1 part manure). Seedling emergence percentage, rate, and uniformity were determined by daily scoring.

For solid matrix priming, field soil was used as a solid carrier. The soil was sterilized in an oven at 100°C for 24 h. The procedures for these experiments were the same as with hydropriming but differed in priming mixtures. The solid medium (10 and 15 g of field soil for nightshade and African eggplant, respectively) was mixed with water (1 and 1.5 ml for nightshade and African eggplant, respectively) and then equilibrated for 24 h inside a refrigerator set at 11 °C. The seeds (2.5 and 5.0 g for nightshade and African eggplant, respectively) were then thoroughly mixed with the solid media inside the plastic bag before placing in the refrigerator for different days of priming. The mixture was turned daily to ensure that the seeds were well covered by the solid matrix, to allow the seeds to imbibe moisture from the matrix at an equal rate. After drying, the solid carrier material was separated from

Table 159. *Effects of hydropriming (HYP) and solid matrix priming (SMP) on seedling emergence characteristics of African eggplant (*Solanum macrocarpon*) and African nightshade (*S. scabrum*).*

Priming duration (days)	Seedling emergence (%)		Mean time (h) to seedling emergence (T_{50})		Seedling emergence rate ($1/T_{50}$)		Uniformity in seedling emergence (seed/h)	
	HYP	SMP	HYP	SMP	HYP	SMP	HYP	SMP
*UVPP (*Solanum macrocarpon*)*								
0	40.7 b[1]	40.7	360	360	0.0028 c	0.0028	1.52 a	1.52 a
3	78.0 a	74.0	323	310	0.0031 ab	0.0032	1.17 b	1.20 b
5	76.0 a	76.3	325	324	0.0031 ab	0.0031	1.25 b	1.23 b
7	73.3 a	70.6	306	327	0.0033 a	0.0031	1.20 b	1.23 b
9	70.3 a	74.6	329	325	0.0031 abc	0.0031	1.21 b	1.19 b
11	73.0 a	75.3	343	304	0.0029 bc	0.0033	1.22 b	1.17 b
LSD (5%)	14.0	16.6	32	54	0.0003	0.0006	0.15	0.11
F-test	*	NS	NS	NS	*	NS	**	***
CV (%)	13.6	16.4	5.3	9.1	5.5	9.94	6.49	4.91
*SS49 (*Solanum scabrum*)*								
0	37.7 b	37.7	249 a	249	0.0041	0.0041	1.68 a	1.68 a
3	83.0 a	62.5	212 ab	242	0.0048	0.0042	1.31 c	1.33 b
5	73.7 a	54.5	205 ab	225	0.0049	0.0045	1.41 bc	1.42 b
7	67.0 a	76.8	174 b	258	0.0058	0.0040	1.62 ab	1.39 b
9	81.2 a	55.8	201 b	207	0.0051	0.0050	1.36 bc	1.49 b
11	88.0 a	75.7	180 b	215	0.0056	0.0050	1.41 bc	1.42 b
LSD (5%)	14.4	22.9	44	81	0.0011	0.0039	0.25	0.21
F-test	**	NS	*	NS	NS	NS	*	*
CV (%)	13.4	24.4	11.8	19.1	12.3	20.60	9.50	7.80

[1]Mean separation in columns by Duncan's multiple range test at $P \leq 0.05$.
NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

the seeds before carrying out seedling emergence tests. The seedling emergence tests were performed in RCBD design with three replicates using seed trays half-filled with sterilized medium (3 parts soil, 1 part sand, and 1 part manure). For sterilization, the soil mixture was quarter-filled in a 100-L drum and heat-treated with fire.

In each tray, 200 seeds of nightshade were sown in four rows of 50 seeds each while 100 seeds of African eggplant were also sown in four rows of 25 seeds each. Scoring of emerging seedlings was done twice a day, at 0800 and 1800 HR. Emerged seedlings were clipped after every counting to avoid miscounting. Irrigation was done as needed. Probit analysis was used to determine the log mean time to emergence and the variance of emergence. The significance of the main effects of seed priming treatments for arcsine transformed emergence percentages, emergence rate, and uniformity in emergence were compared by ANOVA using COSTAT software.

It was evident that priming significantly enhances germination performance in both species (Table 159). Germination percentage, uniformity, mean time and rate of primed seeds were generally higher compared to the control treatment for both crop species (Table 159). Quality of primed seeds increased with an increase in the number of priming days, with the optimum period ranging from 3–5 days, depending on the species and treatment (Table 159).

In conclusion, we recommend that nightshade and African eggplant seeds are primed because of the gained seed performance. This study is being repeated and the results are being validated.

Determination of seed longevity of amaranth, nightshade and African eggplant

Improved methods of seed multiplication and processing can increase the amount of seed for long-term conservation of genetic resources. This, in turn, is vital for breeding of improved varieties. Increasing seed longevity will reduce the need for frequent seed multiplication, thereby reducing risk of seed contamination and the likelihood of genetic shift from an original gene pool.

An important aspect of seed production is the maintenance of seed viability and vigor once the seed reaches physiological maturity. Main factors affecting seed viability and vigor are storage temperature and relative humidity. By using proper storage conditions, seed deterioration rates can be slowed significantly, although seed aging and loss of germination cannot be prevented. Viability is an ongoing process, which continues to decrease as seeds respire during storage.

Amaranth, nightshade and African eggplant are important vegetables crops in Africa as they contribute to reducing poverty and micronutrient deficiencies. Therefore, preserving seed longevity of these crops is of great importance. The objective of the study was to determine seed longevity and the germination potential of seeds of amaranth, nightshade and African eggplant following a range of accelerated aging treatments aimed at modeling seed deterioration in storage.

Experiments were conducted at AVRDC-RCA from September to November 2002. For accelerated aging experiments, 15-g samples of seeds of amaranth lines MX (*Amaranthus hypochondriatus*), NL and ZIM (both *A. cruentus*), 10-g samples of nightshade lines SS52, SS49 (both *Solanum scabrum*), SV (*S. villosum*), and 15-g samples of African eggplant line UVPP (*S. macrocarpon*), were used. Deionized water was added to seeds of African nightshade (1, 2 and 3 ml), and African eggplant and amaranth (1.5, 2 and 3 ml), respectively. The water was mixed with seeds in a sealable plastic bag and then cooled in a refrigerator at 11°C for 24 h to reach equilibrium moisture content. After 24 h, the seed samples were taken from the refrigerator and placed in an oven maintained at a constant temperature of 40°C for accelerated aging.

Samples were taken out from the oven after 24, 48, 72, 96 and 120 h and dried back to normal moisture contents for each treatment. After 48, 72, 96 and 120 h, the second, third and fourth samples were taken out respectively, and dried back to normal moisture contents. Seed drying was done in a desiccator for four days to attain moisture content of 6–8%. Silica gel was used as a desiccant.

The dry-aged seed samples were then sown under the conditions recommended for a standard germination test. Seed trays were filled with sterilized field soil (3 parts soil: 1 part sand: 1 part manure) and each treatment was sown with 100 seeds each. Controls for each treatment were included in the germination test. Emerged seedlings were scored twice daily in the morning and afternoon for the first 7 days and daily for the next 14 days. Emerged seedlings were clipped after every counting to avoid miscounting. Irrigation was done daily. The experiment was laid out in RCBD design with three replications.

Results were variable and inconclusive. Sometimes higher seed moisture contents increased seedling emergence percentages, rates and uniformity, while other times it decreased these characteristics. This indicates that the accelerated aging process may not have been entirely effective. Other results indicate that the seeds may have undergone a priming treatment during the process of equilibrating seeds after mixing with water.

For amaranth line ZIM and nightshade line SS52, the effect of accelerated aging was shown by the reductions in seedling emergence percentages, rates and uniformity as accelerated aging time increased (data not shown). This may indicate the loss of viability and vigor in storage is species-specific, likely due to variations in seed moisture content. This experiment was repeated in August 2003 and data are under analysis.

Effect of seed development on seed yield of amaranth

Amaranth is an indigenous leafy vegetable in Africa with great potential for improving food security on the continent. This vegetable is rich in vitamins A and C, iron, calcium, protein, and lysine, all of which are essential micronutrients lacking in most person's diets. Amaranth is an annual crop that grows rapidly and is harvested within 3–4 weeks after sowing.

The main limitation of amaranth production in Africa is lack of quality seed. Amaranth seed attains its highest quality at its physiological maturity; however most farmers find it difficult to determine this stage when harvesting seed. Most farmers wait until the onset of seed shattering before harvesting, a practice that reduces both seed yield and quality. The objective of this experiment was to determine the optimum time to harvest amaranth seed for improved seed yields.

The experiment was conducted from July to December in 2001, 2002 and 2003, at AVRDC-RCA, in Arusha, Tanzania. Two lines of *Amaranthus*, MX (*Amaranthus hypochondriatus)* and NL (*A. cruentus*), were sown and harvested at 48, 52, 56, 60, 68, and 72 days after sowing (DAS). The experiments were 2 × 4, 2 × 3, and 2 × 7 factorial experiments for years 2001, 2002, and 2003, respectively. The experiments were laid out in RCBD with three replications; each plot measured 0.6 × 6.0 m. The seeds were sown in two rows per plot and a spacing of 0.25 m between plants was used. The seeds were directly sown by drilling after mixing with sand to optimize uniformity of seeding. Two weeks after emergence, the seedlings were thinned into two plants per hill and then into one plant in the third week. A basal fertilization of 50N–10.8P–20.8K kg/ha was applied, followed by applications of 23N–0P–0K three and six weeks after sowing. Data collection was carried out and statistic analysis done using Costat, COHORT software.

Results showed a significant increase in seed yields as seed development time increased (Table 160). The 500-seed weight, however, was not clearly influenced by seed developmental stage (Table 160), which indicates that the increase in seed yields may not be correlated to physiological seed maturity. There were marked differences in seed yields among the two *Amaranthus* lines evaluated, with *A. hypochondriatus* showing significantly heavier seeds than *A. cruentus* (Table 160).

From these experiments, we conclude that seed yield of amaranth increases with time as a result of continuous flowering and new seed formation. The best time to harvest amaranth is just at the onset of seed dehiscence and when leaves start senescing.

Table 160. *Seed yield of amaranth as affected by seed development.*

Treatment	Seed yield (g/plant)			Seed yield (kg/ha)			500-seed weight (g)		
	2001	2002	2003	2001	2002	2003	2001	2002	2003
Days after sowing									
48	16.0 b[1]	8.5 c	12.8 e	1332 b	567 c	8529 e	0.36	0.31 b	0.32 a
52	18.5 b	13.4 b	32.9 d	1542 b	892 b	2202 d	0.42	0.37 a	0.33 a
56	28.1 a	21.0 a	47.4 c	2346 a	1399 a	3156 c	0.33	0.38 a	0.31 a
60	27.1 a	-	58.2 abc	2256 a	-	3878 abc	0.32	-	0.29 a
64	-	-	63.7 ab	-	-	4244 ab	-	-	0.26 b
68	-	-	57.2 bc	-	-	3811 bc	-	-	0.24 b
72	-	-	71.2 a	-	-	4744 a	-	-	0.30 a
LSD (5%)	10.4	4.7	12.6	870	311	838	0.14	0.01	0.04
F-test	*	***	***	*	***	***	NS	***	*
CV (%)	34	25.4	21.6	34	25.4	21.6	28.9	2.49	11.1
Lines									
MX *(A. hypochondriatus)*	27.7 a	19.5 a	49.8 a	2306 a	1300 a	3317 a	0.46 a	0.48 a	0.39 a
NL *(A. cruentus)*	18.0 b	9.1 b	48.3 a	1496 b	605 b	3221 b	0.26 b	0.22 b	0.19 b
LSD (5%)	7.0	3.8	6.7	586	254	448	0.09	0.01	0.02
F-test	*	***	NS	*	***	NS	***	***	***
CV (%)	34	25.4	21.6	34	25.4	21.6	28.9	2.49	11.1

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

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Training

Regional Vegetable Crops Production Training Course

The 10th Regional Vegetable Production and Research Training Course for African countries was held from 7 July to 7 November 2003. Twenty-four participants (10 female and 14 male) from NARES in 20 countries, namely Tanzania (4), Malawi (1), Zambia (1), Ghana (1), Angola (1) Zimbabwe (1), South Africa (1), Lesotho (1), Botswana (1), Kenya (1), Senegal (1), Swaziland (1), Togo (1), Sudan (1), Eritrea (1), Uganda (1), Seychelles (1), Namibia (1), Ethiopia (1), and Burkina Faso (1) attended the training course. A course evaluation by the training participants found the lectures and practicals useful for them to improve the quality of their research, training and extension duties upon returning to work. The names of these and other trainees at AVRDC-RCA are listed on page 187.

Training courses in nursery management, vegetable production, IPM techniques, and vegetable processing and utilization

Twelve two-day courses were conducted in Kilimanjaro, Arusha and Manyara regions in northern Tanzania for women groups and small-scale farmers. Two hundred and fifty farmers were trained, 90% of them women. The trainees learned new skills on how to establish seedling nurseries and were familiarized to new vegetable varieties, production and IPM techniques. They also learned vegetable processing, preservation and utilization techniques to prevent micronutrient malnutrition, including a component on proper hygiene and sanitation practices.

Field day

A Farmer's Field Day was held at AVRDC-RCA on 22 October 2003. The event featured new vegetable varieties and technology demonstrations for applied vegetable production. A total of 140 farmers, research scientists, and personnel from NARES and the private sector attended the field day. Demonstrations were followed by a question-and-answer session with the aim of addressing farmer's problems.

Workshops

National review and planning workshop in Malawi

In collaboration with the Department of Agricultural Research Services, Malawi Ministry of Agriculture, Irrigation and Food Security, a national review and planning workshop on vegetable research and development in Malawi was held at the Malawi Institute of Management (MIM) in Lilongwe, Malawi, on 23–24 September 2003. The objectives of the workshop were to identify the current constraints to vegetable production and develop a workplan for strategies in vegetable R&D in Malawi. Forty-five participants from NARES, relevant ministries, universities, and farmer organizations attended the workshop.

Planning workshop on promotion of neglected indigenous vegetable crops

A planning workshop for BMZ/GTZ funded project on "Promotion of Neglected Indigenous Vegetable Crops" was held at AVRDC-RCA from 26–28 March 2003. The purpose of the project is to enhance the role of neglected indigenous vegetables and vegetable legumes for improved nutrition, healthy diet, and diversified income generation in home garden and commercial farming systems in eastern and southern Africa. Twenty-seven participants from Tanzania, Uganda, Malawi, Kenya, Rwanda, Germany, and Taiwan attended the workshop. The participants were from NARES, NGOs, international agricultural research centers, donor organizations and universities. The workshop developed a workplan to implement the activities of the project.

For more information, contact: M.L. Chadha

West Africa Vegetable Network

AVRDC – WARDA collaboration on vegetable research and development

The objective of this joint project between AVRDC – The World Vegetable Center and WARDA – the Africa Rice Center is to promote year-round vegetable production and consumption in West Africa. The project is focusing on increasing productivity and sustainability of vegetable cultivation through the application of improved varieties and practices as well as the generation of new technologies. Work is conducted in close collaboration with national research institutions of Burkina Faso, Benin, Chad, Côte d'Ivoire, The Gambia, Mali, Senegal and Togo.

Since the project started in September 2003, time has been devoted to the assessment of vegetable consumption, production and research in West Africa and to establish partnerships with vegetable specialists in the national research institutions. These partnerships will address needs related to the development of integrated rice-vegetable systems, which include: 1) selection of adapted improved varieties of tomato, peppers, onion and shallot for West Africa; 2) identification of promising indigenous vegetables; 3) development of technologies to enable tomato production in the hot-dry season; 4) training of vegetable specialists and extensionists on vegetable management practices, disease and insect pests diagnosis, and seed production technologies; 5) identification of pathways for wider-scale seed multiplication of selected improved varieties; and 6) dissemination of information on vegetable cultivation and seed production practices.

For more information, contact:
Virginie Levasseur

Organizational statement

Our Mission

Reduce malnutrition and poverty among the poor through vegetable research and development

Our Strategy

Build partnerships and mobilize resources from private and public sectors to effectively tackle problems of vegetable production and consumption in the tropics. This strategy will contribute to:

- Increased productivity of the tropical vegetable sector
- Equity in economic development in favor of rural and urban poor
- Healthy and more diversified diets for low-income families
- Environmentally-friendly and safe production of vegetables
- Improved sustainability of cropping systems

Our Core Expertise

- Management of diverse vegetable germplasm
- Innovations in crop improvement, including the use of molecular tools
- Sustainable production of safe and nutritious vegetables in the tropics
- Networks of strategic alliances for generating and sharing knowledge
- Analysis of direct and indirect impacts of vegetables

Our Unique Role

AVRDC functions as a catalyst to:

- Build international and interdisciplinary coalitions that engage in timely issues
- Generate and disseminate international public goods that address economic and nutritional needs of the poor
- Collect, characterize, and safeguard genetic resources for worldwide use
- Provide globally accessible, user-friendly, science-based information

Board members

Mr. Declan J. Walton, Chairman[1]
United Kingdom

Dr. Paul M.H. Sun, Chairman[2]
Republic of China

Dr. Gilles Saint-Martin, Vice-Chairman[2]
France

Dr. Shan-Ney Huang
Republic of China

Dr. Viroch Impithuksa
Thailand

Dr. Kang-Kwun Kim
Republic of Korea

Dr. Romano M. Kiome
Kenya

Dr. Stephan Krall
Germany

Mr. Ming-Lai Wang
Republic of China

Dr. William Medrano[2]
Philippines

Dr. Ichiji Yamashita[2]
Japan

Mr. Hiroto Hirakoba[2]
Japan

Mr. Robert Havener[2]
USA

Dr. Anna Ferro-Luzzi[1]
Italy

Dr. Richard L. Lower[1]
United States of America

Dr. Eliseo R. Ponce[1]
Philippines

Mr. Hideo Tarumi[1]
Japan

Dr. Hiroaki Yoshikawa[1]
Japan

Dr. Thomas A. Lumpkin (ex-officio)[2]
Director General, AVRDC

[1] Left during 2003
[2] Assumed office during 2003

Staff

Administration

Dr. Thomas A. Lumpkin[2], Director General, <lumpkin@avrdc.org>
Dr. Jürgen Friedrichsen, Deputy Director General, cum Acting Director of Administration, <jfrie@avrdc.org>
Dr. Meisaku Koizumi, Assistant Director General, <koiz_arc@ksc.th.com>
Dr. S. Shanmugasundaram[3], Deputy Director General (Research) <sundar@avrdc.org>
Friedemann Markus Kaiser[2], Grant and Gift Development Coordinator, <kaiser@avrdc.org>
Shaw-wei Chai, Associate Comptroller, <nancy@avrdc.org>
Kuo-teng Ma[1], Internal Auditor, <samuel@avrdc.org>
Chia-hui Wu[2], Internal Auditor, <ritawu@avrdc.org>
Jeng-hua Chen, Superintendent, Technical Service Office, <jhchen@avrdc.org>
Sui-fang Wu, Superintendent, Food and Dormitory Services Unit, <lydia@avrdc.org>

Program I: Vegetables in cereal-based systems

Dr. S. Shanmugasundaram, Program Director (Project 2 Coordinator), <sundar@avrdc.org>

Bulb Allium Unit

Dr. Paul A. Gniffke, Plant Breeder (Pepper/Allium), <gniffke@avrdc.org>
Shin-jiun Cherng, Principal Research Assistant, <sjcherng@avrdc.org>
Swee-suak Ko[4], Principal Research Assistant, <rachelko@avrdc.org>

Legume Unit

Dr. S. Shanmugasundaram, Plant Breeder (Project 3 Coordinator), <sundar@avrdc.org>
Miao-rong Yan, Principal Research Assistant, <yanmr@avrdc.org>

Pepper Unit

Dr. Paul A. Gniffke, Plant Breeder (Pepper/Allium), <gniffke@avrdc.org>
Sheue-chin Shieh, Principal Research Assistant, <jin@avrdc.org>
Dr. Do-Ham Pae, Plant Breeder (Pepper), <pdoham@avrdc.org> (Seconded Scientist from Korea)

Plant Pathology: Mycology Unit

Dr. Lowell L. Black[1], Plant Pathologist, <llblack@avrdc.org>
Dr Tien-chen Wang, Associate Specialist, <tcwang@avrdc.org>
Zong-ming Sheu, Principal Research Assistant, <zmsheu@avrdc.org>
Chien-hua Chen[2], Principal Research Assistant, <wallace@avrdc.org>

Plant Pathology: Virology Unit

Dr. Sylvia K. Green, Plant Pathologist, <skg@avrdc.org>
Wen-shi Tsai, Principal Research Assistant, <wenshi@avrdc.org>
Su-ling Shih, Principal Research Assistant, <suling@avrdc.org>

Plant Physiology Unit

Dr. C. George Kuo, Plant Physiologist, <gkuo@avrdc.org>
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Huei-mei Chen, Associate Specialist, <hmchen@avrdc.org>
Jean-yu Lin, Principal Research Assistant (Project) <jean@avrdc.org>
Li-chien Weng, Principal Research Assistant (Project) <claire@avrdc.org>
Yen-wei Wang, Research Assistant (Project) <vivian@avrdc.org>

Tomato Unit

Dr. Peter H. Hanson, Plant Breeder (Project 1 Coordinator), <hansp@avrdc.org>
Jen-tzu Chen[3], Associate Specialist, <jtchen@avrdc.org>

Program II: Year-round vegetable production systems

Dr. Lowell L. Black[1], Program Director (Project 4 Coordinator), <llblack@avrdc.org>

Crop and Soil Management Unit

Dr. Rajasekaran Lada[1], Vegetable Production Physiologist and Head of Crop and Soil Management Unit, <rlada@avrdc.org>
Dr. Chin-hua Ma, Associate Specialist, <mach@avrdc.org>
Dolores R. Ledesma, Assistant Specialist, <didit@avrdc.org>
Deng-lin Wu[3], Principal Research Assistant, <dlwu@avrdc.org>

Entomology Unit

Dr. N. S. Talekar, Entomologist (Project 5 Coordinator), <talekar@avrdc.org>
Mei-ying Lin, Principal Research Assistant, <turtle@avrdc.org>
Fu-cheng Su[3], Principal Research Assistant, <sufc@avrdc.org>

Nutrition and Analytical Laboratory

Ray-yu Yang, Assistant Specialist, <ryy074@avrdc.org>
Wan-jen Wu, Research Assistant, <janewu@avrdc.org>

Olericulture Unit

Dr. Rajasekaran Lada[1], Vegetable Production Physiologist and Head of Crop and Soil Management Unit, <rlada@avrdc.org>
Lien-chung Chang, Associate Specialist, <lcchang@avrdc.org>

Plant Pathology: Bacteriology Unit

Dr. Jaw-fen Wang, Associate Plant Pathologist (Project 7 Coordinator), <jfw@avrdc.org>
Chih-hung Lin, Principal Research Assistant, <chlin@avrdc.org>
Ying-ju Tsai, Research Assistant, <dinah@avrdc.org>

Socioeconomics Unit

Dr. Mubarik Ali, Agricultural Economist (Project 6 Coordinator), <mubarik@avrdc.org>
Dr. Katinka Weinberger, Assistant Scientist – Socio-Economist[3], <weinberg@avrdc.org>
Mei-huey Wu, Principal Research Assistant, <mhwug@avrdc.org>

Program III: Collaboration in research and germplasm management

Dr. C. George Kuo, Program Director (Project 9 Coordinator), <gkuo@avrdc.org>

Computer Services Unit

Hsien-yang Tien, Assistant Specialist, <tien@avrdc.org>
Yuh-ling Chen, Research Assistant, <shirley@avrdc.org>

Genetic Resources and Seed Unit

Dr. Liwayway M. Engle, Geneticist and Head (Project 8 Coordinator), <lmengle@avrdc.org>
Dr. Takanori Sato[1], Associate Geneticist (Seconded Scientist from Japan), <ryutoku@avrdc.org>
Dr. Hidekazu Sasaki[2], Associate Vegetable Physiologist, <hsasaki@avrdc.org>
Yung-kuang Huang, Principal Research Assistant, <ykhuang@avrdc.org>
Jia-chain Shieh, Research Assistant, <jcshieh@avrdc.org>
Ching-huan Chang, Research Assistant, <jessica@avrdc.org>
Min-mei Su[2], Research Assistant (Project), <kasumi@avrdc.org>

Information and Documentation Unit: Library

Fang-chin Chen, Officer/Chief Officer, <fcchen@avrdc.org>

Communications and Training Office (CTO)

Tom Kalb, Information and Training Officer and Head (Project 10 and 11 Coordinator), <kalb@avrdc.org>
Chris Cottorone[1], Associate Information Officer, <chris@avrdc.org>
Yi-ming Chen, Principal Research Assistant, <ymchen@avrdc.org>

Technology Promotion and Services Unit

Dr. George Kuo, Acting Unit Head (Project 12 Coordinator), <gkuo@avrdc.org>
Li-ju Lin, Principal Research Assistant, <mandy@avrdc.org>
Yun-yin Hsiao, Principal Research Assistant, <ruby@avrdc.org>

Regional Programs

Asian Regional Center, Bangkok, Thailand

Dr. Meisaku Koizumi[1], Acting Director and CLV Network Coordinator, <koiz_arc@ksc.th.com>
Efren Altoveros, Training and Information Officer, <ealtoveros@yahoo.com>

Regional Center for Africa, SADC-AVRDC-CONVERDS, Arusha, Tanzania

Dr. Madan Mohan Lal Chadha, Director, <avrdc-arp@cybernet.co.tz>
Dr. Mel O. Oluoch, Training Specialist at AVRDC-RCA, <avrdc-arp@cybernet.co.tz>
Dr. Drissa Silue, Associate Plant Pathologist at AVRDC-RCA, <avrdc-arp@cybernet.co.tz>

AVRDC' s "Peri-urban Vegetable Production Systems" Project Philippines Site

Dr. James R. Burleigh[1], Philippines Site Coordinator, (c/o Dr. Gerard Bruin, Philippine Site Director <gbruin@ne-link.net>)

AVRDC/CIRAD "SE-Asia Peri-urban Agriculture Project," Hanoi, Vietnam

Dr. Hubert de Bon[1], Production Systems Specialist and Project Coordinator (Seconded Scientist from France), <hubertdebon@hn.vnn.vn>

AVRDC/WARDA "Collaboration on Promotion of Superior Vegetable Cultivars" Project, Bamako, Mali

Dr. Virginie Levasseur[2], Associate Scientist in Crop Production

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[1] Left during 2003
[2] Arrived during 2003
[3] Promoted in 2003
[4] On study leave

Trainees

AVRDC Headquarters

Biotechnology Unit

Katherine R. Ramirez, Philippines, 01 October 2003–30 April 2004, Genetics and molecular biology.

Hai T.H. Truong, Vietnam, 01 September 2003–28 February 2004, Identification of molecular markers for resistance to anthracnose by using AFLP.

Bulb Allium Unit

Fu-hui Deng, Taiwan, 01 July 2003–29 August 2003, Pathogenicity of isolates of *Fusarium oxysporum* and *Aspergillus niger* on onion scale disks.

Communication and Training Office

Raymond F. Cerkauskas, Canada, 31 August 2003–31 July 2004, To write a vegetable disease field guide and write fact sheets relating to the diagnosis and control of several vegetables.

Crop and Ecosystem Management Unit

Yong-Hoon Han, Korea, 31 August 2003–29 November 2003, (1) Nutrient management of plug seedlings for efficient transplants production and high qualities; and (2) Process for assessing anthracnose (*Colletotrichum acutatum, C. capsici, C. gloeosporioides*) reactions of peppers.

Boumchamh Komboungnasith, Lao PDR, 04 March 2002–27 February 2003, Techniques for year-round vegetable production.

Shin-yi Kuo, Taiwan, 01 July 2003–29 August 2003, Evaluation of *Capsicum* spp. accessions for tolerance to flooding conditions during the hot-wet summer.

Akiko Tomaru, Japan, 25 February 2003–22 March 2003, Vegetable transplant production.

Manuel C. Palada, USA, 10 February 2003–18 February 2003, International Cooperators' Guides for indigenous vegetable and off-season tomato production.

Entomology Unit

Chanthy Pol, Cambodia, 03 April 2003–28 November 2003, The dependence of eggplant fruit and shoot borer (*Leucinodes orbonalis*) on eggplant for feeding and oviposition.

Marianne Cherise C. Lazaro, Philippines, 01 April 2003–30 May 2003, Chemical attractants of vegetables to insects.

R Srinivasan, India, 09 October 2002–29 March 2003, Basic aspects of host mediated behavior of tomato fruitworm (*Helicoverpa armigera*).

Meng-ying Lin, Taiwan, 01 July 2003–29 August 2003, Biochemical characterization of infestation of *Cleome gynandra* by various crucifer insect pest and characterize of resistance to *Callosobruchus chinensis* in some *Vigna* accessions.

Shiue-re Wu, Taiwan, 01 July 2003–29 August 2003, Identification of biochemical factors responsible for attraction or infestation of cabbage webworm, diamondback moth, and striped flea beetle to *Barbarea vulgaris*.

Chun-chun Chang, Taiwan, 01 July 2003–29 August 2003, Identification of biochemical factors responsible for oviposition of *Maruca vitrata* on *Sesbania cannabina*.

Yu-tz Hsu, Taiwan, 01 July 2003–29 August 2003, Mating and sex pheromone related behavior of eggplant fruit and shoot borer in the presence of synthetic sex pheromone.

Shu-yen Huang, Taiwan, 01 July 2003–29 August 2003, Evaluation of holy basil extracts for attraction of CWW, DBM, and CAW.

Shao-chuan Hsu, Taiwan, 01 July 2003–29 August 2003, Effect of components sex pheromone of *Leucinodes orbonalis* on various sex pheromone related activities.

Genetic Resources and Seed Unit

Jessica Paula C. Mallillin, Philippines, 01 April 2003–30 May 2003, Chromosome number and meiotic behavior of selected *Solanum* species.

Al-Marie Grace T. Logrono, Philippines, 01 April 2003–30 May 2003, Analysis of genetic diversity in *Amaranthus* species using RAPD-PCR.

Yi-wei Tsai, Taiwan, 01 July 2003–29 August 2003, Analysis of diversity in *Corchorus* spp. (white jute) using random amplified polymorphic DNA-polymerase chain reaction (RAPD-PCR).

Pei-sheng Chu, Taiwan, 01 July 2003–29 August 2003, Germination testing of tomato seeds stored in medium-term and short-term storage.

Shu-yi Ho, Taiwan, 01 July 2003–29 August 2003, Viability of pepper seeds stored for different periods in medium-term storage.

Yung-lin Hsieh, Taiwan, 01 July 2003–29 August 2003, Variation within accession in mungbean.

Chien-liang Chou, Taiwan, 01 July 2003–29 August 2003, Viability of soybean seeds stored in different storage rooms.

Tanya Jane C. Escalona, Philippines, 01 April 2003–30 May 2003, Evaluation on antioxidant activity in leaf of pigeon pea.

Radha K. Pant, India, 24 March 2003–30 March 2003, Conservation, storage and utilization of vegetable germplasm.

Hari Har Ram, India, 24 March 2003–30 March 2003, Vegetable germplasm conservation and evaluation.

Young Chae, Korea, 01 December 2002–31 March 2003, Characterization of *Capsicum* spp. and evaluation of selected accessions of *Capsicum* spp. for reaction to anthracnose and Phytophthora.

Su-yi Chou, Taiwan, 01 July 2003–29 August 2003, The drying curves of lima bean, garland chrysanthemum and amaranth.

Yi-xuan Wu, Taiwan, 01 July 2003–29 August 2003, Drying curves of some crops seeds under different conditions: eggplant, chinese cabbage, jute, and red Malabar spinach.

Legume Unit

Wen-long Chen, Taiwan, 01 July 2003–29 August 2003, Effects of storage conditions on germination rate of soybean.

Jung-Kyung Moon, Korea, 11 January 2003–13 June 2003, (1) Generation advance and seed multiplication of Korea soybean breeding lines; and (2) fingerprinting of AVRDC soybean cultivars and potyvirus- infected soybean plants using molecular technique and different cultivars.

Davinder K. Grover, India, 01 December 2002–28 February 2003, Research on analysis of the baseline survey of mungbean in Indo-Gangetic Plains of India with emphasis on Punjab.

Frailaine M. Carandang, Philippines, 01 April 2003–30 May 2003, Legume breeding.

Harbhajan S. Sekhon, India, 15 July 2003–10 October 2003, Agronomic research on improved mungbean cultivars.

Kiran Bains, India, 17 March 2003–15 April 2003, Household nutrition survey and iron-rich mungbean recipe development.

Dhan P. Singh, India, 15 July 2003–14 October 2003, Evaluation and selection of elite mungbean breeding lines for India.

De-ying Hou, Taiwan, 01 July 2003–29 August 2003, Breeding of male-sterile vegetable soybean.

Tejinderjit S. Bains, India, 15 July 2003–10 October 2003, Agronomic research on improved mungbean cultivars.

Nutrition and Analytical Laboratory

Hsuan-hua Tseng, Taiwan, 01 July 2003–29 August 2003, Alpha-gamma-and delta-tocopherol contents of 98 edible plants.

Tzu-I Hsu, Taiwan, 01 July 2003–29 August 2003, Effect of low pH condition on antioxidant activity of *Cassia tora, Cassia sophera, Cedrela sinensis, Ipomea batatas, Moringa oleifera*, and *Rosemarinus officinalis*.

Mei-ha Chio, Taiwan, 01 July 2003–29 August 2003, Potential use of near infrared spectroscopy for the analysis of vrious types of vegetables.

Ceferino A. Lustre, Philippines, 01 April 2003–30 May 2003, Changes of antioxidant activities of vegetables during in vitro digestion.

Lou Mervyn A. Tec, Philippines, 01 April 2003–30 May 2003, Effect of high and low temperatures on radical powers of vegetables.

Cheryl O. Dalid, Philippines, 01 April 2003–30 May 2003, Relationship of antioxidant activities and near NIR spectra of vegetables.

Rylene A. Baquilod, Philippines, 01 April 2003–30 May 2003, Using NIRS method for vegetable quality evaluation.

Olericulture

Manuel C. Palada, USA, 10 February 2003–18 February 2003, International Cooperators' Guides for indigenous vegetable and off-season tomato production.

Pepper Unit

Myeong-Cheoul Cho, Korea, 02 May 2003–15 September 2003, Effect of temperature on infection and symptom expression of chilli veinal mottle virus (ChiVMV).

Sonam, Bhutan, 03 October 2002–29 January 2003, (1) Pepper seed production; and (2) tomato breeding and hybrid seed production.

Rinchen Sonam, Bhutan, 03 October 2002–29 January 2003, (1) Pepper seed production; and (2) tomato breeding and hybrid seed production.

Wing Yee Liu, China, 17 March 2003–22 March 2003, The stability of AVRDC's cytoplasmic male sterile (CMS) pepper lines in winter season.

Wing Yee Liu, China, 01 October 2002–30 January 2003, The stability of AVRDC's cytoplasmic male sterile (CMS) pepper lines in winter season.

Sheryl N. Sierra, Philippines, 01 April 2003–30 May 2003, Genetic study of geminivirus resistance in tomato lines.

Shiferaw N. Urguma, Ethiopia, 04 November 2003–29 November 2003, Breeding and evaluation of tomato and pepper lines.

Hai T.H. Truong, Vietnam, 01 September 2003–28 February 2004, Identification of molecular markers for resistance to anthracnose by using AFLP.

Plant Pathology–Bacteriology Unit

Vanla Dittapongpitch, Thailand, 17 May 2003–16 July 2003, To summarize results of collaborated projects, prepare manuscripts for publications, and discuss future collaboration.

Yu-ting Tzeng, Taiwan, 01 July 2003–29 August 2003, Preliminary studies on the competition among *Ralstonia solanacearum* strains in tomato.

Wen-rong Hsiao, Taiwan, 01 July 2003–29 August 2003, Use urea and calcium oxide as a soil amendment to control tomato bacterial wilt.

Raymond F. Cerkauskas, Canada, 31 August 2003–31 July 2004, To write a vegetable disease field guide and write fact sheets relating to the diagnosis and control of several vegetables.

Plant Pathology–Mycology Unit

Tze-huang Shen, Taiwan, 01 July 2003–29 August 2003, Mating type and metalaxyl sentivity of Taiwanese *Phytophthora infestans* isolates collected in 2003.

Koshlendra K. Pandey, India, 11 October 2003–28 December 2003, Integrated disease management of vegetable crops particularly fungal diseases.

Plant Pathology–Virology Unit

Gug-Seoun Choi, Korea, 02 May 2003–29 October 2003, Molecular characterization of chilli veinal mottle virus.

Shu-haei Guo, Taiwan, 01 July 2003–29 August 2003, Distribution of two distinct local and three exotic tomato geminiviruses in Taiwan by the use of specific primers.

Ramadhani Safitri, Indonesia, 03 March 2003–14 March 2003, Identification, screening and control of geminiviruses.

Plant Physiology Unit

Su-ru Wu, Taiwan, 01 July 2003–29 August 2003, Effects of flooding stress on tomato and eggplant.

Chien-hui Yang, Taiwan, 01 July 2003–29 August 2003, Flooding tolerance of tomato and eggplant.

Woo-Moon Lee, Korea, 01 July 2003–29 July 2003, Identification of transformed tomato by southern blot analysis.

Mun-Jung Lee, Korea, 01 July 2003–29 July 2003, Identification of transformed tomato by southern blot analysis.

Ngoc Bao Chau Nguyen, Vietnam, 14 January 2002–13 January 2003, Agrobacterium-mediated transformation of tomato (*Lycopersicon esculentum* L.) with new pest resistance protein-Vrcrp.

Jacquelyn Victoria, Philippines, 01 April 2003–30 May 2003, Genetic diversity analysis of garlic.
Michael Leonardo C. Delomen, Philippines, 01 April 2003–30 May 2003, Morphological and molecular characterization of mungbean

Socio-economics

Andrea Ilsabe Kuehn, Germany, 11 September 2002–20 February 2003, Economic impacts of tomato production in Taiwan.

Technology Promotion and Services

Hsing-hua Tsai, Taiwan, 09 June 2003–29 August 2003, Observation trial of *Baobab* seedlings as leafy vegetables.
Ting-chen Chu, Taiwan, 01 July 2003–29 August 2003, Productivity evaluation of ivy gourd young shoots by staking and non-staking methods.
Hung-wei Chen, Taiwan, 01 July 2003–29 August 2003, Leaf productivity of *Moringa* seedlings.
Yong-yi Chen, Taiwan, 01 July 2003–29 August 2003, Evaluation of flooding tolerance in indigenous vegetables.

Tomato Unit

Sonam, Bhutan, 03 October 2002–29 January 2003, (1) Pepper seed production; and (2) tomato breeding and hybrid seed production.
Rinchen Sonam, Bhutan, 03 October 2002–29 January 2003, (1) Pepper seed production; and (2) tomato breeding and hybrid seed production.
Wing Yee Liu, China, 17 March 2003–22 March 2003, The stability of AVRDC's cytoplasmic male sterile (CMS) pepper lines in winter season.
Wing Yee Liu, China, 01 October 2002–30 January 2003, The stability of AVRDC's cytoplasmic male sterile (CMS) pepper lines in winter season.
Sheryl N. Sierra, Philippines, 01 April 2003–30 May 2003, Genetic study of geminivirus resistance in tomato lines.
Shiferaw N. Urguma, Ethiopia, 04 November 2003–29 November 2003, Breeding and evaluation of tomato and pepper lines.

AVRDC-Regional Center for Africa

Graduate Research Trainees

Tefera Tolera (from June 21, 2003 to present)
Gudrun Keller (from June 7 to October 1, 2003)
Gideone Mwai (from December 1, 2003 to present)

Socio-economics (23 February to 31 March 2003)

Japheth Pallangyo, Undergraduate Student Trainee, Tanzania
Shishira Sadik, Undergraduate Student Trainee, Tanzania
Ayub Mndeme, Undergraduate Student Trainee, Tanzania
Sylvestre G. Ngenzi, Undergraduate Student Trainee, Tanzania

Vegetable Crops Production and Research (7 July–7 November 2003)

Evance R. Shaba, Production Research Scholar, Malawi
Susan Akinyi Otieno, Production Research Scholar, Kenya
Boipuso Chepete, Production Research Scholar, Botswana
Silvanus K. Naunyango, Production Research Scholar, Namibia
Maria Alfredo Joao Damingos, Production Research Scholar, Angola
Sandra Julianne Sinon, Production Research Scholar, Seychelles
Stephen Phuza Maseko, Production Research Scholar, Swaziland

Timothy Phillemon Sakala, Production Research Scholar, Zambia
Hind Abdelmonem Elbashir, Production Research Scholar, Sudan
Batumbya Isaac, Production Research Scholar, Uganda
Naledi Peter Martins, Production Research Scholar, Lesotho
Selamawit Katema Ashinie, Production Research Scholar, Ethiopia
Komlan Batawila, Production Research Scholar, Togo
Antonia Y. Tetteh, Production Research Scholar, Ghana
Phillip Ndivhaleni Rammela, Production Research Scholar, South Africa
Safari Philip M., Production Research Scholar, Tanzania
Mamadou Koutou, Production Research Scholar, Burkina Faso
Fatou Diop, Production Research Scholar, Senegal
Gamie Omer Ali, Production Research Scholar, Eritrea
Bahati Nehemia Samzugi, Production Research Scholar, Tanzania
Shomari Mjape Sijali, Production Research Scholar, Tanzania
Dhaiyya Rashid Abdalla, Production Research Scholar, Zanzibar, Tanzania
Shungu Doris Ndebele, Production Research Scholar, Zimbabwe
Gregory Theresia Leopold, Production Research Scholar, Tanzania

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Financial information

Summary financial statement, 2003. **(USD 000)**

	Core		Project		Total		Budget (Board Approved)	
Revenues								
Grant	4,745		4,612		9,356		8,720	
Other revenues and support	657		0		657		372	
Total revenues	**5,402**	**54%**	**4,612**	**46%**	**10,013**	**100%**	**9,092**	
Expenditures								
Object Expenditures								
Personnel								
IRS	1,153		700		1,852	20%	1,812	18%
NRS	2,747		573		3,319	35%	3,150	32%
Operating expenses								
Field labor	461		244		705	7%	691	7%
Supplies	185		748		933	10%	869	9%
Travel	56		164		219	2%	298	3%
Training and workshop	18		748		766	8%	587	6%
General expenses	267		538		805	8%	941	10%
Contract outreach research	0		651		651	7%	1,287	13%
Equipment, facilities & renovations	0		247		247	3%	203	2%
Total	**4,886**		**4,612**		**9,497**	**100%**	**9,838**	**100%**
Strategic Themes								
1. Genetic improvement	936		1,063		2,000	21%	2,272	23%
2. Safe, year-round vegetables	893		1,164		2,057	22%	2,409	24%
3. Indigenous vegetables	359		1,354		1,713	18%	1,287	13%
4. Information dissemination	623		667		1,289	14%	1,263	13%
Administration and Services	2,075		363		2,438	26%	2,607	26%
Total expenses	**4,886**	**51%**	**4,612**	**49%**	**9,497**	**100%**	**9,838**	**100%**
Revenues less expenses	516		0		516		(746)	
Translation adjustment	(352)				(352)			
Changes in net assets	164				164			
Net assets beginning of the year	386		0		386		386	
Net assets at the end of the year[1]	**550**		**0**		**550**		**(360)**	

[1] Excludes working capital fund of $900,000 as end of 2003.

Breakdown of revenues, 2003 and 2004. (USD 000)

	2004 Proposed		2003 Actual		2003 (Board Approved)	
Core funds						
ROC	4,235		4,152		4,034	
United States	0		200		200	
Japan	96		96		96	
Korea	75		0		75	
Thailand	101		110		101	
Philippines	50		39		50	
France	76		147		147	
UK/DFID	540		0		0	
Other revenues (see below)	405		657		372	
Subtotal	**5,578**	**51%**	**5,401**	**54%**	**5,075**	**56%**
Project funds[1]						
ACIAR	12		86		69	
Asian Development Bank	548		354		520	
APSA	20		0		0	
France	212		123		180	
Farm Africa	54		0		0	
Germany/BMZ/GTZ	1,363		1,475		1,490	
IPGRI	0		40		0	
Japan	62		83		62	
JIRCAS	200		0		0	
Korea/RDA	20		53		40	
ROC/COA & MOFA	1,011		368		0	
ROC/COA & NSC	723		893		649	
Swiss/SDC	399		256		496	
UK/DFID	352		315		281	
USAID	337		200		200	
USDA	0		40		30	
Training and other	0		326		0	
Subtotal	**5,313**	**(49%)**	**4,612**	**46%**	**4,017**	**44%**
Contribution in-kind[2]						
France	(2)		(1)		(1)	
Japan	(1)		(1)		(1)	
Korea	(1)		(1)		(1)	
Total revenues	**10,891**	**100%**	**10,013**	**100%**	**9,092**	**100%**
Other						
Revenue on project support			532			
Interest earned			73			
Miscellaneous income			10			
Refund on previous payment			9			
Technical service			3			
Training overhead			30			
Total			**657**			

[1] The grants are recognized as revenue based on the expenses actually incurred. Excess of grants received over expenses, representing grants applicable to succeeding year is classified as accounts payable.

[2] Number of outposted scientists (in kind).

Statement of financial position, 2003. (USD)

		Totals
Current Assets		
Cash		4,962,370
Petty cash		2,545
Deposit paid		29
Accounts Receivable		822,568
Employees	19,645	
Regional centers	802,923	
Advance payment		1,324,506
Contract outreach research	565,339	
Donor project	751,805	
Prepaid expenses	7,362	
Inventories		8,524
Fixed Assets		51,104
Equipment and furniture	72,024	
Less accumulated depreciation	(20,920)	
Total Assets		**7,171,645**
Current Liabilities		
Accounts payable		2,819,571
Grant received in advance	2,450,664	
Accrued expenses	368,907	
Total Liabilities		**2,819,571**
Net Assets (assets less liabilities and translation adjustment)		3,756,014
Operation fund	549,771	
Working capital fund	900,000	
Appropriated fund	2,306,243	
Total Net Assets		3,756,014
Translation Adjustment		596,060
Total Liabilities and Net Assets		**7,171,645**

Meteorological information

Data (monthly mean) collected at the AVRDC weather station, Shanhua Taiwan, 2003.

	Daily avg humidity (%)	Daily air temp. max (°C)	Daily air temp. min (°C)	Daily soil temperature 10 cm max (°C)	Daily soil temperature 10 cm min (°C)	Daily soil temperature 30 cm max (°C)	Daily soil temperature 30 cm min (°C)	Daily avg wind velocity (m/s)	Daily avg solar radiation (W-hour/m^2)	Monthly precipitation (mm)	Daily avg evaporation (mm)
January	82	23.1	13.0	22.0	17.6	20.7	19.4	2.38	3516	9.3	3.0
February	79	26.2	16.3	25.2	19.9	22.5	21.2	2.41	4107	16.8	3.5
March	78	26.6	17.2	28.4	21.7	24.9	23.4	2.23	4155	12.4	3.8
April	82	29.9	22.0	30.0	25.1	27.5	26.2	1.80	4142	60.0	4.0
May	72	32.6	24.1	34.6	28.2	31.0	29.4	1.89	5203	62.0	6.3
June	76	32.3	25.0	32.4	27.5	30.2	28.8	2.49	4925	495.0	6.4
July	68	35.1	26.7	33.8	29.6	31.4	30.4	2.26	5588	46.5	6.1
August	76	33.9	26.1	33.0	28.6	31.1	29.7	1.94	4749	251.1	4.9
September	75	33.4	25.7	33.1	28.1	30.9	29.6	1.60	4495	81.0	4.1
October	67	31.5	21.6	30.5	25.6	28.6	27.6	1.54	4452	0	4.3
November	74	29.1	20.6	29.8	24.8	27.4	26.3	1.97	3176	3.0	3.4
December	64	25.2	13.5	26.5	19.9	23.8	22.5	2.13	3474	0	3.6

Data (monthly mean)collected at Tengeru weather station, Arusha,Tanzania, 2003.

Month	Daily air temp. (°C) max	Daily air temp. (°C) min	Monthly precipitation (mm)	Rain days	Daily avg evaporation (mm)	Relative humidity (%)
January	27.0	17.8	52.5	2	4.6	89.6
February	29.6	19.1	69.5	6	6.3	88.3
March	29.1	20.1	62.5	4	6.0	95
April	26.6	26.6	123.0	9	4.1	95
May	21.9	15.9	180.7	16	1.9	94
June	22.3	16.4	32.0	3	2.5	88
July	21.9	14.5	6.0	3	3.2	94
August	23.0	15.0	3.5	1	4.2	94
September	25.4	16.7	26.5	4	4.4	88
October	27.5	16.2	12.0	4	5.2	94
November	28.7	19.5	5.5	2	5.8	90
December	30.6	19.9	44.5	2	5.0	95