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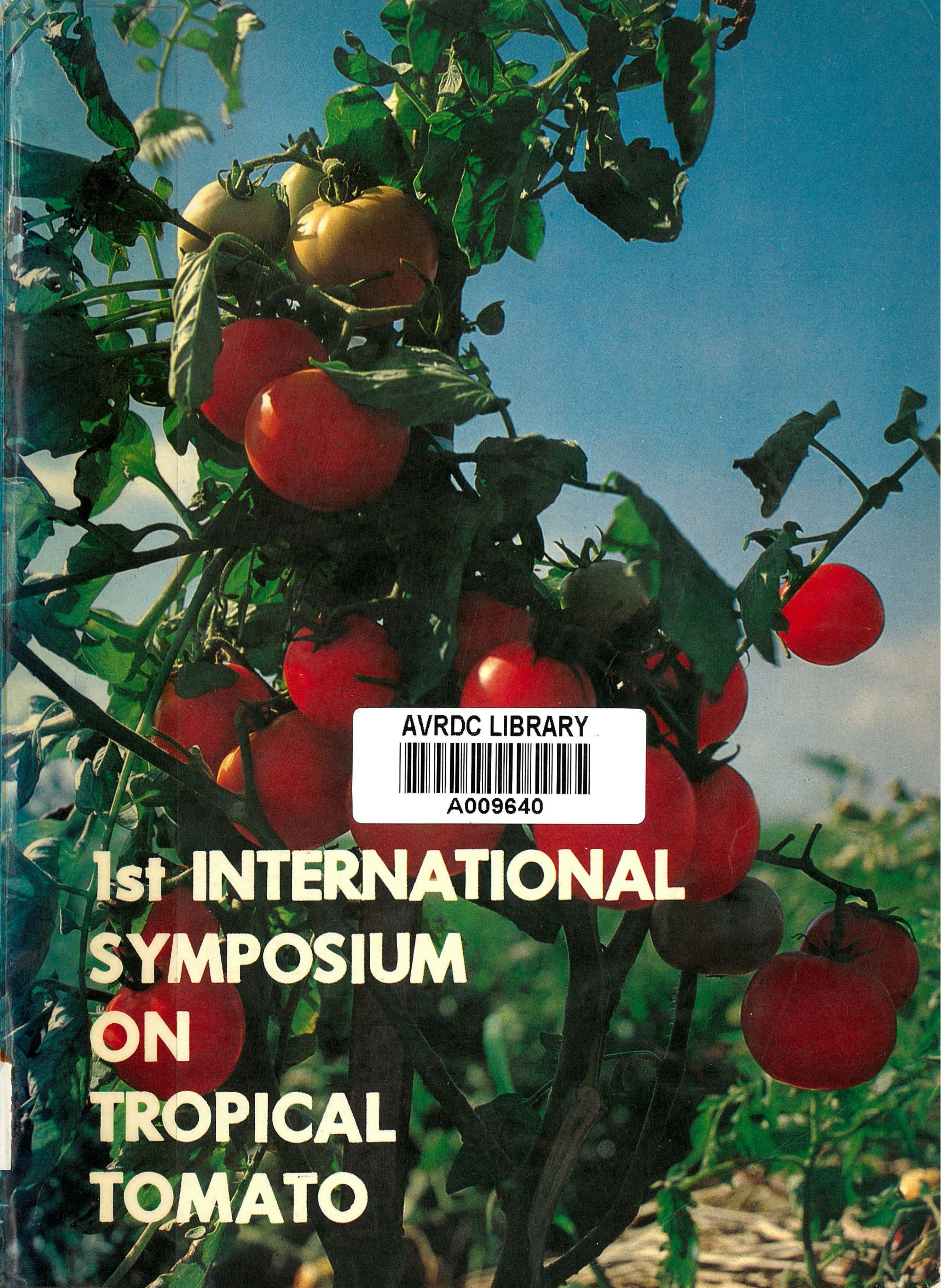
TROPICAL TOMATO SYMPO



1st INTERNATIONAL SYMPOSIUM ON TROPICAL TOMATO

1st INTERNATIONAL SYMPOSIUM ON TROPICAL TOMATO

FOREWARD

This Proceedings contains papers presented at the 1st International Symposium on Tropical Tomato. Held at the Asian Vegetable Research and Development Center (AVRDC) in Taiwan on 23-27 October, 1978.

The following notes apply to the 27 papers published herein. All references to tomato are to *Lycopersicon esculentum* Mill., unless otherwise noted. The metric system is used throughout the Proceedings and all currency is in US$ based on local currency equivalents at time of publication. A single asterisk (*) means statistically significant at the 5% level; a double asterisk (**) means significant at the 1% level. References cited are listed in the text by number and refer to the corresponding citation at the end of the respective paper. As a point of clarification, AVRDC defines "the tropics" to include the area between $0-30^{o}$ north and south latitudes for purposes of its experiments. Non-AVRDC authors may or may not use the same definition.

The Editor sincerely thanks the staff of AVRDC's Office of Information Services and the many people who assisted in the timely preparation of this Proceedings. Special appreciation goes to all the sponsoring organizations and their staffs, to the many who organized the Symposium and worked to make it a success, and to all who attended and carried back to their countries information about the tropical tomato.

Robert Cowell
Editor
AVRDC

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B230

INTRODUCTION

The 1st International Symposium on Tropical Tomato represents several points of achievement and decision in tropical agriculture. The culmination of 5 years of intensive research and testing by AVRDC has brought about tomato production on farms where high temperatures and disease had prevented tomato growing before 1977. Three cooperating countries have released tomato varieties to farmers after successfully selecting and testing AVRDC materials in national agricultural research programs. These achievements, and many other favorable reports, derive from solution to two basic problems: tolerance to high night temperatures and resistence to bacterial wilt. Other problems remain.

In addition to reviewing the international status of tomato research, AVRDC sought to obtain from the Symposium participants an evaluation of the needs and priorities for research on the tropical tomato's remaining problems. As might be expected, the group generally felt that so much work remained that AVRDC should not reduce the emphasis it places on the crop. Problems of virus diseases, *Stemphylium* and stem rots, nematodes, fruit size and quality, and management techniques suitable for wet monsoon climates remain to be solved. Much work on post-harvest handling and marketing for small-holders is also required, although this is somewhat outside AVRDC's mandate.

The principal sponsors of the Symposium, AVRDC and the United States Agency for International Development, were joined by many other contributors. The governments of Japan and the Republic of China, the Philippine Packing Corporation, the World Bank, and several US universities provided all or part of the cost of their participation. Other contributors were the Asia-Pacific Food & Fertilizer Technology Center, the International Potash and Phosphate Institute, the Campbell Institute of Agricultural Research, and the Taiwan Pineapple Corporation. We are also grateful to the local contributors for their hospitality and assistance: President Enterprises, Taiwan Kagome, and Known-You Nursery and Seed companies, among others.

The Director-General of Posts of the Republic of China honored the Symposium and AVRDC by issuing two stamps depicting the tropical tomato (see over).

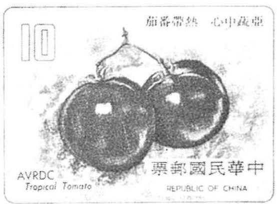
More than 140 participants representing 57 organizations from 20 countries gathered to exchange and expand current information on tomato production in the tropics. Observers were sponsored by: the International Agricultural Development Service; Rural Development Corporation, Malaysia; Methodist Rural Life Development Program; Pohang State Agricultural Development Corporation, Malaysia; CATIE, Turrialba, Costa Rica; the Philippine

Packing Corporation; the Asian Development Bank/AVRDC/Korean Outreach Program; the Sugar Industry Research Institute, Mauritius; Xavier University, Philippines; B.M. Domingo, Philippines; and the Takii Seed Company, Japan.

We are grateful to all the participants for making this meeting an event of significance to the farmers of tropical Asia.

Ruben L. Villareal
Symposium Coordinator and
AVRDC Tomato Breeder

J. C. Moomaw
Director
AVRDC



第一屆國際熱帶番茄會議紀念

In Commemoration of the First International Symposium on Tropical Tomatoes

October 23, 1978

"AVRDC HAS BEEN MAKING SIGNIFICANT CONTRIBUTIONS TO HUMAN NUTRITION IN ASIA. THIS YEAR THE AVRDC HELD THE FIRST INTERNATIONAL SYMPOSIUM ON TROPICAL TOMATOES, OCTOBER 23-29, IN TAIWAN. IN HONOR OF THE ACHIEVEMENT OF THE SYMPOSIUM, A SET OF 'TAIWAN VEGETABLE POSTAGE STAMPS' WAS RELEASED ON OCTOBER 23, 1978."

(from the souvenir first day cover)

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TOMATO IN THE TROPICS

TOMATO PRODUCTION IN THE TROPICS - PROBLEMS AND PROGRESS

R.L. Villareal[a]

Lycopersicon esculentum originally came from tropical Mexico to Peru. All tomato varieties in Europe and Asia descend from seeds taken from Latin America to Europe and Asia by Spanish and Portugese merchants during the 16th century. African tomatoes on the other hand, were introduced by European merchants or colonizers. Thus, today, modern cultivars and hybrid tomatoes can be grown and produce fruit in climates far different from the site of origin.

In 1975, the world production of tomatoes was 39.5 million t (Table 1).

It is obvious that the leading tomato producers are in the temperate regions of the world. The highest yields also are found in temperate countries. Yield trends among the best and the worst tomato growers show that tomato yield in the tropics is much lower than in the temperate zones (Table 2). There was an increase of only 7.7% over a period of 9

Table 1. Tomato production by country.[a]

Country	1000 T
U. S. A.	8,620
U. S. S. R.	3,590
Italy	3,545
Spain	2,309
Turkey	2,250
Greece	1,826
Egypt	1,750
Romania	1,243
Japan	880

[a]Ref. 6.

[a]Program Leader, Horticultural Crops, and Plant Breeder, Asian Vegetable Research and Development Center, P.O. Box 42, Shanhua, Tainan 741, Taiwan, ROC.

Table 2. Comparative tomato yields between tropical and temperate countries.

	1966	1969	1972	1975	1966 - 1975 Yield
	------------t/ha------------				-% change-
Tropical[b]	13	12	14	14	+7.7
Togo	1	1	1	1	0
Sri Lanka	2	2	2	2	0
Honduras	3	3	4	4	+33.3
Reunion	20	18	18	18	-10.0
Polynesia	29	26	24	26	-10.3
Dominican Republic	25	23	33	32	+28.0
Temperate[c]	68	74	82	94	+38.2
Yugoslavia	11	10	11	11	0
Poland	14	12	16	12	-14.3
Germany DR	19	19	20	18	- 5.3
Belgium	97	101	121	154	+58.8
Norway	120	129	140	167	+39.2
Denmark	145	170	181	202	+39.3

[a]Adapted from ref. 6. [b]Data are from the highest and lowest national averages in tropical Asia, Africa, and Latin America. [c]Data reported are from 3 highest and 3 lowest national averages in temperate countries.

years in the tropics, compared to 38.2% in the temperate zone during the same period. The range in the tropics was between 1-33 t/ha, compared to 10-202 t/ha in the temperate zone. The high yields in Belgium, Norway, and Denmark came from crops grown mainly or totally under glass. A more realistic high yield from field production in the temperate region is 39 t/ha registered by the United States in 1975.

PRODUCTION PROBLEMS

In the tropics, tomatoes, like most vegetable crops, are normally produced in mountain regions or in the lowlands during the cool season (10,11). Production per hectare has remained far below that of countries in the temperate zones (Table 2). Seeds of imported varieties bred for use in temperate climates are often the only ones available to farmers. Yield from these varieties is often low and normally erratic, especially when grown during the summer months. Because of this, tomato production in the tropics is characterized by extreme seasonality and low yields. The seasonal fluctuations in price and supply of fresh market tomatoes for Taiwan (Fig. 1) is typical of the pattern of variation observed in tropical markets (Table 3). Thus, the use of unadapted varieties is one of the production constraintslimiting tropical tomato production.

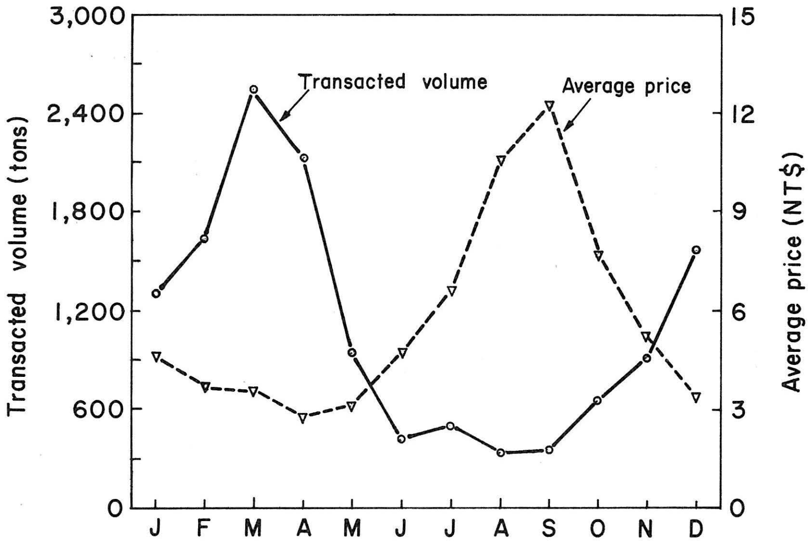

Fig. 1. Seasonal fluctuations in the supply and price of fresh market tomatoes in the Taipei wholesale market; Taiwan, 1976.

Table 3. Retail price range of tomatoes in some tropical Asian countries.[a]

	Price/kg	Price/kg	Ratio high/low
		-US$-	
Thailand	0.5 baht - 18 bahts	.02 - .90	45
Indonesia	40 rupiahs - 150 rupiahs	.10 - .36	3
Philippines	0.5 peso - 5 peso	.07 - .70	10
Taiwan	3 NT$ - 20 NT$	.08 - .53	7
Singapore	0.60 S$ - 4 S$	.24 - 1.63	7
Malaysia	0.50 M$ - 3 M$	.20 - 1.21	6

[a]Based on staff observations and personal communication with cooperators.

Our cooperators in the tropical regions of Africa, Asia, and Latin America wrote us why they consider varieties grown in their respective areas unadapted (Table 4). The listing shows that the tropical areas have many common problems with tomato cultivars. Those problems indicate that tomatoes in the tropics are grown both in the highlands and in the lowlands, as shown by diseases that are inherent in each location.

Table 4. Reasons why temperate-bred tomato cultivars are unadapted in the tropics;[a] AVRDC, 1978.

Location	Problems
Africa	Susceptibility to bacterial wilt, early & late blight, viruses, fusarium wilt, root knot nematodes, poor fruit set due to heavy rainfall and high temperature, poor quality fruits.
Asia	Same problems as in Africa plus susceptibility to septoria leaf spot, gray leaf spot, leaf molds, black molds, southern blight, and acid soils.
Latin America	Same problems as in Africa plus susceptibility to gray leaf spot, and spider mites.

[a]Based on personal communication with cooperators in the tropics. Comments regarding Asia are from AVRDC staff travel.

For example, bacterial wilt (*Pseudomonas solanacearum* is a serious disease of tomato throughout humid areas, including many of the warm temperate, semi-tropical and tropical countries (9). Mostly a lowland disease, it thrives at relatively high temperatures(14). Late blight (*Phytopthora infestans*) on the other hand, is a fairly common disease in the cooler highlands. The pathogen multiplies rapidly and to epiphytotic proportions during cool nights and moderately warm days with abundant moisture. Using adapted varieties will minimize the risks in growing tomatoes in highlands or lowlands at any season.

The lack of appropriate cultural practices during both the wet and dry season is another barrier to successful tropical tomato production. Some of the most critical barriers, especially during the wet season, are rapid multiplication of insect pests, diseases and weeds, high temperature, and heavy rainfall. The risk of growing tomato in the tropics will be further reduced by using the appropriate improved cultural practices.

The apathy towards vegetable research in general contributes to the two attendant problems of tomato production in the tropics. In developing countries vegetable production ranks low in food production priorities. Consequently, progress in improving vegetable productivity is slower than with cereals (Table 5). Average yearly increases in cereal yields range between 1.7 - 3.2%, whereas that of vegetables is between 0.4 - 1.3%. Because cereals have priority, vegetable research and production gets inadequate financial support. It suffers also from lack of trained research staff, who will conduct experiments, and extension personnel, who will extend information to vegetable farmers and backyard gardeners. And to make matters worse, no technician has yet been trained to deal specially with only tomatoes. Trained personnel in a developing country must work on cereals first and other crops second. And, if assigned to work on vegetables, they must deal with several kinds of vegetables, probably more than they can reasonably handle.

Table 5. Comparative % increase in yield between selected cereals and vegetable crops in developing countries.[a]

Crop	1965	1975	Increase over 10 yrs	Avg. yearly increase
	-----t/ha-----		--------%--------	
Cereals				
Rice	1.61	1.98	22.7	2.3
Corn	1.13	1.33	17.0	1.7
Wheat	.98	1.30	32.7	3.2
Vegetables				
Cabbages	10.40	10.91	4.0	0.5
Green beans	3.42	3.86	12.8	1.3
Sweet potatoes	7.09	7.41	4.5	0.4
Tomatoes	11.63	13.17	13.2	1.3

[a]Adapted from ref. 7.

PROGRESS IN SOLVING TOMATO PRODUCTION PROBLEMS

The creation of the Asian Vegetable Research and Development Center (AVRDC) has opened the way to solving many tropical tomato production problems through problem-oriented research, and the training of researchers and extensionists for various national programs. Additionally, more and more food production loans from various international funding institutions for research and manpower development include funds not only for cereals but for vegetables as well. Some examples are the programs in Indonesia, Nepal, Botswana, Dominican Republic, and Ecuador (8).

The creation of AVRDC established the first international agricultural research and training organization responsible for improving the production and quality of selected vegetable and legume crops in the humid tropics. These crops are: mungbean, soybean, white potato, sweet potato, Chinese cabbage, and tomato (1, 2, 3, 4, 5).

AVRDC functions under the same guiding principle as the other international centers -- an inter-disciplinary approach towards the resolution of key crop problems - since problems besetting crop production are never simple and always encompass several well-defined disciplines. An example of how AVRDC operates in its Horticultural Crops Program is illustrated in Figure 2.

Note, however, that AVRDC breeding lines go directly to national programs, where they are evaluated rigidly prior to recommendation for commercial planting. AVRDC will neither release nor name varieties. Therefore, it is up to the national breeding programs to use AVRDC's materials.

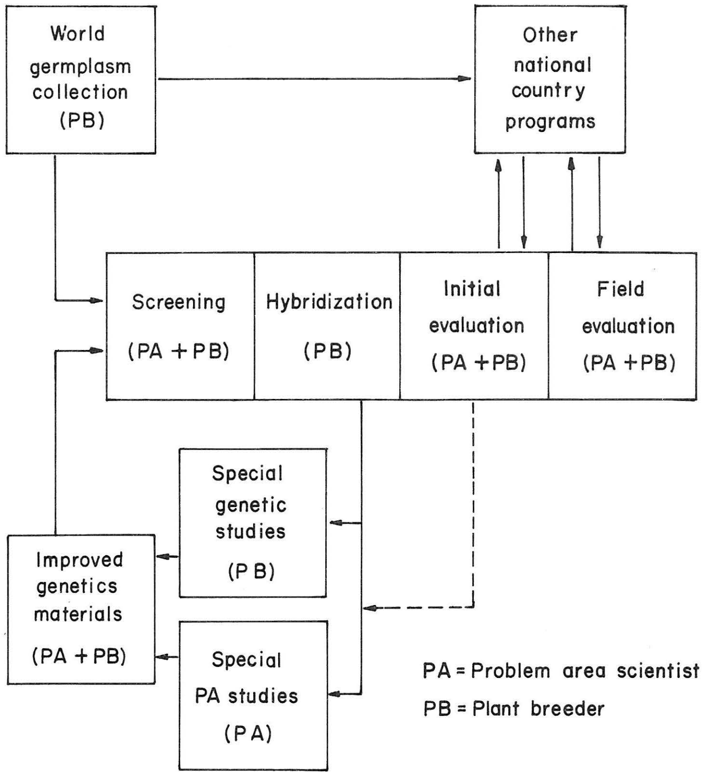

Fig. 2. Flow of germplasm through the Horticultural Crops Program; AVRDC, 1978.

TRAINING PROGRAM

AVRDC has trained 111 specialists, and currently is training 58 more (Fig. 3). These specialists come from 14 tropical countries. AVRDC's training program, similar to those at other international agricultural research centers, is designed to help meet the demand for properly trained and highly motivated agricultural specialists in tropical regions. Those trained at AVRDC have been our most vigorous and active cooperators in the evaluation of the breeding materials and technology which the Center develops.

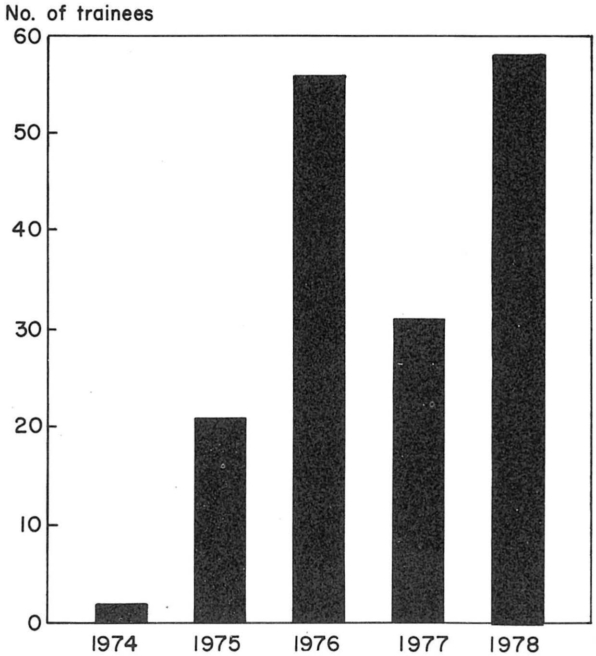

Fig. 3. Growth of AVRDC's training program; 1978.

RESEARCH PROGRAM

AVRDC has adopted the following strategies to help solve tomato production problems in the tropics:

1. Germplasm collection and evaluation. The cornerstone of most successful breeding programs is the availability of massive and diverse genetic materials where desirable traits can be drawn out when needed. As of October 1978, AVRDC has collected and received donations of 4752 accessions from 79 countries. About 90% of our collection belongs to *L. esculentum*, the remaining 10% belongs to its wild relatives (Table 6).

The tomato germplasm has been subjected to repeated screening during the last 5 years, principally for bacterial wilt resistance and heat-tolerance (i.e., high temperature fruit setting ability). In addition, AVRDC pathologists have evaluated selected cultivars for resistance to other diseases.

2. Hybridization and application of breeding techniques. Desirable genotypes (i.e., heat-tolerant and bacterial wilt resistant) identified in the screening program are used by the breeders in making crosses to

Table 6. Distribution of *Lycopersicon* accessions by species; 1978, AVRDC.

Species	Number of accessions 1977	Number of accessions 1978	% Total 1978
L. exculentum	4177	4225	88.9
L. pimpinellifolium	244	245	5.2
L. peruvianum	85	85	1.8
L. cheesmanii	4	4	0.1
L. hirsutum	25	25	0.5
suspected crosses			
L. esculentum/L. pimpinellifolium	166	166	3.5
L. esculentum/L. hirsutum	2	2	Trace
	4703	4752	100

recombine these traits in a single variety. From 1974 to the present, most AVRDC crosses involved the improvement of selections found to be heat-tolerant and bacterial wilt resistant. Since 1973, AVRDC has been sending breeding lines and genetic materials to scientists in more than 60 countries throughout the tropical areas of South America, Africa, Asia, and Pacific Islands (Fig. 4).

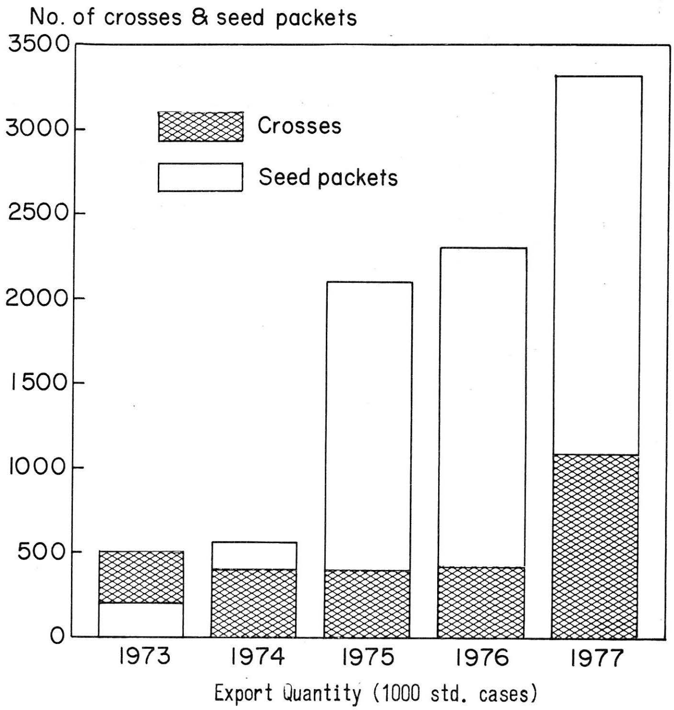

Fig. 4. Number of crosses made and seed packets sent to cooperators; AVRDC, 1977.

Our breeding lines have demonstrated superiority over the local cultivars in many tropical Asian countries. Performance of selected AVRDC breeding materials are presented below:

India - In Maharashtra, India, 4 AVRDC lines outperformed Co-1, a popular variety in southern India. Only two AVRDC lines, however, gave higher yields than "Pusa Ruby". In wilt infested areas, all AVRDC lines included in the trials should outperform both checks, since neither check possesses bacterial wilt resistance. The best performers are presented in Table 7. CL 33d-0-2-2 and Cl 122-0-3-4 are being considered for large scale production and release to farmers by Nimbkar Agricultural Research Institute (NARI).

Table 7. Performance of AVRDC lines in a preliminary trial, Maharashtra, India, 1977.[a]

AVRDC no. or cultivar name	Marketable yield	First flowering	Fruit weight
	-t/ha-	-days-	-g-
CL 33d-0-22	43	37	45
CL 9d-0-1-6	41	36	53
CL 11d-0-2-2	37	40	43
CL 33d-0-2-1	36	39	52
Pusa Ruby (check)	34	34	35
CL 103-0-5-2	31	35	37
Co-1 (check)	30	39	52
LSD 5%	5	4	6

[a]Data supplied by Mr. H. Bedekar, NARI; planted Apr, 1977; harvested 11 times beginning Jun 28 and ending Aug 16.

Malaysia - The Malaysian Agricultural Research and Development Institute (MARDI) featured several AVRDC-derived lines in a field day in which these lines demonstrated wilt resistance. The check cultivars, "Roma" and "Banting", were completely wiped out by wilt (Table 8). The identification of resistant genotypes was considered a breakthrough by MARDI because in the past tomatoes had to be grafted to wilt resistant eggplant root stock.

Papua New Guinea - At the Plant Introduction and Horticulture Research Station (PIHRS), two observational trials of AVRDC breeding lines were conducted. In the first trial of 10 lines, the level of wilt infestation was not high and so only a few indicator plants wilted. The twice a week application of fungicide was effective in controlling leaf diseases, thus prolonging the production period. Eleven harvests were

Table 8. The best yielding breeding lines in an advanced trial; Malaysia, 1977.[a]

SSD No.	Marketable yield	Fruit size	Days to flowering	Transformed[b] survival rate
	-t/ha-	-g-	-no-	-%-
CL 502-F_5-20	25	34	25	46
CL 507 F_5-14	22	51	28	58
CL 502 F_5-34	19	50	28	60
CL 502 F_5-39	16	36	28	44
CL 507 F_5-34	16	43	28	46
CL 507 F_5- 6	16	30	25	45
CL 507 F_5-44	15	35	23	41
LSD 5%	9	12	5	ns

[a]Data supplied by Ms. Melor Rejab and Dr. T.S. Tee, MARDI; planted May 5 and harvested Jul 13; data are means of 3 replications.
[b]Under natural epiphytotic of P. *solanacearum*; Banting, the check cultivar was completely wiped out by disease; data transformed to arcsine before analysis of variance was made.

made instead of the usual 4-7 made with AVRDC lines. The two highest yielders were CL 8d-0-7-1 and NG 7111 (Table 9). Their palatability and market assessment, however, were not high compared to CL 32d-0-1-1 and CL 9d-0-0-1. In PNG, tomatoes of about 50g or less are considered culls. In fact, most of their culls belonged to this group. The marketable yield included only fruit of at least 60g.

Table 9. Performance of AVRDC breeding lines in an observational trial; Papua New Guinea; 1976.[a]

AVRDC selection no.	Pedigree	Yield			Palata-bility	Market[c] assessment	Remarks
		Total[b]	Total	Marketable			
		-kg/plant-	-----t/ha-------				
8d-0-7-1	VC 11-1-2-1/Venus	6.9	85	70	3.5	3	med-large round
Philippines	NG 7111 (check)	6.9	85	63	3.5	3	med, egg
7-0-10-1	VC 11-1-2-1/Florida MH 1	5.8	72	54	4	4	med-large egg
32d-0-1-1	VC 9-1-2-3/Venus	5.7	70	53	2	2	med-large
9d-0-0-1	VC 11-1-2-1/Saturn	5.7	70	52	1	1.5	med-large
179-0-4B-2	VC 11-1/Tamu Chico III	4.4	54	34	2	3.5	small, egg

[a]Data supplied by Mr. Kevin J. Blackburn, agronomist in-charge, Plant Introduction and Horticultural Research Station (PIHRS), Laloki, PNG. [b]Means of 49-103 plants. [c]A scale of 1-5 in the decreasing order of palatability and market assessment.

The second trial involved one set of SSD materials, CL 555 with pedigree VC 8-1-2-3/Venus//Kewalo. No symptoms of bacterial wilt occurred, even in the indicator plants. A severe infestation of TMV resulted in many stunted plants. A heavy incidence of leaf diseases led to premature defoliation and a large reduction in yield. The leaf diseases prevalent were *Coryonospora sp* and *Fulvia fulva*, with *Alternaria solani* and *Cercospora sp*. CL 555 F_5-19 was selected on the basis of disease tolerance, palatability, and size, and used for commercial trials. Selection 555 F_5-19 had yielded 39 and 48 t/ha in the first and second pilot trials, respectively.

Philippines - Several locations in the Philippines submitted equally encouraging reports (Table 10). The three reporting stations represented evaluation of our breeding lines in the northern (Ilocos Sur), central (Laguna), and southern (Davao) Philippines. These yields are very impressive, considering that the national average yield for tomato is 7.4 t/ha.

Nigeria - The Institute for Agricultural Research, Zaria, Nigeria, supplied us information on the performance of AVRDC breeding lines grown under rainfed conditions. Materials were grown on Jul 20, 1977, and harvested 3 times, beginning Sep 26 and ending Oct 12, 1977. Selections 11d-0-1-2, 246-0-3B-9, and 143-0-4B-1 gave excellent fruit set, and yielded about 24-34 t/ha. Serious diseases reported were early blight, gray leaf spot, and leaf molds. Selections 1119-1-2, 123-2-4, and 8d-0-7-1 were scored free from gray leaf spot infection, while CL 114-5-5 was scored resistant to leaf molds.

Tahiti - Three AVRDC breeding lines: CL 246-0-3B-9, CL 32d-0-1-1, and CL 127-4-1 had 100% survival to bacterial wilt infestation compared to no survival in the check. All yielded about 33 t/ha.

Taiwan - The Taiwan Pineapple Co. evaluated 2 of our selections from TK 70. In 1977, they extended planting of TK 70-5 to about 400 ha. Selections 9-0-0-1 and 11-0-1-2 showed promise for yield when grown in Hualien, Taitung, and Lotung during the rainy season. These selections had fruit size comparable to White Skin, the local check. However, the fruit of most selections are more acidic (sour) than White Skin, which will deter consumer acceptance of these lines under local conditions. They are, however, comparable in eating quality with the local cultivars in other Asian countries where tomatoes are used as vegetables and not as fruit.

The results of our comparative trials in the tropics in 1977 using AVRDC lines gave us an average yield of 34.3 t/ha. If we use this figure as our yield goal, then present tropical tomato yields can be increased from about 1 to 5000% (Table 11). To attain this goal, a package of technology for tomatoes should first be made available.

We are pleased to have partially developed a tropical tomato that we envisioned at the inception of our program" -- resistant to bacterial wilt, root-knot nematodes, leaf molds, gray leaf spot, septoria leaf spot, early blight and virus diseases; heat and moisture tolerant, and which bears fruits that are medium, uniformally red, firm and resistant to cracking and blotchy ripening. It should also be early maturing."

Table 10. Yields of AVRDC breeding lines in 3 trials conducted in different locations; Philippines, 1977.

Vigan, Ilocos Sur[a]		Los Baños, Laguna[b]		Madaum, Davao[c]	
AVRDC select no.	Marketable yield	AVRDC select no.	Marketable yield	AVRDC select no.	Marketable yield
	-t/ha-		-t/ha-		-t/ha-
32d-0-0-1-1	63	8d-0-7-1-1	51	11d-0-1-2	27
8d-0-7-1	60	32d-0-1-15	49	8d-0-7-1	25
11d-0-1-2	46	32d-0-1-4	45	170-3-1	16
7-0-10-1	44	32d-0-1-25	43	32d-0-1-19	17
170-0-2B-2	37	32d-0-1-13	43	143-0-6-9	17

[a]Data supplied by Mr. Amador B. Ragasa, Vegetable Program Officer, Ilocos Sur; planted Oct 4, harvested Jan; means of 3 replications. [b]Data supplied by Mr. Benjamin M. Legaspi, senior plant pathologist, BPI Economic Garden, planted Mar 18, 18 harvestings beginning May 6, ending Jun 20; means of 4 replications. [c]Data supplied by Mr. Jaime B. Rebigan, horticulturist, Twin Rivers Research Center, planted Apr 6, harvested Jun; means of 2 replications.

Table 11. National average yield of tomatoes in selected tropical countries and possible improvement.

	Yield[a]	Possible improvement[b]
	-kg/ha-	-%-
Africa		
Togo	674	4996
Angola	1,250	2648
Kenya	15,238	125
Reunion	15,625	120
Asia		
Guam	1,333	2477
Thailand	2,849	1106
Tonga	21,739	58
French Polynesia	29,000	18
Latin America		
Panama	4,692	632
Nicaragua	4,800	616
Brazil	25,742	33
Dominican Republic	33,963	1

[a]Ref. 7; 2 highest and 2 lowest national yield average in each category. [b]Computation was based on (34, 347 kg/ha), the average yield obtained from various experiments in the tropics using AVRDC breeding lines (5).

FUTURE OUTLOOK

Although AVRDC has started research and training programs to help solve tropical tomato production problems, we must admit that we can still do much as a group to resolve the problems associated with this crop. Initially, however, I feel that we can focus our attention on a single cooperative project.

I am certain that most of you have heard of the international rice and wheat testing programs of IRRI and CIMMYT, respectively, and the benefits that have accrued from such programs. In tomato research, cooperation of that kind is best illustrated by the Southern Tomato Exchange Program trials (STEP; 12). The program was organized in the US in 1945 by a group of collaborating state and federal scientists interested in tomato improvement (13). The purpose of the STEP trials is to help tomato breeders identify lines with the widest range of adaption, thus encouraging the development and release of cultivars with maximum adaptation.

In the tropics, we should have a similar international testing program, not only for variety trials but for evaluation of cultural practices as well. Initially we can start with variety trials. As we gain experience and funds are made available, we can expand the program to include other disciplines. The program can have the following objectives:

1. To foster cooperation among tomato scientists and programs.

2. To facilitate exchange of germplasm and research information on common problems pertaining to the production and utilization of tomato.

3. To assemble the most promising cultivars and breeding lines in the tropics and systematically test them in uniform trials in as many tropical locations as possible.

4. To assist national programs in establishing a mechanism by which outstanding lines obtained from such a testing program could be effectively used in the concerned country.

If there is enough interest in this type of cooperative project, we can discuss and plan the details of its operation and future activities during the last day of our symposium.

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Dr. Ruben L. Villareal, AVRDC's tomato plant breeder, inspects tropical tomato yield in a Taiwan farmer's field.

IMPROVING SMALL-SCALE TOMATO PRODUCTION IN THE TROPICS

Peter. H. Calkins[a]

INTRODUCTION: UNTAPPED POTENTIAL

The tomato is one of most popular vegetables in the tropics. Of the more than 100 species of vegetable crops which could have been selected for intensive study in 9 representative Asian countries, tomato ranked first overall; first in Taiwan, the Philippines, Thailand, and Sri Lanka; second in Japan, Indonesia, and Bangladesh; and third in Nepal (1). Agricultural researchers and government planners are interested in promoting tomato production in the tropics because, perhaps more than any other vegetable, it has great potential for improving three fundamental components of the standard of living:

1. Income. Because of its high yield potential and price (it is popular with consumers), greater tomato production can vastly improve the annual incomes of tropical farmers, especially those operating small farms who have the labor required for this intensive crop. Studies (4) suggest that not only the level but also the distribution of income is improved when more high-income vegetable crops are grown because those farmers with smaller holdings profit relatively more.

2. Employment. Tomato in Taiwan requires 2180 (processing) to 8020 (fresh market) labor hours per hectare, compared to only 761 for rice (15). Thus, tomato has a great potential for using idle or seasonally underemployed farm workers to increase the family's total cash earnings. Tomato is well-suited to processing, and can provide jobs in processing factories for urban and rural workers. Especially if these factories are dispersed throughout the countryside, the rural-urban migration can proceed at an optimal rate, with any potential migrants first finding jobs in rural-based factories. The tomato processing industry in southern Taiwan has located factories near the source of production, helping to smooth the shift of 15% of the work force from fields to factories over the past decade.

3. Nutrition. Although its potential lies primarily in improving

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income and employment, tomato is a respectable source of some key nutrients. Of 16 nutritious crops considered for inclusion in 42 m^2 kitchen gardens in Hawaii, tomatoes grown for only 90 days ranked 8th in protein and ascorbic acid, and 9th in iron production per hectare per day (12).

Not only does tomato have the potential to contribute directly to the income,employment, and nutrition of urban and rural populations in the tropics, but there are cross-effects among these components. Higher nutrition can lead to more efficient employment, more efficient employment to higher income, and higher income to better nutrition.

Many biological and economic problems[a] prevent tomatoes from achieving their full potential. Superficially, only a few directly limit production. In fact, however, the lack of a processing industry or an adequate distribution system can deter a farmer from planting tomatoes just as much as the lack of production capital or the prospect of devastation from bacterial wilt.

RISK VS PROFIT

Farm decision-makers are concerned with increasing family income without large fluctuations in that income. In addition to variations in weather and yield, the degree of risk depends on the level of economic development, the quality of roads and input supplies, the accessibility of markets, and the degree of price variability. Moreover, risk factors tend to be greater for the small-holder than for the large-holder, so that small-holders who contemplate tomato production constantly face the trade-off between profit and risk.

Government and private industry can help reduce risk by restricting the man-made environment to provide contract or guaranteed prices, better transport, improved markets, easier credit, and input subsidies. Farm supply response equations usually list planted area as the dependent variable; and price, variability in price; yield, variability in yield; and the relative profitability of competing crops as the major determining factors (2). A final determinant of supply response is time, for not all farmers adopt new technology with equal speed. It is often the small-holders who accept improved technology last (again, because of the greatest sensitivity to risk). Thus, research and development programs must be maintained long enough to make sure that the full benefits of the expansion of the tomato industry reach the small-holder.

Table 1 demonstrates the extreme variability of tomato yield performance in each year between 1964-75 under current production conditions and how this affects planted area. We conclude:

1. Yield from 1964 to 1975 exhibits a wide range between countries. Thailand had the lowest yields in both years and the USA the highest. There was a large yield gap between developing and the developed countries.

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[a]See R. L. Villareal, Tomato Production in the Tropics: Problems and Progress, p.96.

Table 1. Trends and variability in planted area and yields of tomato in selected nations, 1964-1975; AVRDC, 1978.[a]

Location	Area planted				Yield			
	1964	1975	% Change (+ or -)	C.V.[b]	1964	1975	% Change (+ or -)	C.V.[b]
	--1000 ha---			-%-	-----t/ha----			-%-
World	1462	1869	21.8	8.58	17.16	21.12	18.7	6.13
Developed nations	498	591	15.7	5.24	26.36	35.47	25.7	9.47
Developing nations	657	903	27.2	11.84	11.11	13.16	15.6	5.55
Africa	180	289	37.7	15.41	12.81	12.40	-3.3	3.79
South America	92	114	19.3	9.39	15.71	16.37	4.1	5.94
Panama	4[c]	5[c]	20.0	17.64	4.67	4.73	1.3	4.04
Asia	313	412	24.0	9.82	11.68	15.13	22.8	8.72
India	55[c]	72[c]	23.6	8.91	9.27	9.47	2.1	1.16
Indonesia	43[c]	59[c]	27.1	10.59	5.88	6.35	7.5	2.55
Mal / W. Malaysia	3[c]	6[c]	50.0	20.45	5.00	4.96	-0.7	0.87
Philippines	15	17[c]	11.8	6.63	3.46	7.30	52.6	26.75
Thailand	5	5[c]	0.0	6.12	2.90	2.98	2.4	2.75
USA	173	204	15.2	9.42	29.33	42.21	30.5	12.92

[a]Adapted from FAO, Production Yearbook. [c]estimate.

[b]Coefficient of Variation = $\frac{\text{Standard Deviation}}{\text{mean}}$ x 100 computed on 12 years of data.

2. In almost every location yield has increased and, as a result, planted area. This reflects the improvements in tomato production technology and the decision-making environment. In the developed countries technological change has been faster, but planted area has grown less.

3. The variability of yield between years exhibits a wide range. The developing countries had more stable, if lower, yields than the developed countries. Thus, yield variability may not be as great a deterrent to planting large areas to tomato on small tropical farms as other components of risk (e.g. low or unstable price). These other components made variability in planted area in developing countries more than twice as great as that in developed countries.

FACTORS AFFECTING PROFIT

Results from many countries show that tomato is one of the most profitable crops, planted alone or in rotation. The major proportion of area grown to tomato in the tropics is planted during the cool-dry season when temperature and moisture are most favorable for high yields. Summer or monsoon tomatoes are rare.

AGRONOMIC FACTORS

In Taiwan, tomato production can be divided into five(including summer) seasons. In each, tomato is very profitable compared with alternatives. In winter, fresh market tomato is most promising for irrigated farms and processing tomato for unirrigated farms(5). Despite agronomic problems, summer tomato has a sufficiently high price and yield to make it more profitable than winter processing tomato, winter fresh-market tomato or rice(9).

In Chiang Mai, Thailand, the cropping system peanut - tomato - rice (1) involved planted tomato from April to July, so that a heat tolerant cultivar such as AVRDC VC11-3-1-8 was suitable. This system had the highest economic potential, largely due to tomato's high price during the hot season. A close second in net and farm income was tomato - mungbean - rice, which included tomato grown in the cool season. Labor and capital requirements were also low, making this system feasible for a wide range of farm sizes and resource availability.

In Tarlac, the Philippines, rice (Jul - Nov), 90-day tomato (Nov - Feb), and early summer corn (May - Nov) yielded the highest net income ($827/ha) of all cropping patterns tried, and provided 149% more net income than from rice alone (3). Lin and Chow (13) report, however, that this cropping pattern sometimes leads to low returns if tomato price is low (sometimes only $0.004/kg). This reflects the low consumer preference for tomato in the Philippines. In selected pilot barrios, the net income and employment generated from tomato were second only to eggplant (7).

In the Caqueza Project, Colombia, tomatoes returned US$746/ha, second to onion (16). In the Cameroon Highlands, Malaysia, tomato had the third highest gross margin per hectare of 19 vegetables ($2422), ranking behind only watercress and Chinese cabbage (6).

PRODUCTION BUDGETS

Farm level production technology data are available for Panama, Taiwan, and the Philippines (Table 2). Yield was highest in Taiwan but, because of low price, revenue was second to Panama. Yields and profit were lowest in the Philippines.

Farmers in Panama spent most in both absolute and percentage terms on pesticides and other materials. They also invested the most labor in absolute and percentage terms in planting and irrigation.

Table 2. Comparative production budgets for tomato in 3 tropical countries; AVRDC, 1978.[a]

	Panama		Taiwan[b]		Philippines	
	US$/ha	%	US$/ha	%	US$/ha	%
Seeds	10	1.0	34	3.9	10	2.7
Fertilizer (chemical)	144	13.8	51	5.8	75	19.7
Organic fertilizer	30	2.9	9	1.0	-	-
Pesticide	142	13.6	35	4.0	44	11.8
Other material	127	12.2	51	5.8	54	14.4
TOTAL VARIABLE CAPITAL COSTS	453	43.6	180	20.5	183	48.8
Land preparation & bed formation	72	6.9	14	1.6	56	14.8
Planting	75	7.2	42	4.8	7	1.8
Fertilization	15	1.5	11	1.3	5	1.4
Pesticide spraying	54	5.2	73	8.3	16	4.3
Intertillage & weeding	96	9.2	91	10.4	4	1.1
Irrigation	69	6.6	42	4.8	7	1.8
Harvesting	141	13.6	333	38.0	27	7.2
Other labor	15	0.1	-	-	19	5.4
TOTAL LABOR COSTS	537	51.6	606	69.2	132	35.2
Irrigation water fee	-	-	-	-	7	1.8
Interest on capital	-	-	21	2.4	26	6.9
Interest on land	-	-	44	5.0	27	7.2
Land tax	50	4.8	25	2.9	-	-
Depreciation	-	-	-	-	-	-
TOTAL FIXED COSTS	50	4.8	90	10.3	60	16.0
TOTAL EXPENSE (US$)	1040	100.0	876	100.0	376	100.0
YIELD (t/ha)	22.7		47.2		10.0	
Price (US$/kg)	0.11		0.03		0.07	
Revenue (US$)	2500		1271		678	
NET INCOME (US$)	1460		395		302	

[a]Angelina C. Macaso and Adoracion Virtucio, the Philippines, Banco de Desarrollo Agropecuario, Panama; AVRDC survey results, winter processing tomato, Tainan County, Taiwan, 1976-77. [b]Avg. of 4 farmers; 3 intercropped processing tomatoes w/ sugarcane.

Farmers in Taiwan were willing to spend the most on seed, but they spent the least in absolute and percentage terms on fertilizer, pesticide, and capital inputs as a whole. The secret to their high yields seems to be the amount of time and care they put into harvesting. A full 38% of all production costs were for harvest labor in Taiwan vs 14% for Panama, though total labor input was the same in the two countries.

High percentages of investments by Filipino farmers went to fertilizer capital, land preparation, and bed formation, although they did not spend the most in absolute terms on any of these inputs. Yields were low largely because total expenses were less than half those in the other countries.

Panamanian farmers spent the most on capital inputs and the most overall, suggesting that tomato should be a capital intensive crop to achieve high levels of return.

The secret to high yields seems to be the amount of time and care Taiwan farmers put into harvesting.

Dr. Peter Calkins and Dr. John Hubbell (see pg 154) of AVRDC's NEM team examine summer tomato in Taiwan.

FACTOR PRICES AND APPROPRIATE TECHNOLOGY

If farmers in Panama, Taiwan, and the Philippines are producing tomato using appropriate technology, then they should be using relatively more of the production input (labor or capital) which is relatively cheap in each country. The Philippines has the cheapest labor in both relative and absolute terms, Taiwan and Panama have nearly the same proportion of wage to capital costs, and the costs of all inputs in Taiwan are the most expensive. We would expect, then, that:

1. Farmers in the Philippines would use the most labor in production of tomato and have the highest labor-capital ratio.

2. Panama and Taiwan would have similar labor-capital ratios in their production mix.

3. Taiwan would use fewer production inputs than Panama.

From Table 2 we cannot accept the first two hypotheses. The data suggest that:

1. Filipino farmers do not use appropriate production technology because they use far too little labor to achieve adequate yields. Capital use may also be too low.

2. Farmers in Taiwan have substituted capital for labor (as labor has become relatively more expensive), but they have not gone far enough.

3. Farmers in Panama have achieved the most nearly appropriate technology. The capital-labor use ratio reflects well the ratio of labor to capital rental costs. Panamanian farmers also can afford to use high levels of production inputs because the wage and interest rates are lower than in Taiwan.

FACTORS AFFECTING RISK

DEGREE OF YIELD VARIABILITY AND LOSS

Given the high potential profit from tomato production in most countries, risk is the major barrier to small farmer production of tomatoes. Figure 1 shows for Malaysia that tomato had the highest income but the highest risk of any vegetable crop in the Cameroon Highlands. When linear programming was used to compute the optimal solution for increasing levels of risk (i.e. variation in expected income), the area planted to tomato increased from 0.26 to 1.19 ha and income increased from US$-637 to US$2354 on the farm (6).

In the Caqueza area of Colombia, risk was an important consideration. There, tomato was the most labor-intensive crop (221 mandays/ha, of which only 81 were furnished by the farm family) and intermediate in capital intensity (US$236/ha). Given credit charges of 43%, such high input requirements made tomato a risky crop. When risk was calculated using the expected value of loss per hectare, corn-bean and beet only had values of US$24 and $55, respectively, while tomato had $108 (16). While onion and potato-pea had even higher levels of risk, the inability of small farmers to obtain credit constituted a great deterrent to expanding the area planted to tomatoes.

Although quantified studies do not exist for other countries, the major problems listed earlier reflect the high levels of risk associated with expanding tomato production. Unless researchers work through agronomic means, and government and business through economic means to reduce yield and price variability, it will be difficult to increase the area planted to tomato.

CONTRACTUAL ARRANGEMENTS

A prime example of industry's success in reducing risk to small farm producers is the introduction of farmer-factory contracts in southern Taiwan. There, Japanese-owned processing factories supplied varieties, pesticides, fertilizer, sprayers, wooden crates, transportation, and

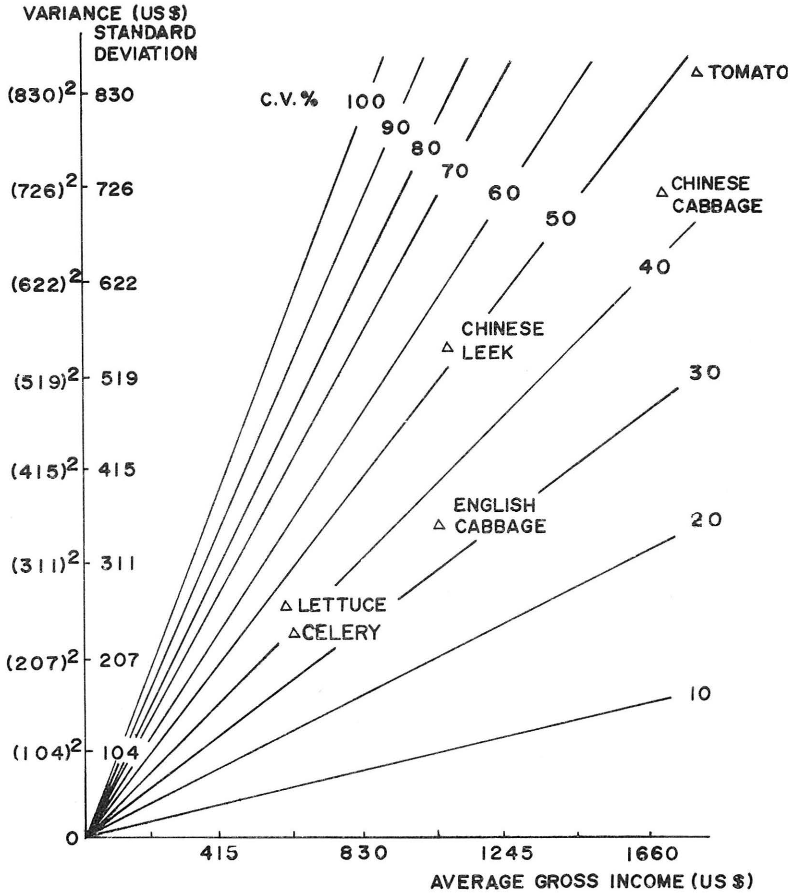

FIG. I RELATIONSHIP BETWEEN STANDARD DEVIATION, VARIANCE AND COEFFICIENT OF VARIATION IN SELECTED VEGETABLES

technical advice. In return, the farmer was bound to sell his entire output to the factory and was encouraged to produce high quality tomatoes by a system of grading (US$32/t for first grade tomatoes and $24/t for second-grade). While these prices were generally lower than farmers could achieve on local markets, income was guaranteed and the provision of inputs afforded further security. Under this system the area planted to processing tomatoes in Taiwan increased from 18 ha in 1967 to nearly 3,000 ha in 1975 (9).

SEASONAL PRICE VARIABILITY AND THE POTENTIAL FOR TRADE

Seasonal price fluctuations contribute to the variability in returns and, hence, to risk. But, such fluctuations may be a blessing in disguise if specialization and trade can be developed between regions and countries. Different optimal growing periods for tomatoes open the possibility for trade among nations with complementary production seasons.

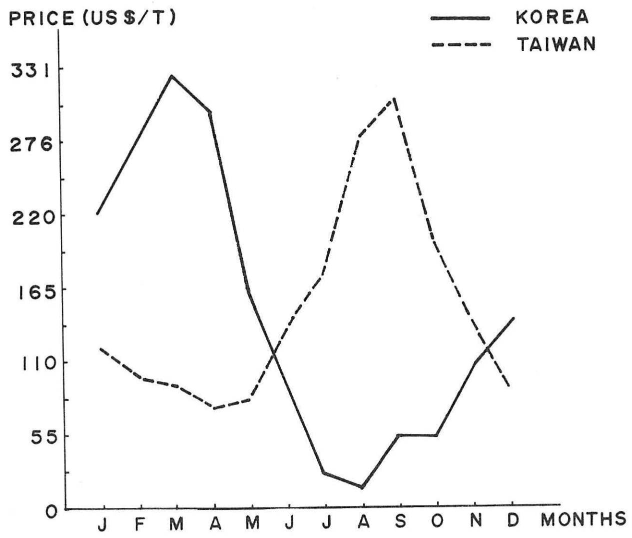

Fig. 2. SEASONAL PRICE VARIATIONS FOR TOMATOES IN KOREA AND TAIWAN, AVRDC, 1978

Figure 2 shows that Taiwan and Korea, for example, could take advantage of this situation. The price of tomatoes is highest in Korea in Dec-May, just when it is lowest in Taiwan. A trade policy would help to:

1. assure consumers of more even prices throughout the year and, hence, stimulate the use of tomato as a regular vegetable in the diet;

2. elevate the price for producers in the season in which they enjoyed a comparative advantage by expanding consumer demand; and,

3. reduce the risk and expense of farmers trying to produce in seasons with unfavorable environmental conditions.

Equity problems might occur if the producers who would gain in the season of comparative advantage were already better off than those who would lose in the other season. In general, this arrangement should benefit all concerned.

In Nepal, as in Taiwan, the price is higher in the summer ($0.05/kg) than in the winter ($0.02; 14). In Thailand, the period of high price is Oct-Dec, and of low price Mar-May. In the Philippines, by contrast, prices are high from Jul-Dec, and low from Jan-Jun.

OPTIMAL CROPPING PATTERNS

Once production risks and lack of internal and external markets are overcome, tomatoes will be profitable and high-yielding enough for inclusion in improved cropping patterns and extension to farmers. A linear programming study in India (10) involved the specification of optimal cropping patterns for a 4 ha typical farm near Ludhiana, Punjab. Even though this vegetable farm already helped to supply the needs of a large urban populace, the program called for an increase in area planted to tomatoes from 2.5 to 5.0 ha to replace spring potatoes and fallow. Earnings would rise 25%.

In another linear programming study in the Cameroon Highlands, Malaysia (6), the optimal area planted to tomatoes was determined to be the highest of any crop, and to increase as the land constraint was relaxed. However, it increased at a lower rate because,as farm size was expanded from 0.80 to 1.99 ha labor and other inputs became constraining. In other words, small-holders should and can plant proportionately more tomatoes and will, therefore, gain more from the introduction of improved technology. Under actual conditions in the Cameroon Highlands, only 0.29 ha/farm are grown, while optimal solutions call for 0.47 ha.

CONCLUSIONS

Tomatoes are a popular choice for consumers and have great potential for improving the income, employment, and nutrition of tropical populations. However, despite gradual increases in yield and planted area between 1964-75, four major problems prevent small-holding farmers from planting maximum areas to tomato:

1. Markets and distribution systems are inadequate. Combined with unpredictable prices, they make for great variability in farm returns.

2. Poor seed quality, and unfavorable environmental conditions lead to great yield variability. Small-holders are unwilling to plant large areas to tomato unless research and policy measures reduce elements of risk.

3. Tomato is sometimes grown under production technology which does not reflect the relative costs of inputs.

4. Seasonal price variations make peak-season production less profitable and off-season production more risky. Unless programs of specialization and trade lead to larger demand and better returns during the peak season, only large-holders and risk-takers will be willing to expand tomato area.

Such measures as research in genetic and cultural practices, the extension of appropriate technologies, contractual arrangements through private industry, government guarantees and subsidies, market improvements, and the development of interregional and international trade could reduce the risk to small-holding farmers in the tropics and encourage them to plant more tomatoes. Tomatoes could then be grown at optimum scale. Because tomato is labor-intensive, the expansion of planted area would benefit small-holders relatively more than large-holders, and provide for both equity and growth in the agricultural sectors of tropical nations.

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PROCESSING TOMATOES: AN INTERNATIONAL PERSPECTIVE

George A. Johannessen[a]

The need for increased food production and for improved varieties and methods of production has been recognized for a long time. World population continues to increase by leaps and bounds. Some experts predict a world population of 6 billion by the year 2000. Much of this increase will be in countries that currently have insufficient food supplies and little extra land on which to produce food. This critical situation calls for all the ingenuity, knowledge, and management skills we in agriculture can muster to increase food production within those countries as well as in the areas of the world best suited for food production.

Whether it be in the tropics, sub-tropics, or the temperate zone, in wet or dry climate, in underdeveloped or developed countries, large- or small-scale operations, mechanically harvested or hand harvested, fresh market or processing, our goals and objectives are basically the same: improvement in tomato production, processing, and marketing. This will come about through increased yields and quality, by lowering costs, and by expanding markets. It is necessary to understand that, despite common goals, requirements differ greatly from one area of the world to another. Each situation must be assessed and different methods applied. This is true of varieties, cultural practices, harvesting, handling, and transportation.

Most of the developing countries are in the tropics or subtropics. Many are poor. Tomatoes are grown in areas of high humidity and rainfall, as well as in areas of low rainfall. And they are grown where a dry season requires irrigation for maximum production. Small acreages are the rule for most of these areas, but we are seeing increases in the size of units in many parts of the world outside of California. As our knowledge increases and communications among all countries improve we will see further expansion of tomato production for both the fresh market and for processing.

Processing tomatoes are grown in many parts of the world (Table 1.) Note particularly how much Italy produces - second only to the United States. Within the United States, close to 85% of the production is in California. Much of this is in large plantings that range generally from 70-500 ha, with some up to 2400 ha. All are mechanically harvested.

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Table 1. Tomatoes for processing: area and production in 12 selected countries 1974-1977.[a]

Country	Area						Production					
	1974	1975	1976	1977	1977	1977	1974	1975	1976	1977	1977	1977
	1,000 ha				% change 1975	from 1976	1,000 t				% change 1975	from 1976
Taiwan	1.5	4.7	2.2	2.4	-48	+ 9	90	223	110	120	-46	+ 9
Domin Rep	7.9	4.1	4.2	4.6	+12	+10	212	101	103	113	+12	+10
France	12.0	10.0	6.0	5.7	-43	- 5	229	280	203	215	-23	+ 6
Greece	17.6	20.0	10.1	17.0	-15	+68	925	979	445	794	-19	+78
Israel	27.1	45.3	34.0	35.0	-23	+ 3	83	163	116	120	-26	+ 3
Italy	117.0	112.2	96.2	100.5	-10	+ 4	1,787	1,575	1,240	1,160	-26	- 6
Mexico	3.2	3.9	3.4	5.0	+27	+47	160	210	170	250	+19	+42
Morocco	16.0	16.5	17.5	16.2	- 2	- 7	62	130	160	150	+15	- 6
Portugal	25.0	23.5	17.1	21.0	-11	+23	705	800	450	650	-19	+44
Spain	25.0	26.0	15.4	23.0	-12	+49	660	827	437	712	-14	+63
Turkey	24.0	25.0	25.5	26.0	+4	+ 2	500	520	550	580	+12	+ 5
USA	139.1	159.4	140.4	142.5	-11	+ 1	6,368	7,715	5,871	7,052	- 9	+20
Total	415.4	450.7	371.9	398.8	-12	+ 7	11,781	13,523	9,855	11,916	-12	+21

[a] U.S. Department of Agriculture, Foreign Agricultural Service, March, 1978.

Recent visitors to our Institute from southern Italy were interested in our cooperatives because most of their growers are small, with only .5-2 ha of tomatoes - all hand harvested. Also of interest and special concern to them is that many of their young people leave the farms and do not return. So, in addition to problems of production, there are social problems as well. This is not confined just to Italy, but to many other countries with small farms and where returns are too often low. However, there are also many small producers in countries around the world that successfully grow and market processing tomatoes. Among them are Italy, France, Greece, Israel, Portugal, Spain, Taiwan, and others. Some small sized units of tomato production can be and are being managed profitably. For the struggling growers, both large and small, there is a desperate need to reduce crop losses, and to maximize yield. That, it seems to me, is exactly what AVRDC is addressing here this week. This program of training and exchange of timely information is exactly what is needed to bring to all parts of the world the knowledge and techniques that will enable growers to increase their production of tomatoes.

In widely separated parts of the world - in Europe, Africa, Central America - I have seen the same mistakes repeated, and they have greatly hampered the production of processing tomatoes, and their industry. A common problem since the development of the mechanical harvester (so successful in California,) is the rush to mechanize. Modernizing does not equate mechanization. Where funds are readily available, the purchasing of harvesters has many times been quite premature. This has occurred in the United States as well. When one sees the smooth once-over operation of a tomato harvester on level, well drained fields in California, it is tempting to want to duplicate this seemingly simple method elsewhere. But there are many areas of the world, including parts of the United States, where the climate, current technology, size of production units, or other conditions present severe obstacles to successful mechanical harvesting operations. Probably the single most important limiting condition is rain during the harvesting season. But there are many others and they include unsuitable varieties and cultural practices, uneconomically sized production units, and lack of training in equipment operation and repair. Now, where and when improved varieties are coming in, better cultural practices are being implemented, larger economically sized units are developed, and the necessary training in mechanization and maintenace is accomplished, there are opportunities for expanding mechanical harvesting outside California. One most important consideration in successful mechanical harvesting is to have a reasonable spread in harvest maturities so that both the producer and the processor can capitalize on the economies that are provided by this longer season. Unit costs decrease as the season is lengthened. We have mechanical harvesters operating in the eastern and midwestern United States, Canada, Europe, Africa, the Middle East, the Balkans, Russia, and other countries. However, in the developing countries, and particularly in the wet and humid tropics, there are far more important steps that need to be taken. First is the development of adaptable varieties that have crack, disease, and nematode resistance, and that set and develop fruit under high day and night temperatures.

In California we experienced disastrous rains during the 1978 harvest. One grower had to disc close to 180 ha of tomatoes because of water mold (a species of *Pythium*) that followed a heavy rain just prior to harvest.

That was about 18,000 t, and in excess of $1,000,000 worth of ripe fruit lost. Such a staggering loss is of the same magnitude as when a smaller tomato grower loses 2 of his 4 ha to mold. In California, most ripe tomatoes in contact with a wet soil for as little as 5 hrs will develop water mold within 2-3 days, and will be rejected at the grading station. If there is more than 8% mold in a load of tomatoes, it is rejected by the station. Canners contracts generally specify a maximum of 5% mold. Despite this, we are encouraged by the progress our breeders have made in several extremely important fruit characteristics. One is that both VF 134, and the more recent University of California release, UC 82, have excellent vine storage. They are firm-fruited varieties that withstand mechanical harvesting, and transport with minimum damage. In the factory, they produce an excellently colored paste and sauce with the much-desired characteristic of high consistency. Although VF 134 and UC 82 are subject to water mold like all the other varieties we grow, there is another important difference. I have observed that, following a rain, these 2 varieties have an additional 2-4 day delay in the appearance of water mold infection. Further, if the rain is followed immediately by good drying weather, they may escape water mold altogether. This very important point enables growers to save much of the crop that would otherwise be lost. In addition to the other favorable attributes of these two "square rounds", processors realize a much higher recovery of sauce in the factory. This is not to imply that we are entirely happy with these two varieties. VF 134 is often very difficult to shake off the vine. Soluble solids are lower than the conventional "rounds" that we grow and this adversely affects the yield of concentrated tomato products. They are also lower in acid and flavor. The economic advantages of these two newer varieties are very great. For example, in 1976, before we had UC 82 and when plantings of VF 134 were limited, I estimate that California growers lost a minimum of 1,300,000 t of ripe tomatoes following rains. The major loss was due to water mold which penetrates the unbroken tomato skin of ripe tomatoes. Black mold which built up rapidly also accounted for a substantial part of this loss. In all areas, including the tropics, firm-fruited varieties such as VF 134 and UC 82 may well play an important role in improving tomato production where humidity is high and where rain occurs during the harvest.

Let's shift our attention from varieties for a moment. Once we have achieved the desired production, terrible things can happen if we aren't careful. By excessive delays in getting the fruit from the field to the factory, a high-yielding, high-recovery crop can deteriorate and yield very little of the potential it had at the moment of harvest. The time from harvest to processing is important in terms of quality delivered to the factory, and on the recovery and quality of the finished product. In Western Europe, I was surprised to see harvested fruit being brought out of the field in slatted crates. These crates were unloaded at the end of the rows. They were then loaded on a truck and transported to a "gathering place" where they were unloaded again and judged for quality. They sat until another truck, dispatched by the cannery and at the cannery's will, came along to pick them up. Once again they were unloaded and sat in the cannery yard until the factory was ready to receive them. In addition to the deterioration of quality and recovery of product, the mold increased to a level that limited the market of the finished product to areas not as demanding on mold content as many countries. In both Africa and Western Europe, I was also surprised to find newly constructed harvesting crates made with slats on all sides as well as on the bottom. In both cases, the roads in the areas were rough and the factories located some distance from the fields. The exposed edges of each slat provided cutting surfaces, particularly in transit to the factory. The obvious recommendation: never use a slatted crate, but one which is smooth and rigid. Damage caused by the container can be greatly minimized.

It might be helpful to touch on reasons for growth and the success of those areas around the world that have increased their production and sale of processing tomatoes and tomato products. In California this has doubled every 10 years since 1954, when California produced 1.2 million tons, followed by 2.8 million in 1964 and 5.5 million in 1974. The reason is: California can produce and process tomatoes cheaper than other areas of the United States. We also consistently provide a high quality product in the quantities demanded and with a high degree of dependability of both supply and quality.

In the humid tropics, Taiwan has made important recent advances and they are the result, in large measure, of the success of research and varietal development, much of which has been accomplished through this modern facility - the Asian Vegetable Research and Development Center with its fine staff. I remember well in the early 1960's, my efforts in Hawaii to grow various crack-resistant tomato lines, only to find they were all wiped out; wiped out primarily by bacterial wilt.

I have the good fortune of knowing both Drs. W. A. Frazier and Jim Gilbert (both formerly with the University of Hawaii). Dr. Frazier made some of the first important advances in resistance to the bacterial and virus diseases that so greatly affect tropical tomato production. Jim Gilbert continued work in these same diseases with great success, and his were the only lines that survived in my small tomato plots. Now we see from the latest progress report from AVRDC that they have distributed over 1000 seed packets of elite breeding lines to scientists in more than 40 countries throughout tropical areas of South America, Africa, Asia, and the Pacific Islands. Many of these carry good resistance to bacterial wilt and virus diseases. Unlike the drier climates where night temperatures are generally favorable for fruit set, the tropics pose a far greater challenge to researchers, producers, and processors. However, the fact that Taiwan, for one, is increasing its share of the world market for processing tomatoes and tomato products is proof of the advances that have been made in tropical areas.

Taiwan's prominent position among the developing countries of the world continues to surge forward, and its total trade with the United States alone is now approaching US$6 billion a year. American total investment in Taiwan is reported to be close to US$600 million. Recent advances in the food industries have been most pronounced with implementation of modern management practices and the use of the most modern equipment available, both aimed at upgrading production and product quality while simultaneously striving to reduce costs through efficiency and volume. Production and processing of tomatoes represents an important share of this growing segment of Taiwan's economy. In 1976/77, 14% of US imports of tomato paste and sauce came from Taiwan. The 5 year average was 3% according to the American Farm Bureau Federation's Horticulture Department.

Beginning in the last half of the 1960's, market demands increased sharply, particularly for tomato products and primarily for paste for remanufacture. First, we can see the almost universal acceptance of processed tomatoes and tomato products over a wide part of the world. In the US, the fast food chains with their hamburgers, hot dogs, and french fried potatoes help consume huge quantities of ketchup, much of it remanufactured from paste. These chains have sprung up in the Far East, in Europe, Africa, and South America. Tastes are changing rapidly in countries that traditionally had seldom or never been served these foods. I believe the frozen french fry and the pizza pie have moved more of our processed tomato products than any other single phenomenon, and we in California are most appreciative of the acceptance of these food items and their rapid spread to all parts of the world.

It is of interest to note that in the 1960's up to 1968 there was an apparently insatiable world demand for tomato paste. California's production figures reflect this. So, too, do the production figures of countries in Europe - Portugal, Spain, Italy, and later, Israel, Greece, and France. Up until 1968, US imports of paste from Portugal, Spain and Italy increased drastically. The great over-production of processing tomatoes and tomato products that finally came to the US in 1968 markedly reduced foreign imports. In addition to the supply, there were problems mainly in consistency and color in the paste being imported. However, there were also, during this period of development, increasing markets at home and, following a short period of market adjustment after the huge 1968 pack, demand around the world continued its upward momentum. Once again in 1975 we overdid it, not only in California but in Europe and the Middle-East as well. By this time, and after a number of years that saw both producers and processors profit, all of these areas had greatly increased their processing capacities and many new facilities had been established. This was true particularly in California, but equally important, in Canada, Mexico, Europe, the Middle-East, the Far East, the Balkan countries, and Taiwan as well. After 1975, when the market for products around the world was saturated, processing facilities in most of these foreign countries sat idle and processing was carried out in many areas at just about half. There is no way, barring severe crop failures in important producing and processing areas of the world, that growers or processors can make money under these conditions. In 1976, two serious conditions prevailed which quickly corrected the oversupply. First, at the start of the season, there was a cannery strike in California which resulted in the loss in the fields of thousands of tons of growers' fruit. Then, at the height of the harvesting season, the entire state was subject to periodic and heavy rains. Growers in California, who had a 6½ million ton crop, lost close to 1.3 million tons of ripe tomatoes in the fields. Once again, the market strengthened for processing tomatoes and tomato products.

This points up two very important factors that influence the stability and health of this industry, both on a national and an international level. The first is the fluctuating supply often associated with change in the quality of the pack; the second is the magnitude of losses that occur generally as the result of untimely and excessive rain.

Markets are expanding in all areas of the world. It would appear logical that the growers and processors closest to the area would supply those markets. The next logical step is to seek the export market which, with success, would bring further growth to the industry. This involves some politics - an area outside my field. The arena of trade is complicated and there is a desire of all nations to maintain a balance of trade. However, it is a fact that tomato processors go where they can operate at the lowest costs and greatest returns. Similarly, buyers purchase processed tomatoes and their products where they can get them the cheapest.

In this same direction is the increase in bulk shipment and bulk storage of tomato paste. I have been surprised at how slowly the California processing industry took up the concept of bulk storage of tomato paste or concentrate in large steel tanks. Two of the major national processors already knew about and practiced this for close to 15 years. With the development of the Purdue University research on bulk storage in large steel tanks being offered to all processors in the world, we are now seeing a lot of tomato pulp storage tanks - 75,700, 151,400, 378,500, or 473,125 liter tanks - spring up across the United States and in other countries. Many in the US will be located not only in California but in the East and Midwest. However, those Eastern and Midwestern tanks will be filled mostly with tomatoes grown and first processed in California. This product is then shipped in sterile rail tank cars to the East and Midwest, shipments of bulk paste to the Far East or Europe for remanufacture go by sea. When fully exploited, this will be a real shot in the arm for the processing industry of the areas in which the tanks are located. But, in the United States, it will be mainly California-grown tomatoes that will fill these tanks. The same may hold for some foreign countries. Tomato products will be remanufactured from this product 5 days a week into whatever container size of tomato product is most profitable at the time, with indicated adjustments to the market demand being made with a minimum of time, effort, and money.

Let's go back now and touch once again on the quality factor. I can't overemphasize the importance of uniform grade standards and raw product inspection. This is a necessary step in quality control so important in marketing both the raw product and the finished product.

In California we have a Canning Tomato Advisory Committee made up of 5 growers and 5 canners appointed by the Director of Food and Agriculture. This committee makes recommendations for research on matters of grading, grade standards, and inspection procedures. They also approve research projects that have been developed cooperatively between various subcommittees of the major committee and researchers at the University of California. Funds necessary for the support of such research are provided from canning inspection fee funds which are assessed equally between growers and canners. This committee has been in operation in California for 10 years and has led to significant improvements in grading and inspection. It has done much to assure the maintenance of high standards of grading and inspection, and the assurance of a high quality product. Also, and very importantly, it has brought growers and canners closer together, resulting in better communications, and more intelligent and equitable decisions in all matters relating to this area of quality assurance.

Reflecting on the accomplishments of our grading and inspection processes directly attributable to the Committee and its various subcommittees, I would propose that this concept be expanded on local, national, and international levels. I would think that the creation of an International Tomato Advisory Committee would be worthy of consideration by this group. Not only could such a committee deal with problems of production, quality measurement, processing, or marketing, but, depending on the make-up of the committee, it could more wisely assess priorities and suggest the most promising avenues of approach and solutions to these problems. Such a representation could help greatly in avoiding duplication of research, and bring to bear on each problem the best talents available.

To return to California for a moment, there has just been appointed a new University of California-Industry Tomato Breeding Committee. Its purpose is to periodically review objectives and progress of the tomato breeding program at the University of California. The committee consists of 6 producer representatives who have been selected from the Board of Directors of California Tomato Research Institute, and 6 processors from major canners in California, and representatives of the seed companies who conduct tomato breeding programs. Currently, the University of California's tomato breeding program is supported financially by both growers and canners. This will continue in the years ahead. The California Tomato Research Institute is funding not only Dr. Allen Stevens' breeding program but the variety evaluation trials conducted by farm advisors throughout California. In addition to this, our Institute equipped and is supporting a central laboratory at the University where important tomato quality characteristics are measured. I am telling you of this to illustrate the success we have had with the interaction between the university, the grower, and the processor. This concept might be incorporated in other countries because the future is here. It will remain so depending on what we do now. No one can rest on their laurels. No area has a corner on the brains in this world. We have progressive growers and processors everywhere. Research stations such as AVRDC add great strength to the opportunities that can be exploited. The world needs our product. The problems of the world are ours. They include hunger, increasing labor costs, the need for higher productivity, new product development, and marketing. Through research we must plan for the future. As the world makes greater demands for high quality processed tomatoes and tomato products, we will succeed in proportion to the kinds and quality of our research, the skills and dedication of our people to excellence, and the development of successful programs for increasing productivity on the world's agricultural lands.

CONSUMPTION AND UTILIZATION OF TOMATO IN TAIWAN

C.S. Tsou and S.C.L. Chiu[a]

INTRODUCTION

Vegetables play an important role in the Chinese diet. More than a hundred kinds can be found in most Taiwan vegetable markets. During the last 10 years, vegetable consumption in Taiwan has increased remarkably. Per capita consumption of vegetables has doubled since 1967 (15). The price index of food items indicates that vegetable prices increased more rapidly than those of other food items (10).

Tomatoes are important fruit vegetables in the Chinese diet, and an important commodity for processing. During the last 10 years, the production and planting acreage of tomatoes has rapidly increased due primarily to the canning industry for export (12). The development of the processing industry, however, has stimulated domestic consumption. This paper will review the consumption and utilization of tomatoes in Taiwan since 1968. The possible role of lowland tropical tomato being developed at the Asian Vegetable Research and Development Center (AVRDC) will also be discussed.

PROCESSING TOMATO

The food processing industry in Taiwan concentrates on canned products. Pineapple initiated the rapid development phase of the canning industry. Although the tomato processing industry has existed for a long time (14), the establishment of Taiwan Kagome Company opened a new phase since 1967. In 1969 there were only 3 factories that canned tomatoes (13). By 1977, 53 factories or processors exported canned tomatoes. The export volume of each factory varied from 83 - 308,194 standard cases per year. The frequency distribution of factories according to the export volume is shown in Fig. 1. Tomato paste and peeled tomatoes are the major canned products (64% and 24%, respectively). Unfortunately, the markets are not very stable. For example, in 1976, 592,920 standard cases of tomato products were exported to Canada (38% of the total export volume); in 1977, however, this dropped to 81,013 standard cases.

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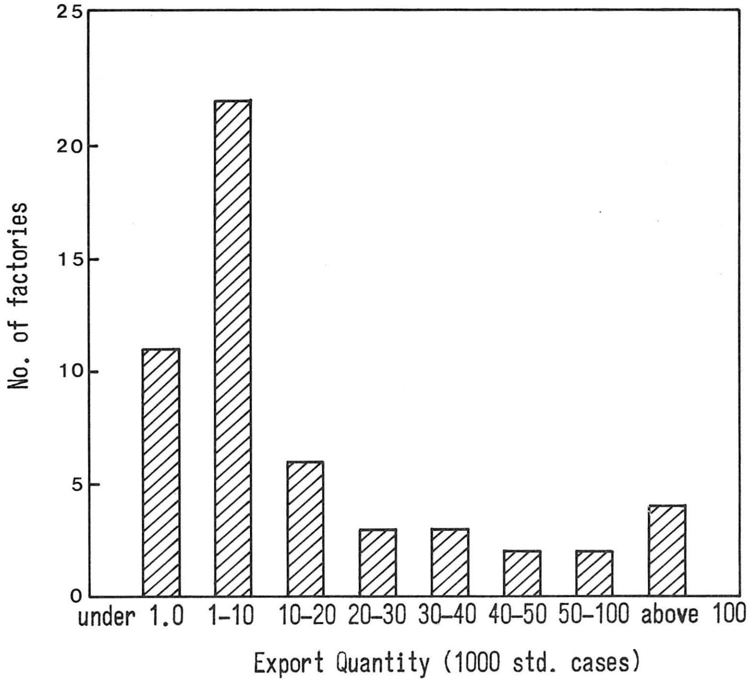

Fig. 1. Frequency distribution of 53 factories by export quantities of tomato products.

Production of tomato is concentrated in the cool winter season in Taiwan. Most of the processors are located in the major production areas (Tainan, Chiayi, and Yunlin). None of the processors (including Taiwan Kagome Co.) processes only one commodity. The pack seasons of major canned foods are shown in Fig. 2. The pack season for tomato starts in Nov and ends in Apr.

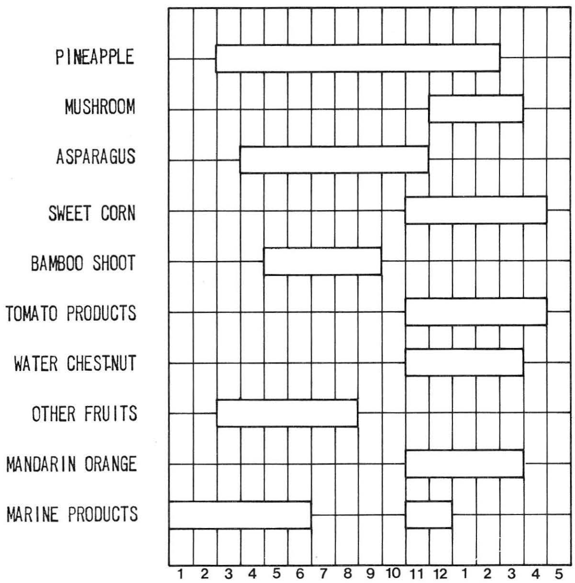

Fig. 2. Canned food pack seasons.

Processing tomatoes are generally medium-small in size. Harvested at the fully ripe stage, processing tomatoes are transported directly to factory. These tomatoes are different from the fresh market tomatoes bought in the domestic markets. However, recently, the processing tomato has appeared in the market, especially during the peak production season. It seems to be accepted by the consumers.

FRESH MARKET TOMATO

Tomato in Taiwan is often considered a fruit rather than a vegetable. Consumers prefer a medium to large size tomato, harvested at mature-green or breaker stage, and consumed without post-harvest ripening. Fruit with green shoulders are prefered. Ripened tomatoes are sliced and prepared with other foods as a vegetable. Fruit size is not considered critical. Recently, the consumption of fresh market tomato increased dramatically. The transaction volume, average price, and percentage of a few selected vegetables to total volume of vegetables transacted in Taipei are compiled in Table 1 (11).

Chinese cabbage (heading type), common cabbage, and radish are three important vegetables in the Chinese diet. Since 1975, tomato has become number four. The big jump from 1974 to 1975 in tomato consumption is due to the introduction of processing tomato into the market. The average price of vegetables increased from US$99/t in 1974 to US$162/t in 1977. The tomato price, however, remained stable during this period.

Seasonal variation of vegetable supply is a common complaint among urban consumers. Due to the high temperature and rainfall, summer vegetable growers have a higher risk of crop failure. Many vegetables have to be grown in the highlands during the summer. The monthly consumption of total vegetables and tomatoes is shown in Fig. 3. During the summer (Jun - Sep), there were fewer vegetable transactions in Taipei. In 1974, the monthly transaction volume of tomato was not much different throughout the year except the slight increase in Dec. In 1975, the supply of tomatoes showed strong seasonality. In Mar, per capita transaction volume increased from 0.083 kg in 1974 to 1.04 kg in 1975.

Nutrients from vegetables, fruit, and tomatoes are listed in Table 2. In most countries vegetables and fruit are the primary sources of vitamin A and C. However, in Taiwan, vegetables are also the major source of B_2, calcium, and iron. As indicated by nutrition surveys, the Chinese diet is deficient in these three nutrients (3). Unfortunately, tomatoes contribute only 1.77%, 1.36%, and 2.20% of B_2, calcium, and iron, respectively. However, tomatoes are a good source of vit. A, a nutrient slightly deficient in Taiwanese diets.

TOMATO CONSUMPTION PATTERNS

Unlike staple food, the consumption patterns of vegetables can be affected by many factors even in a specific location or a specific group of people. Family income is one of the major factors that affects the quality and kind of vegetables consumed in the household. In general, the lower income groups spend higher percentages of their income on

Table 1. Transaction volume, average price, and percentage of selected vegetables to total vegetables transacted in Taipei City (11).

	Headed Chinese cabbage			Common Cabbage			Radish			Tomato		
	Volume		Average price	Volume		Average price	Volume		Average price	Volume		Average price
	-t-	-%-	-US$/kg-	-t-	-%-	-US$/kg-	-t-	-%-	-US$/kg-	-t-	-%-	-US$/kg-
1969	6,117	6.17	0.071	3,123	3.15	0.054	2,411	2.43	0.039	690	0.70	0.051
1970	11,747	10.38	0.044	6,137	5.43	0.036	3,625	3.20	0.033	1,296	1.15	0.071
1971	12,837	10.05	0.062	7,719	6.05	0.036	4,100	3.21	0.039	1,649	1.29	0.054
1972	10,961	8.47	0.081	7,647	5.91	0.056	4,028	3.11	0.045	1,869	1.45	0.104
1973	7,798	5.42	0.060	7,676	5.34	0.063	6,259	4.35	0.045	1,794	1.25	0.109
1974	8,969	6.37	0.074	10,112	7.18	0.088	7,636	5.42	0.070	2,859	2.03	0.135
1975	29,958	13.54	0.070	19,389	8.77	0.085	13,086	5.92	0.076	9,542	4.31	0.132
1976	32,865	13.17	0.067	23,880	9.57	0.072	16,890	6.77	0.062	13,356	5.35	0.115
1977	30,945	12.45	0.087	22,026	8.86	0.109	15,865	6.38	0.090	12,414	4.99	0.132

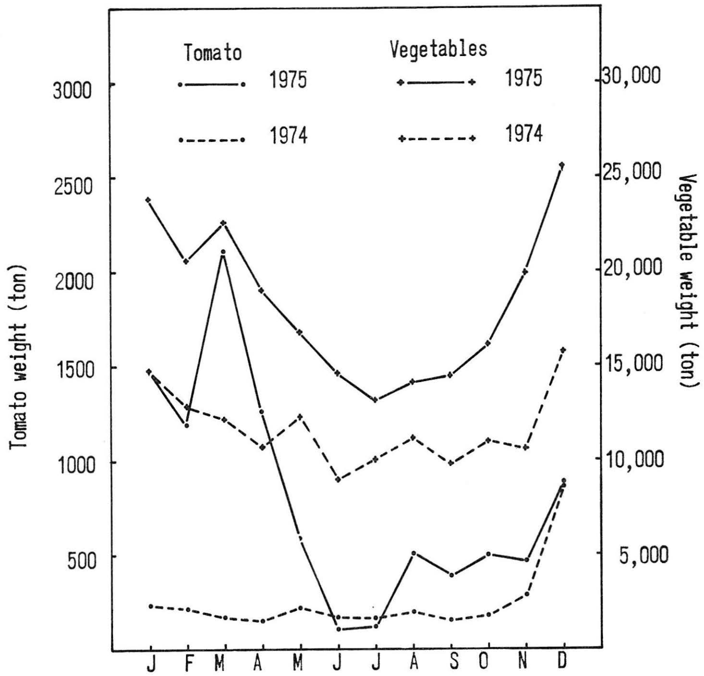

Fig. 3. Monthly transaction volumes of vegetables and tomatoes in Taipei City, 1974-75.

Table 2. Food nutrients - percentage of total amount in food contributed by vegetables, fruit, and tomatoes in Taipei during 1976.

Nutrients	Vegetables	Fruit	Tomato
Energy	3.1	2.7	0.13
Protein	8.7	1.8	0.16
Calcium	33.6	7.0	0.46
Phosphorus	10.5	2.2	0.36
Iron	24.3	5.5	0.54
Vitamin A	74.6	11.5	0.64
Vitamin B_1	15.2	7.2	0.53
Vitamin B_2	30.1	6.8	0.53
Niacin	11.4	4.5	0.52
Vitamin C	60.7	38.3	2.82
Fat	1.1	0.4	0.05

food. The Engel coefficient of various income groups in Taipei varied from 36-54% with a mean of 41% (7) which was high compared to developed countries. The expenditure coefficients of selected food items to total food expenditure from 1972-1977 are summarized in Table 3. The average incomes of each respective year are also listed. Cereals was the only food group showing a clear trend. Although it is difficult to see a general trend in total vegetable consumption from this table, we can still see changes in consumption by comparing each individual vegetable (Table 1).

Table 3. Monthly income and expenditure coefficients (to total food expenditure) of selected foods per household in Taipei.[a]

Year	Income	Cereals	Meat	Vegetables	Fruit
	-US$-	%			
1972	184.9	14.83	29.76	15.06	7.45
1973	197.1	15.59	30.01	17.06	7.22
1974	261.9	17.37	28.35	17.23	7.52
1975	292.7	16.36	30.52	16.92	7.42
1976	346.8	15.93	30.60	15.85	8.24
1977	371.4	13.93	31.13	17.14	8.32

[a] Ref. 6.

The agricultural economics group of AVRDC conducted a survey in 1977 to study the vegetable consumption patterns in 5 cities (2). This survey revealed that as income increased, consumers increased overall real food expenditures and those to fruit, fish, meat, and milk. Vegetable expenditure, on the other hand, declined as income increased, except among the highest income groups. This tendency holds for all the vegetable sub-groups (leafy, green, root, flower, fruit, and legume). Consumer buying patterns and attitudes on specific vegetables were also studied. The survey showed a positive relationship between tomato consumption and income class. The major factors leading them to consume tomatoes are nutritional content, taste, and appearance. Taipei is the only city that has more consumers who consider the tomato a vegetable (52.4%). In the other four cities, tomatoes are consumed as fruit. In all five cities surveyed, red tomatoes are preferred by consumers. However, there are more people in Kaohsiung and Changhua than Taipei in favor of green tomatoes.

Unlike in the United States, canned tomato products are not popular in Taiwan. Less than 4¢ per household per month was spent for tomato sauce in Taipei. There was a slight increase from 1973-75. However, it leveled off after 1975. In the United States, the per capita consumption of canned tomatoes was 9.57 kg in 1974 (16).

POTENTIAL ROLES OF TROPICAL TOMATO IN TAIWAN

The consumption pattern of fresh market tomato in Taiwan changed in 1975. Fully ripened,small size tomatoes were introduced into the fresh market and accepted by the consumers. The price, however, is generally lower than for those big mature-green fruit produced by indeterminate varieties. During the hot humid summer, the tomato supply is still very limited (Fig. 4). The percentage of tomato as total vegetable consumed in Taipei is much less in the summer regardless of the fact that there are fewer vegetables available then. The development of the processing industry did not provide technologies for summer tomato production. In order to have a better understanding of summer tomato production in Taiwan, the agricultural economics group made a survey in 1977 (4). Three distinct sub-seasons have been identified -- lowland late summer, upland early summer, and upland full summer (Table 4). Although the late summer season has a higher yield, the income and net return are much less than those of the early summer season. Correlation studies reveal that reduction of production expenses increases farmers' net return in all three sub-seasons. Rainfall has been identified as one of the important factors which cause yield reduction of summer tomatoes, since the late summer sub-season is already in the lowland and can be harvested by early Oct. A heat-tolerant variety is not essential for lowland production in this season. The major gap to be filled is from Jun to Sep.

The tropical lowland tomato developed at AVRDC has shown a promising yield potential under summer conditions (1). It may not have immediate impact on the processing industry but it could serve as a fresh-market tomato during the summer season. The quality needs improvement to meet local preferences.

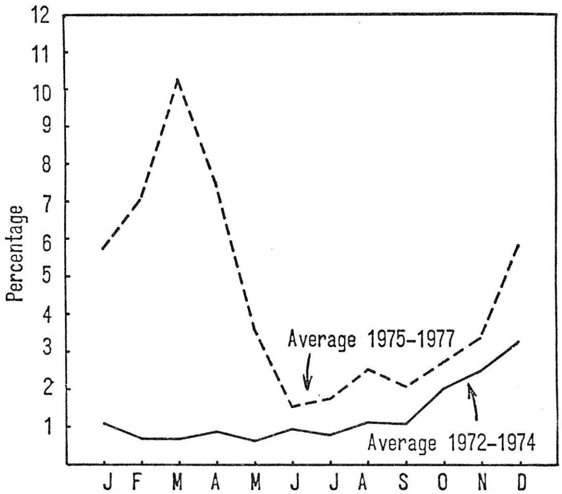

Fig. 4. Percent of tomato to total vegetable transaction volume.

Table 4. Selected information on three sub-seasons of summer tomato.[a]

Sub-season	Major area	Harvest	Yield	Price	Production expenses	Farm income	Net return
			-t/ha-	-US$/kg-	-----thousand US$/ha-----		
Late Summer	Changhua (lowland)	Early Oct - Mid Dec	69.4	0.10	8.0	4.0	-1.1
Early Summer	Taipei (highland)	Early Jun - Late Jul	40.1	0.37	7.2	13.6	7.8
Summer	Nantou (highland)	Early Jul - Late Aug	25.8	0.33	8.4	4.8	0

[a]Ref. 4.

Experiments have been conducted at AVRDC to evaluate the quality of one promising line (CL11d) harvested during the summer season. Since the fruit size of this line is relatively small, the quality at ripening was tested (Table 5). Results show higher vitamin C than fruit harvested during the cool season. No significant differences were found in color. Soluble solid and titratable acidity were higher. The soluble solid to acidity ratio remains steady, although slightly higher in the summer season. This property is associated with flavor (8, 9). From a laboratory taste study, we found Chinese panels consider this important to flavor. Since this ratio is relatively low, panels consider the tomatoes slightly sour. However, since this tomato will be used as a vegetable, it may still be accepted by consumers for cooking.

Table 5. Quality characteristics of C11d-0-1-2-0 harvested at various months.[a]

	Ripen. stage[b]	Beta-carotene	Titratable acdity	pH	Soluble solids	Vitamin C	Soluble solids/ titratable acidity
		-m/100g-	-%-		-°brix-	-mg/100g-	
	red	0.92	0.576	4.16	6.73	41.5	11.7
Jul	lt. red	0.67	0.573	4.21	6.27	39.4	10.9
	pink	0.55	0.545	4.17	6.09	40.4	11.2
	red	0.87	0.584	4.10	6.24	37.4	10.7
Aug	lt. red	0.55	0.583	4.07	5.90	34.7	10.1
	pink	0.55	0.562	4.12	5.88	36.6	10.5
	red	0.79	0.551	4.17	6.21	35.7	11.3
Sep	lt. red	0.65	0.540	4.13	5.79	35.0	10.7
	pink	0.53	0.566	4.11	5.63	33.4	9.9
	red	0.94	0.546	4.37	5.66	27.4	10.4
Oct	lt. red	0.83	0.565	4.31	5.70	29.6	10.1
	pink	0.73	0.590	4.27	5.33	26.6	9.0
	red	0.91	0.454	4.28	4.42	26.2	9.7
Nov	lt. red	0.87	0.494	4.23	4.32	26.2	8.7
	pink	0.71	0.482	4.25	4.07	25.3	8.4

[a]Analyses were carried out every week. Data presented are average values of that month.
[b]red - more than 90% of the surface is well colored. Light red - more than 60% of the surface is fairly well colored. Pink - 30 - 60% of the surface is fairly well colored.

Table 6. Days to various ripeness stages of tomato, 1977-78.

Date Planted	Dated tagged	Breaker	Turning	Pink	Red	Red color (Hunter a/b)
		days				
Dec 1	Jan 14	55.8	58.0	60.7	64.7	2.12
Dec 1	Feb 17	49.5	52.8	57.0	60.3	1.95
Jan 15	Feb 17	54.0	54.4	61.2	67.0	1.89
Jan 15	Mar 16	46.7	50.3	53.9	60.8	1.82
Mar 1	Apr 14	32.5	35.6	38.6	41.7	2.25
Mar 1	May 4	30.5	32.8	36.5	39.4	1.91
Apr 15	May 15	37.4	39.9	43.5	47.4	1.97
Apr 15	Jun 8	28.2	31.0	34.1	39.6	2.16
	LSD 5%	5.7	5.3	4.8	5.1	0.18
	1%	10.3	9.5	8.2	9.0	0.33

In order to understand tomato development under tropical conditions, a fruit tagging experiment was conducted by Chemistry in cooperation with Crop Management at AVRDC. Tomatoes were transplanted with an interval of one and half months. Forty small fruit were tagged monthly for each planting. Fruit were divided into five ripening stages and the number of fruit at each stage were recorded every three days. The days to ripening of each planting are summarized in Table 6. During the summer, the days required for ripening are significantly less than in spring. Fruit dropping was a serious problem during summer (Table 7). Fruit can remain on the vine rather well before stage 2 (breaker). Most fruit dropping occurred between stages 3 and 5. This result indicates that, in order to guarantee yield, summer tomato should be harvested during the mature-green and breaker stage. Post-harvest ripening could be a potential solution to improved appearance, although this is not a currently common practice in Taiwan.

Table 7. Tomato fruit dropping (including pest damage) at different ripeness stages, 1977-78.

Date planted	Date recorded	Ripeness stage					Total
		Green	Breaker	Turning	Pink	Red	
		%					
Dec 1	Jan 14 - Apr 3	0	0	0	0	2.4	2.4
Dec 1	Feb 17 - Apr 27	0	0	0	0	16.7	16.7
Jan 15	Feb 17 - May 4	0	0	0	13.3	6.7	20.0
Jan 15	Mar 16 - May 18	0	3.4	27.6	24.1	6.8	61.9
Mar 1	Apr 14 - Jun 5	12.5	0	6.3	22.9	31.3	73.0
Mar 1	May 4 - Jun 19	14.9	1.9	14.9	42.7	5.6	80.0
Apr 15	May 15 - Jul 10	5.0	7.1	21.2	28.2	9.1	70.6
Apr 15	Jun 8 - Jul 24	1.9	0	9.5	23.0	7.6	42.0

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PILOT COMMERCIAL TRIALS WITH TOMATOES IN LOWLAND PAPUA NEW GUINEA

K.J. Blackburn[a]

INTRODUCTION

The national capital and largest urban center of Papua New Guinea (PNG), Port Moresby, is seriously under-supplied with fresh fruit and vegetables. With a population exceeding 100,000 and growing at 9% per year, Port Moresby imports an estimated US$1.5 million worth of fresh vegetables annually. Out of this, some 200 t of fresh tomatoes are imported from Australia, and this figure is growing as population increases and food consumption patterns change.

Local production of tomatoes over the years has been highly seasonal and irregular with no continuity of supply. Retail outlets prefer to import their supplies rather than rely on local production. Market gardening in the Port Moresby area generally lacks technical expertise and capital investment. These gardening projects usually fail after two of three years of production. There are currently four expatriate tomato growers in the area who produce limited supplies during the dv season (Jul-Nov). In the national sector there are no commercial tomato growers; tomatoes are grown as a component of the subsistence gardening pattern and sold through the traditional market outlets.

Tomatoes are grown in highland areas, (Wau, Goroka, Tapini), and air-freighted to Port Moresby. Prices paid can vary from US$2.20 - US$4.50/kg depending on supply and quality. Tomatoes imported from Australia are often chilled in transit, resulting in poor quality and poor keeping ability.

The climate of the Port Moresby hinterland is dominated by strong dry onshore southeast winds extending, usually, from May to Oct. The main wet season coincides with the period of variable northwest winds from Dec-Mar. Doldrums in Nov and Apr mark the seasonal change. The effect of the southeast wind has its dominant agronomic effect on exposed coastal locations where it causes a rapid drying of native vegetation, and it can be damaging to wind-susceptible plants. The average annual rainfall is about 1200 mm/yr. Near Port Moresby, tomatoes have only been cultivated in the dry season resulting in a peak production from Aug-Sep,

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with usually one crop per year. Poor fruit set, waterlogging, and severe leaf disease have discouraged wet season production.

Since 1974, the University of Papua New Guinea (UPNG) and the Department of Primary Industry (DPI) have intensively screened tomato varieties at Laloki. Although all early research concentrated on varieties that are susceptible to bacterial wilt (*Pseudomonas solancearum*), the emphasis now is on wilt resistant breeding lines.

In 1976, DPI evaluated 35 wilt resistant cultivars from the University of the Philippines College of Agriculture (UPCA). These were generally too small and too bitter for commercial value. This work at DPI Laloki was given a significant impetus in 1977 with the acquisition of fifty C 555-F5 breeding lines from the Asian Vegetable Research and Development Center (AVRDC). During the 1977 and 78 growing season 210 breeding lines from AVRDC were evaluated at Laloki. One line, C 555-F5-19, was selected for its exceptional fruit size, palatability, and disease resistance. The early assessments of commercially available varieties were seriously affected by losses from bacterial wilt. All commercial vegetable growers in the Port Moresby area have had tomato crop failures after wilt has built up on their farms and, generally, they have abandoned tomato growing as a viable enterprise.

The PNG government has a firm and important policy of import replacement and self-sufficiency in fresh food production. In 1977, the South Coast Food Production Project (SCFPP) was initiated to meet the demands of the Port Moresby area for locally produced vegetables, fruit, and basic foodstuffs. This project would serve as a model for food production in other urban areas. The absence of any large scale efficient market gardening enterprizes near Port Moresby to supply economic data on vegetable production made the SCFPP necessary. The project aims for large grower groups using intensive production methods and employing management and labor so that the government's objectives can be realized as soon as possible. The lack of detailed and reliable economic data on the production of vegetable crops was considered a serious handicap to any extension effort to encourage vegetable production. Therefore, it was decided that the phasing of crops into production patterns would be preceded by pilot commercial trials on two vegetable varieties per year. In 1977, tomatoes and common cabbage were selected.

MATERIALS AND METHODS

A sequential rotation pattern was designed so that two tomato blocks were in production at any one time (Fig. 1). Each two blocks were planted four weeks apart so that continuous production could be achieved. In the dry season there was considerable production overlap as blocks were allowed to produce longer than the arbitrary four week period. Generally, if a block was producing well then we allowed it to continue, especially if a fallow period followed. The objective in the pilot commercial trial was to have each block produce two tomato crops followed by a fallow period when a cover crop was planted.

The tomato varieties selected for evaluation were AVRDC selection C 555-F5-19 and a selection from the Philippines, S 665. Only four blocks

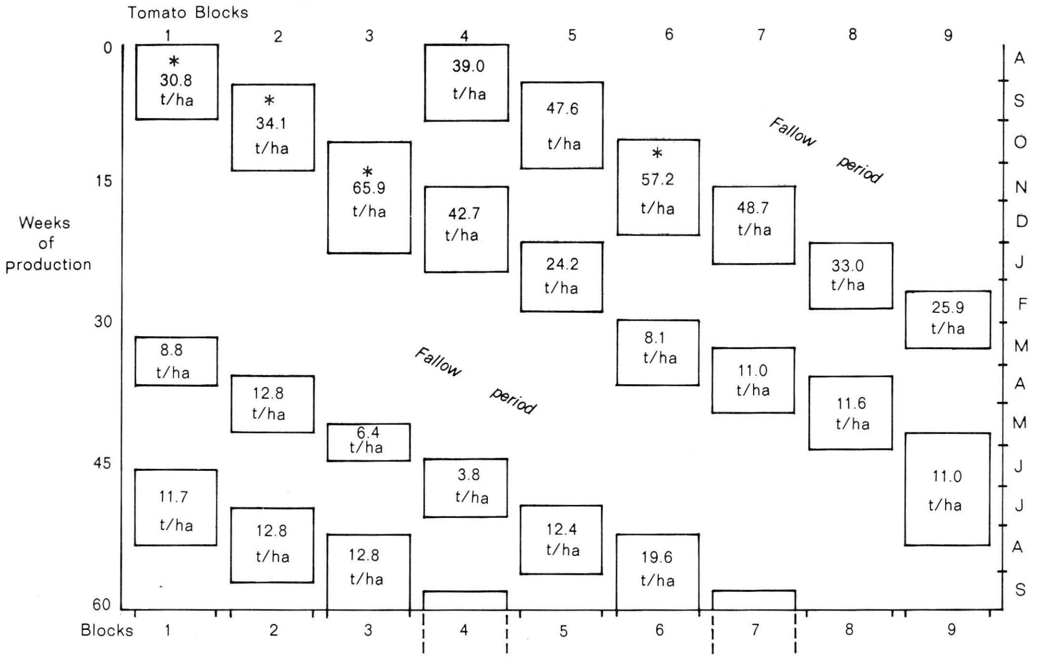


Fig.1. A diagrammatic representation of rotational planting system over nine one tenth hectare tomato blocks showing production per block (t/ha) and length of production period
***Philippines variety S 665**

of S 665 were planted in the trial as yield records and quality assessments highly favored C 555-F5-19. In the third planting both blocks were planted with S 665 as we considered C 555-F5-19 more susceptible to TMV. Subsequent to this decision, C 555-F5-19 proved TMV tolerant although a severe infestation had occurred in the second planting. S 665, was considered the more commercially acceptable type before we had access to AVRDC breeding lines.

Cultural methods employed in the trials were altered as the trials progressed (Table 1). Initially, we used a single overhead wire to which twine was tied for plant support; however, this was insufficient to hold the plants erect. A system using three parallel wire combined with bamboo stakes was then adopted. This system tended to provide more support for the lateral branches of the mature plants.

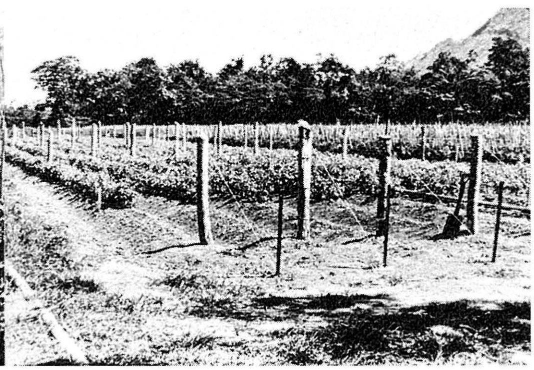


Table 1. General cultural practices used in pilot commercial trials; PNG, 1978.

Item	Specifications	Remarks
Trial design:	Nine one-tenth ha blocks	Sequential planting system with 2 blocks planted/4 weeks.
AVRDC selection:	C 555-F5-19	Four blocks planted with Philippines selection S 665.
Plant Spacings: Staked Unstaked	 (i) 1.37 m x 0.6 m (ii) 1.68 m x 0.6 m	 12,200 plants/ha 9,920 plants/ha Last four blocks only (2, 5, 3 and 6)
Basal fertiliser: NPK (12:12:17:2)	500 kg/ha broadcast on ridge. 500 kg/ha placed as side dressing at transplanting.	Fertiliser on ridge 0.5m wide and raked in. Fertiliser placed in hole 3-4cm from transplant and covered up.
Side-dressed fertiliser: Sulphate of ammonia	500 kg/ha per application	Two applications made. One at early fruit set and one three weeks later.
Pesticides: (i) Insecticides: (ii) Fungicide:	 Acephate (0.75 kg/ha) Mancozeb (0.5 kg/ha)	Applied weekly during dry season but applied twice weekly during rainy periods.
Transplanting drench: D.D.T. Boron: Mancozeb:	 700 mℓ/200 ℓ 100 g/200 ℓ 300 g/200 ℓ	 Approximately 500 mℓ of drench applied around each transplanted seedling.

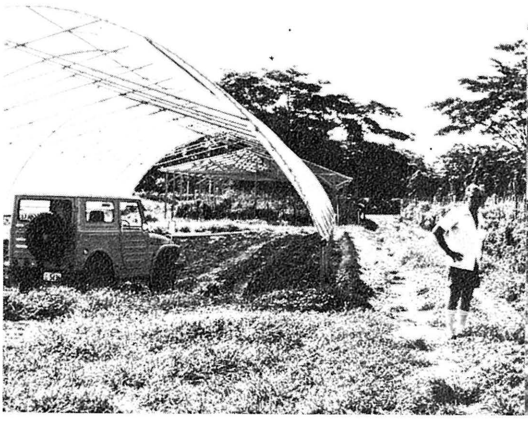
All seedlings were grown in Jiffy 7 peat pellets for convenience in management. The seedlings were propagated on an automatic system using shallow trays with 2.5 cm of gravel and were fed with a complete nutrient solution. They were transplanted to the side of a ridge during dry season operations so that water from furrow irrigation was easily available to the roots. In the wet season, a sweet potato ridger was used to construct a high ridge and the seedlings were transplanted to the high central portion.

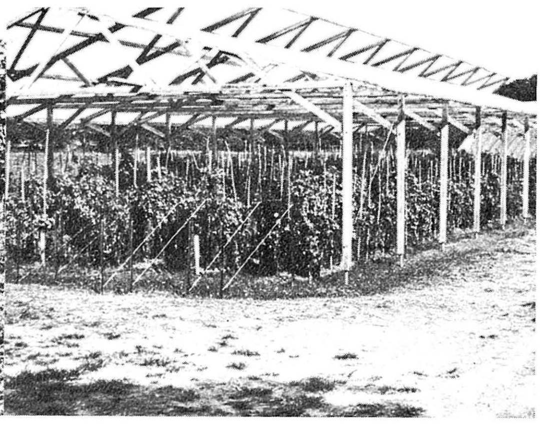
In May 1978, the system of staking plus hand-weeding was changed to one of ground grown crops with inter-row mechanical cultivation. This decision was the result of Labor Union activity which resulted in an increase of laborer's wages from US$16.98/week to US$42.55/week. Recordings were made of all labor operations on each tomato block so that detailed economic analyses could be made.

In May-Jun 1978, field estimations showed that nematodes were affecting 25-30% of the plants in the second planting in each block. Recommended chemicals for nematode control were ordered from overseas but did not arrive in PNG until Sep 1978. In the meantime a granular formulation of fenamiphos was used on the blocks and was compared with dazomid. During the wet season twice weekly applications of insecticide plus fungicide were applied as a management policy but this was reduced to weekly applications during the dry season.

During periods of high production, we harvested daily but three times per week was normal. After harvest, tomatoes were dipped in a bactericide, graded and packed into 10 kg containers, and sold to the National Food Marketing Corporation (FMC). In the original trial criteria we decided that cull tomatoes were fruit of 60 g and below. Fig. 1 shows that six out of the nine tomato blocks completed three cropping periods. This was considered maximum. Over the 60 week trial period 60,946 kg of marketable tomatoes were produced at an average price of US$0.73/kg. This represents a gross income of US$44,490.

Two polythene covered houses were constructed to determine the effects of rain on tomato production during the wet season. The first house was open sided and made from timber. A gap in the roof allowed the release of hot air. The second house, constructed of steel pipe, was shaped like an igloo with walls that descended to within one metre of the ground. Both houses were 30 m long and 9 m wide. The first house was divided into three sections consisting of two beds per section planted at different dates. The igloo house was planted to one crop only. The plant spacing within these houses was very close (50 cm x 45 cm) and the plants were staked similarly to the field plantings. Four weeks after a period of exceptionally hot weather, production in the igloo house almost ceased. However, the plants recovered and continued to produce well for 5 months.





A demonstration block comparing staked tomatoes and no mulch with an equal area of tomatoes and a grass mulch was laid down late in the 1978 wet season. Random samples of commercial tomatoes were examined from time to time to determine average fruit sizes and the percentage of cull tomatoes.

RESULTS AND DISCUSSION

Dry season yield records in 1977 were high and exceeded the best tomato yield records ever achieved at Laloki. The highest marketable yield obtained with C 555-F5-19 was 48.7 t/ha during Nov-Jan while the lowest yields of 6.4 t/ha and 3.8 t/ha were during May-Jul (Fig. 1). These low yields were attributed to a severe nematode infestation at the end of the wet season which did not allow tomato production to significantly increase until nematicide treatments were applied in May and Jun, 1978 (blocks 2, 5, 3, and 6). Although severe nematode damage occurred on the AVRDC selection, it proved reasonably tolerant and produced a crop.

Table 2 shows that the net return dropped suddenly at the onset of the wet season in blocks 1 and 7, second crops, although this decrease in production was also associated with nematodes in all second crops of the rotation. Block 9, first crop, showed a net return of US$6,067 while block 6, which was the second crop on that block, planted at a similar time showed a net loss of US$6,418. The build-up of nematodes in the second crop on each block was so serious that it prevented the production of tomatoes from recovering at the end of the wet season. From blocks 3 and 9, second crops, onwards until the termination of the experiment, there should have been a rapid increase in production of marketable fruit to correspond with the ideal growing conditions.

The final three tomato blocks (5, 3, and 6) were treated with nematicides that were locally available at the time but not recommended for tomatoes. Some control was achieved (Table 3) but assessments have been confounded by changing over to the no-staking system in blocks 2, 5, 3, and 6. The total labor used in these four blocks was reduced but yields were not high. Labor used for dipping in the bactericide and drying increased in the same four blocks due to the excess contamination from soil in non-staked tomatoes.

Table 3. Percentage affected plants with two nematicide treatments.

	Block 3 (fenamiphos treatment)	Block 6 (dazomid treatment)
Nematode affected	36.8	65.5
Healthy plants	63.2	34.5

Table 2. Economic analyses of the 9 tomato blocks over 60 weeks showing percentage labor utilized on major activities and the relative profitability of each crop.

Tomato block	Transplanting to final harvest	Marketable yield (%)	Labor utilisation (%)							Total labor (Man hrs)	Gross return (US$/ha)	Profitability or net return (US$/ha)
			Erecting wire trellis	Tying plants	Hand weeding	Harvesting	Weighing grading packing	Dipping drying	Other			
1[a] (1)[b]	13/6 - 3/10/77	82.7	24.0	8.8	12.5	16.0	18.7	-	20.0	11,836	22,292	7,028
4 (1)	13/6 - 29/9/77	94.6	20.7	17.7	9.5	15.9	17.7	-	18.5	15,230	28,300	12,180
2[a] (1)	21/7 - 6/12/77	70.4	20.3	9.1	7.5	18.1	21.8	-	23.2	11,739	24,699	8,555
5 (1)	10/7 - 12/11/77	88.1	26.9	3.8	9.3	16.7	20.3	-	23.0	11,991	34,491	18,366
3[a] (1)	31/8 - 4/1/78	87.2	18.5	7.5	13.3	28.1	9.8	-	22.8	13,824	47,792	30,038
6[a] (1)	31/8 - 20/12/77	88.9	19.8	14.1	16.8	16.8	8.6	-	23.9	13,822	41,444	25,369
4 (2)	5/10 - 17/1/78	88.8	24.6	11.9	11.8	15.2	8.7	-	27.8	11,376	30,956	16,189
7 (1)	7/10 - 14/1/78	90.2	21.5	14.5	14.1	13.4	8.5	-	28.0	11,740	35,319	20,757
5 (2)	15/11 - 22/2/78	84.2	23.5	11.6	15.5	10.2	12.8	-	26.4	10,897	17,529	3,757
8 (1)	15/11 - 13/2/78	86.7	29.4	6.4	13.3	11.3	13.0	-	26.6	10,339	23,911	10,614
6 (2)	23/12 - 10/4/78	88.4	25.3	9.1	22.0	9.9	6.9	-	26.8	8,533	5,849	-6,418
9 (1)	13/12 - 17/3/78	79.9	22.9	9.9	14.4	15.7	13.3	-	23.8	10,022	18,738	6,076
1 (2)	13/1 - 12/4/78	72.5	25.1	13.9	21.7	6.9	5.1	-	27.3	11,057	6,384	-5,733
7 (2)	18/1 - 6/5/78	71.5	20.9	14.4	26.3	7.6	5.1	-	25.7	10,600	7,943	-4,921
2 (2)	16/2 - 15/5/78	87.4	27.1	11.2	26.4	7.0	5.1	-	23.2	11,264	9,258	-3,512
8 (2)	16/2 - 31/5/78	83.0	26.5	13.1	7.6	9.4	9.4	-	34.0	8,293	8,404	-3,718
3 (2)	20/3 - 9/6/78	86.3	26.1	12.7	25.8	3.3	2.5	2.8	26.8	9,717	4,657	-6,341
9 (2)	21/3 - 11/8/78	72.6	16.2	16.4	22.4	7.5	5.0	10.1	22.4	12,579	7,966	-6,844
1 (3)	14/4 - 10/8/78	79.4	19.2	10.6	23.4	7.1	4.5	8.4	26.8	10,373	8,464	-4,247
4 (3)	14/4 - 19/7/78	53.8	23.0	5.5	25.9	4.7	4.9	4.0	32.0	8,588	2,768	-8,852
2[c] (3)	17/5 - 4/9/78	85.3	-	-	24.8	12.5	9.7	20.0	33.0	6,109	9,260	- 874
5[c] (3)	12/5 - 30/8/78	79.6	-	-	32.8	11.9	7.1	16.7	31.5	6,137	9,022	-3,553[d]
3[c] (3)	14/6 - 2/10/78	88.6	-	-	25.7	11.7	10.5	20.4	31.7	5,338	9,258	-1,237[e]
6[c] (3)	14/6 - 2/10/78	87.2	-	-	13.3	16.3	18.3	24.3	27.8	4,980	14,223	3,012[d]

[a] Philippines variety. [b] Crop number in rotation. [c] Unstaked blocks. [d] Dazomid. [e] Fenamiphos.

In the costing analyses, the rural wage rate was used, (i.e. US$16.98/week or US$0.40/hr) as a commercial enterprise would not be profitable at the urban wage rate and a selling price of US$0.73/kg. Small consignments of tomatoes were sold to retail outlets rather than the FMC to assess their marketability and an average price of US$1.77 was received. Under the present dry-season system of ground grown crops with inter-row cultivation, band placement of nematicide and herbicide, and a high selling price, commercial tomato production may be feasible at the urban wage rate of US$42.55/wk. Continuing trials on this system are being carried out and it has been found that certain skills will have to be developed to undertake the more precise machinery management of these operations.

In the last four blocks (2, 5, 3 and 6) the proportion of labor spent on hand-weeding is high although inter-row cultivation was used. Lack of driver experience in using inter-row cultivation implements for fear of ripping out plants was responsible. Unless he was specifically directed to cultivate, the supervisor usually allowed the blocks to be hand-weeded.

In Fig. 2, the average production for two blocks has been compared to both rainfall and temperature records. The drop in marketable production during the wet season (Jan-May) was caused by the high proportion of cull tomatoes (Fig. 3). Under dry season conditions 5-15% would be culls. The length of the production period for each crop determines

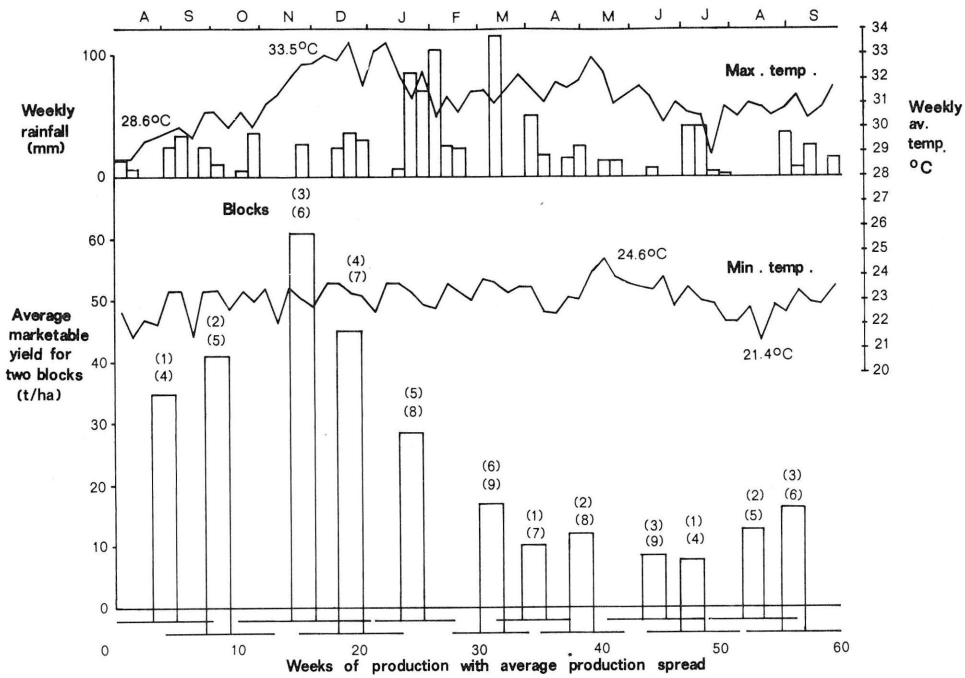


Fig. 2. Average marketable block yields as effected by max. and min. temperature and rainfall over total production period.

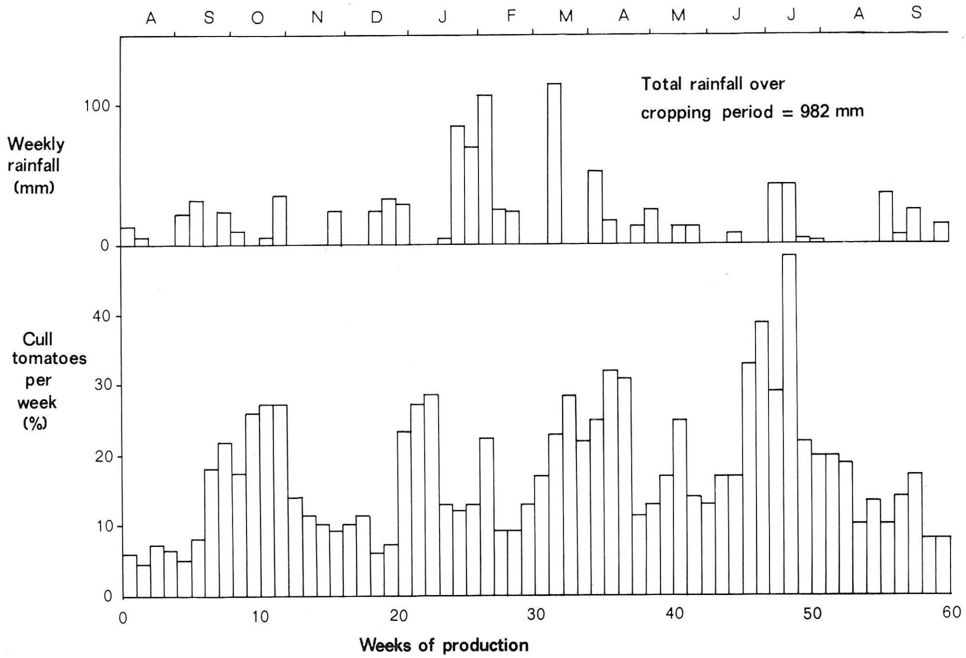


Fig.3. Effect of rainfall on weekly production of cull tomatoes (%)

the relative proportion - the older the plants, the higher the proportion of undersized fruit. During the wet season the percentage of cull tomatoes increased to 48% due to damage caused by high intensity rainfall in mid-July. The AVRDC tomato selection is not considered rain resistant as a result of these trials.

Fig. 4 compares marketable production of tomatoes in the plastic houses against field production. It appears that maximum and minimum temperature conditions on Laloki do not affect the fruit set of the AVRDC selection, which is considered heat-tolerant. The reduction in yield, apart from severe nematode damage, would appear to be the result of rainfall on the crop during the wet season.

Table 4 compares the difference in yield obtained from staked

Table 4. The effect of staking and no staking plus grass mulch on tomato production.

	Staking - no mulch	No staking plus mulch
Yield per block	388.4 kg	170.5 kg
Average fruit weight	91.0 g	72.0 g
Cull fruit (%)	23.3	35.2
Rotten fruit (%)	10.0	17.0

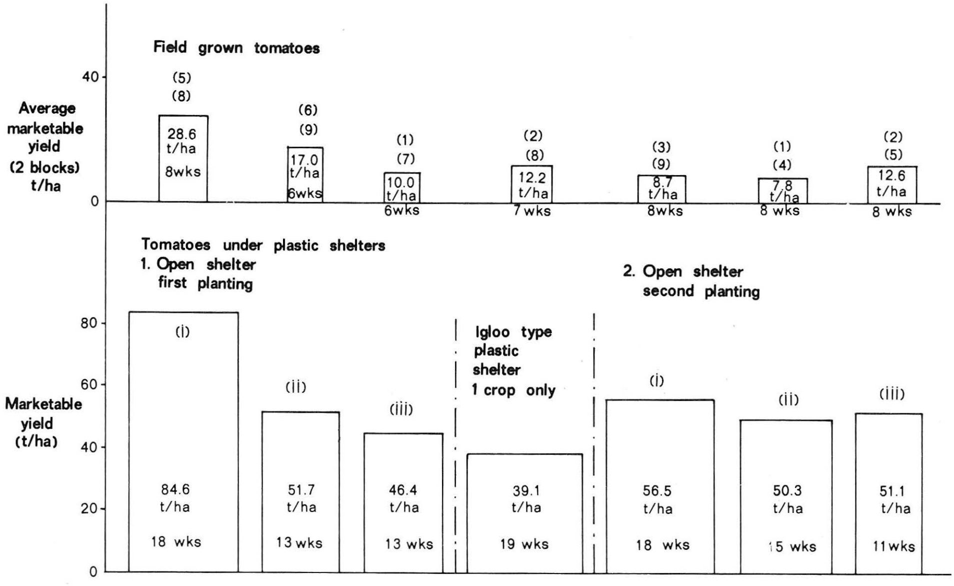


Fig.4. Equivalent yield comparisons of crops grown in plastic houses (2 types) with crops grown in the soil at approximately similar planting dates

tomatoes with no mulching against no staking with a grass mulch. The production period was from May - Jul, 1978 which corresponds to the end of the wet and beginning of the dry period. Approximately 400 plants were planted for both treatments. Average marketable fruit weights are low and do not represent a true figure. Generally fruit weights are well in excess of 100 g per fruit and reach an average of 210 g for large selected fruit.

Determinations of the average size of marketable and cull fruit was made on Oct 1978 from random samples of field production (Table 5).

Table 5. Average fruit size and percentage culls from field; random sample of tomatoes.

	Marketable fruit	Cull Fruit
Total weight (kg)	56.9	3.4
Number of fruit	547	78
Average weight of fruit (g)	104.0	43.6
Cull fruit (%)		5.6
Average weight of cull fruits (g)		48.7

The occurrence of soil fungi, *Scelortium rolfsii*, *Pythium sp.*, and *Phytophtora sp.*, is an important cause of fruit rot in the field, especially with ground grown crops. Tomato leaf diseases identified at Laloki are:

Fungal leaf spots:	*Alternaria solani* *Corynespora casiicola* *Septoria lycopersici*
Fungal leaf molds:	*Fulvia fulvum* *Cercospora fuligera*
Bacterial diseases:	*Pseudomonas solancearum*

(Biotypes three and four have been identified in PNG soils.)

A collar rot, *Sclerotium rolfsii*, causes seedling loss in the field and nematode damage is caused by *Meloidogyne arenaria* and *M. incognita*.

CONCLUSION

The cultivation of the AVRDC selection C 555-F5-19 during the dry season was a commercial success. This line exhibited outstanding qualities of heat-tolerance, bacterial wilt resistance, tolerance to nematode infestation, and a high yielding ability under trial conditions. Nematode infestation was the major limiting factor in production since May 1978. This tomato has been named "Chancellor" in accordance with AVRDC permission. The continued success of AVRDC breeding lines in the Port Moresby environment would be substantially enhanced by the introduction of leaf disease resistance into the breeding program. Popular request has resulted in a limited distribution of "Chancellor" seed throughout lowland PNG. Recent records of its performance have been very good. A large national company has recently adopted this variety as the basis for its tomato production program.

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DISCUSSION SESSION I

Holle: Dr. Villareal, could you quantitatively define "hot, humid lowland" and "main growing (months) periods" in relation to tomato cropping in the tropics?

Villareal: We have not quantified these words yet. However, I would consider the lowlands to be below 500 m above sea level. The humid part comes mostly during the rainy season when temperatures are also high. The main growing months in Taiwan are from Oct to Apr when it is relatively drier. Dr. R.T. Opena, AVRDC's white potato breeder, considers the lowland tropics to be less than 300 m above sea level.

Sonarjono: What are your ideas on breeding for resistance to late blight disease (*Phytophthora infestans*)? As we know, resistance is controlled by polygenic recessive genes. *Phytophthora* pathogens are very variable, paticularly in the tropics, and many factors influence the virulence of the pathogens. Also, not enough breeding materials with complete resistance are available.

Villareal: First, we have not found a truly late blight resistant cultivar. Second, those with acceptable levels of resistance have less than 1 g fruit size. With these two limitations, I am inclined to use a modified recurrent selection technique to increase the levels of late blight resistance in the current cultivars.

Volin: Please clarify your observations that tomato resistance to late blight appears to be unstable. Specifically, what conditions cause or contribute largely to variability of resistance and is this instability mostly determined by new races of the pathogen or is it environmentally induced?

Villareal: I suspect that the instability in AVRDC materials was due primarily to environmental causes. We have not done any studies on differentiating late blight races. Dr. Yang, our pathologist may wish to comment on this.

Yang: The variation in varietal responses to late blight by materials screened at different locations may be attributed to fluctuations of inoculum density occurring naturally at the time of screening and the environmental conditions. Cooler temperatures and longer dew periods are favorable for the field epiphytotics. We have environment conducive to severe late blight during the winter months in the Hsin-Shih area, our chosen location for screening for late blight resistance.

Mutukrishanan: The heat tolerant tomato accessions (AVRDC accession Nos. L22, 15 and CL 123-2-5) have done consistently well at Coimbatore (South India) when grown between Mar-Jun when the night temperatures ranged from 22-23^{o}C. Yields were 30 t/ha for L22, 29 T/ha for L15, and 31 t/ha for CL 123-2-5. These cultivars are highly susceptible to leaf curl virus at our University. How do these observations compare with other locations?

Villareal: The yields you obtained are comparable to those obtained in other countries. Only Thailand reports high incidence of leaf curl virus with AVRDC materials. At present, we are not breeding for leaf curl resistance.

Villareal: Dr. Johannessen, what role do you see for an International Tomato Advisory Committee?

Johannessen: First, this overall committee would be composed of both grower and processor representatives and a few selected scientists and specialists intimately involved with tomatoes. There might be two such committees, one for fresh market tomatoes, and one for processing tomatoes. I visualize liberal use of sub-committees to deal with specific areas and recommend to the overall committee either research or specific actions to solve a problem or to initiate an improved procedure or procedures. Important areas of consideration by such an Advisory Committee might well include:

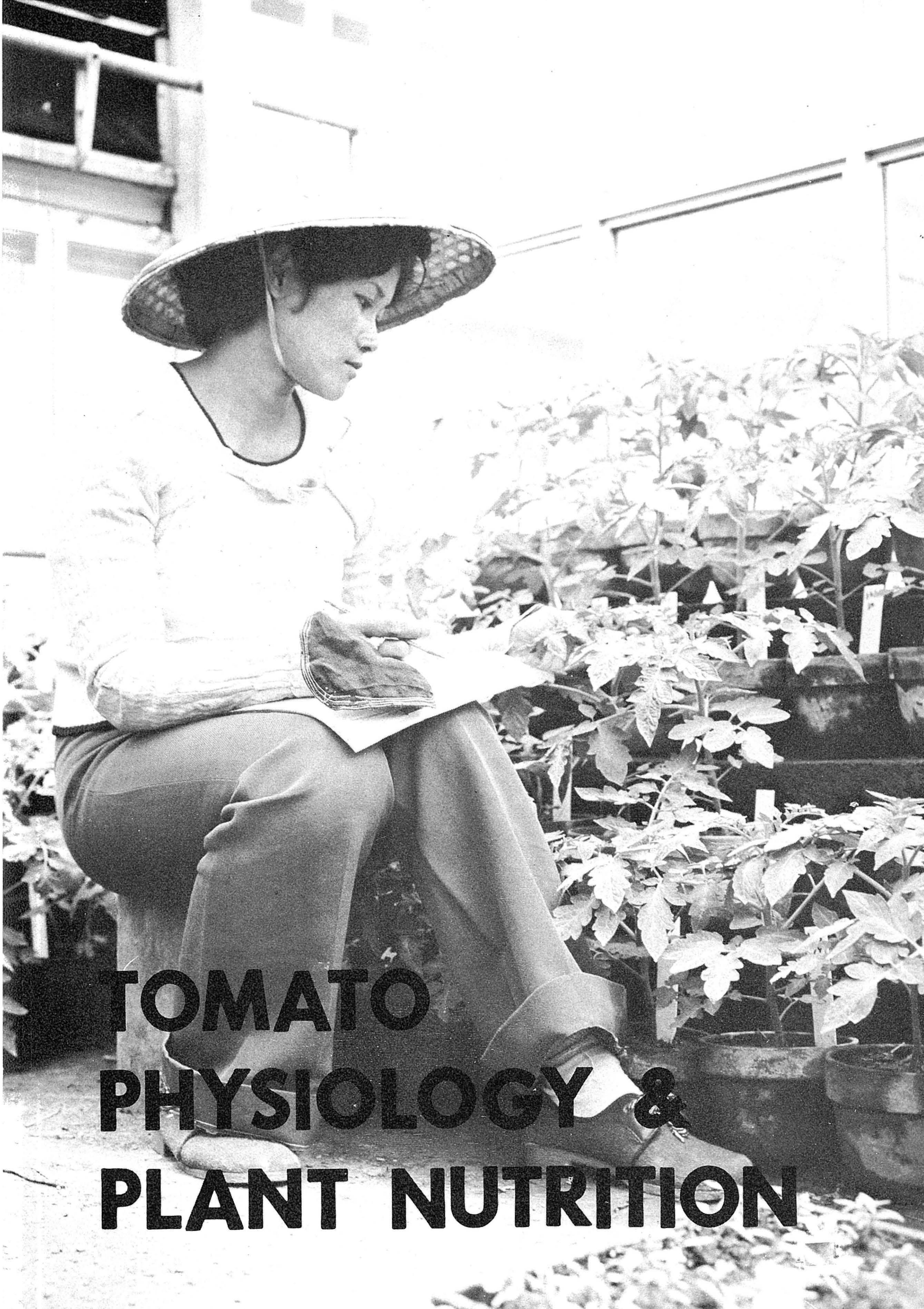
1. The encouragement of research to develop and adopt a quick, simple, objective method of accurately measuring mold in a load of raw tomatoes for processing.
2. Recommendations on a world-wide, uniform method of grading and inspecting tomatoes for processing.
3. The impact of water mold, black mold, and other fruit molds on product recovery and quality.
4. Development of a universal tomato variety quality education system that would enable the tomato processing industry to place an economic value on any variety to be used specifically for juice, sauce, paste, or whole peeled tomatoes.

Bell: Will processing tomato production in the future increase in Europe and Asia at the expense of California production?

Johannessen: Markets around the world are expanding, particlularly for processed tomato products and more specifically for tomato paste. The United States remains the largest market in the world for tomato paste. This, very conceivably, could change in the years ahead. Personally, I believe California will not only hold its own, but it may well take a larger share of the market in the future.

Mr. Lai: What percent of California's tomatoes are hybrids? How do they compare with open-pollinated varieties grown?

Johannessen: Hybrids for processing have increased markedly in the past 4-5 years and several have been at or near the top in yield in country variety trials. The cost of seed is high. There are open-pollinated processing varieties that perform about as well in yield. Probably close to 20% of the processing acreage in California is planted to hybrids.



TOMATO PHYSIOLOGY & PLANT NUTRITION

TOMATO: NUTRITION AND FERTILIZER REQUIREMENTS IN THE TROPICS

H.R. von Uexkull[a]

INTRODUCTION

While all crops vary in yield, few variations are as large as those of the tomato. In most tropical countries average yields to date range between 2-10 t of fruit/ha against yields of 20 t in South Korea, 40 t in the USA, 50 t in Japan, and over 130 t in the Netherlands. Top farmers are harvesting over 160 t fruit/ha (protected culture), 80 times the average yield of many tropical countries.

It is natural that the overall importance of nutrition and the relative importance of individual nutrients undergo dramatic changes as yields change from a 2 t/ha level to 25 t, 50 t, and 150 t/ha. We can assume that the yield potential of the tomato in the tropics is only slightly below that of the temperate regions (longer day length and cooler nights), and that, for a given yield nutrient, requirements will be similar. If this assumption is correct, we can draw heavily on the wide experience of tomato nutrition in temperate and subtropical regions.

NUTRIENT UPTAKE AND REMOVAL

In high yielding tomatoes, 65-75% of the total dry matter is accumulated in the fruit and, as the stalks are usually removed on harvest, total nutrient removal comes close to nutrient uptake.

Detailed studies on the course of nutrient uptake over time and on nutrient removal are so far not available from the tropics. However, intensive studies on nutrient uptake made in Japan (18), North America (32), and Europe (4) are all in reasonable agreement.

The averaged nutrient uptake per ton of fruit is given in Table 1. The mineral composition of a whole tomato plant at maturity and nutrient uptake per hectare is given in Table 2.

Taking the uptake figures per ton of fruit from Table 1 as a basis, the total nutrient requirements at different yield levels are shown in Table 3. The table suggests that serious nutritional problems

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Table 1. Nutrient uptake of tomatoes per ton of fruit.[a]

	N	P	K	Mg	Ca
			kg		
Range	2.1-3.4	0.28-0.45	3.11-4.40	0.26-0.54	1.80-2.99
Average	2.90	0.40	4.00	0.45	2.35

[a]Ref. 18.

can be expected only with yields of above 10 t fruit/ha. Additionally, in many cases factors other than nutrition are currently limiting tomato yields in the tropics. Nutritional problems, however, become very serious once yields exceed 15 t/ha. The higher the yield the more vital it is to secure adequate supplies of the nutrients needed, and to maintain the right balance between nutrients.

ROLE, EFFECTS, AND SOURCES OF NUTRIENTS

NITROGEN

1. Effect on growth and yield. Nitrogen affects vegetative growth and fruit yield more than any other nutrient. It promotes the set of flowers and fruit but tends to delay maturity and decrease fruit size. To obtain a yield of over 100 t fruit/ha, the plants had to absorb about 100 mg N/plant per day, and the optimum nutrient concentration was around 140 ppm N (3). Rajagopal and Rao (24) found that N-deficient plants had lower levels of endogenous anxin and a reduced gibberelin activity. Levels of growth inhibitors were higher in N-deficient plants. Nitrogen deficiency results in high rates of flower drop, especially at high temperatures (1).

2. Effect on plant diseases. Excess nitrogen, absolute or relative to other elements, will decrease resistance to many diseases. Nitrogen applied to deficient plants will increase the root CEC (29) and the uptake of other elements. The severity of root rot caused by *Botrytis cinera* is frequently decreased by the addition of N. Blossom-end rot appears to increase with increasing levels of nitrogen, especially when N is applied in the ammonia form (18).

3. Effect on fruit quality. Adequate nitrogen will improve fruit quality. Fruit size, keeping quality, color, and taste are all decreased by excess nitrogen. Nitrogen tends to decrease the percent total solids in the juice and to increase titratable acidity (11).

4. Nitrogen sources. Nitrogen sources are of minor importance as long as input levels and yields are low. For high yield and good fruit quality, nitrogen sources are very important.

In most cases nitrate is preferable to ammonia (15). Ammonium toxicity may be induced by both too little and too much calcium. Nitrate often improves water-use efficiency and tends to reduce the amount of

Table 2. The mineral composition of a tomato plant at maturity.[a]

Tissue	Green weight	Dry weight	Constituents N	P	K	Ca	Mg
	-kg/plant-	g/plant					
Leaf		136.8	3.77	.75	5.85	8.56	.57
Petiole		48.9	.68	.17	4.07	1.89	.34
Flower & fruit petiole		9.6	.22	.04	.37	.14	.03
Fruit	6.72	443.1	8.55	1.82	16.70	.58	.62
Stalk		41.9	.87	.25	2.34	.90	.19
Root		3.7	.06	.01	.08	.05	.01
Total (g/plant)		684.0	14.09	3.04	29.41	12.12	1.76
Fruit (t/ha)	183.4						
Nutrient uptake (kg/ha)			385	83	803	331	48
Nutrient removal/t of fruit (kg/ha)			2.1	0.45	4.38	1.08	0.26

[a]Ref. 32.

free amino acids in the tomato plant. High temperatures tend to favor absorption of nitrates (and phosphates and potassium) while the relative absorption of ammonium is increased at low temperatures (6).

Pill and Lambeth (23) found that NH_4-N reduced shoot and root-concentration of Ca, Mg, K, P, and NO_3. It increased leaf and root resistance to water flux and reduced water use efficiency as compared with

Table 3. Estimated nutrient uptake requirements of tomatoes at different yield levels.

Yield	Nutrient element[a] N	P	K	Mg	Ca
-t/ha-	kg/ha				
5	14.5	2.0	20.00	2.25	11.75
10	29.0	4.0	40.00	4.50	23.50
25	72.5	10.0	100.00	11.25	58.75
100	290.0	40.0	400.00	45.00	235.00
200	580.0	80.0	800.00	90.00	470.00

[a]To convert P to P_2O_5 multiply by 2.29
K to K_2O " " 1.20
Mg to MgO " " 1.67
Ca to CaO " " 1.40

NO_3. Excess N over K, Ca, and Mg, in turn, is closely related to a number of ripening disorders such as "vascular browning".

Among various slow-release materials tested in Taiwan, ureaform (molar ratio 2:1) gave the best results. CDU proved an inferior source of N for tomatoes. Sulphur-coated urea was a satisfactory slow-release N-source on slate-alluvial soils, but gave poorer effects on latosols (28). In Florida, 392-560 kg N/ha of sulphur-coated urea applied as basal (N-release rate, 11.4%) proved to be superior to the same amount of N applied in the form of NH_4NO_3 in split application (26).

Calcium-ammonium nitrate, ammonium-nitrate sulphate, and potassium nitrate, and some of their slow-release forms, appear to be preferable N sources for tomatoes.

PHOSPHORUS

1. Effect on growth and yield. High levels of available P throughout the root zone are essential for rapid root development and for good utilization of water and other nutrients by the plant. Especially in the tropics where tomatoes are grown without mulch and plants are subjected to alternate periods of low and high amounts of available water, high P-levels are essential. Absorption of water by the roots increases moisture tension immediately adjacent to the roots. This layer of soil contains thinner water films and requires a longer path length for the same amount of P. Irrigation and/or a high level of P in the soil serves to overcome this problem (19).

Phosphorus has a pronounced effect on the number of flowers that develop. Withholding P for 10 days resulted in a sharp decrease of flowers that develop on the first truss. This was accompanied by a decrease in the cytokinin activity of the root exudate (16).

2. Effect on fruit quality. Phosphorus (in combination with N and K) improves peel coloration, pulp coloration, taste, hardness, vitamin C-content, and hastens maturity (28).

3. Sources of phosphorus and method of application. Since tomato has a short growing period and is sensitive to low pH, P-sources should be water soluble. Nitro-phosphate and triple superphosphate are probably the best P-sources and, in most cases, an even distribution of P throughout the root zone would be desirable. Figure 1 shows that on high pH soils (above 7.8), especially when soil temperatures are low, banded P placement can be important (13). On high pH soil large quantities of broadcast P may induce boron and zinc deficiency.

POTASSIUM

1. Growth and yield. Tomato plants deficient in potassium are dark green with shortened internodes. In cases of severe deficiency the older leaves will show marginal necrosis. A mild deficiency will affect fruit size and fruit quality rather than fruit number.

2. Potassium and diseases. Kiraly (14) observed that an increasing K-content in the nutrient solution was associated with a decrease in the

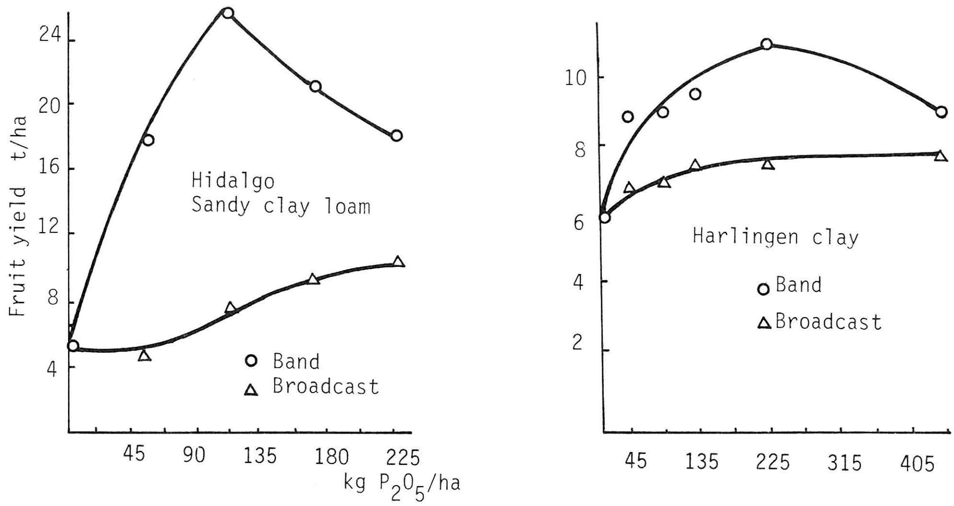

Fig. 1. Yield of tomato grown on two different high pH soils as affected by the method of phosphate application (13).

diameter or lesions caused by *Alternaria*. Potassium seems to have a favorable effect on reducing tomato leaf mold (*Cladosporium fulvum*), stem rot (*Diplodia lycopersici*), verticillium wilt (*Verticillium alboatrum*), and root rot caused by *Botrytis cinera* (9, 7, 25, 31, respectively). In the case of virus diseases, however, the severity of the disease is often accentuated by potassium (34).

3. Potassium and fruit quality.

a) Yield and fruit size. The effect of potassium on yield is usually not as pronounced as that of nitrogen. Where potassium has an influence, it tends to increase fruit size.

b) Fruit color. A number of ripening disorders are associated with inadequate potassium nutrition in tomatoes. They have been described as "blochy ripening", "vascular browning", "coud", "white wall", "graywall", "greenback", etc. (12). Ozbun et al. (21) showed that blochy ripening was caused by low K in the nutrient solution (Fig 2). Petiole K was highly correlated with the extent of white tissue in the fruit. Gallagher (10) observed that the incidence of remnants (non-uniformly colored and irregularly shaped fruits) generally decreased as the level of K increased. Trudel and Ozbun (30) concluded that K plays an important role in the process of tomato fruit pigmentation. K increased carotenoides, particularly lycopene, and decreased chlorophyll.

c) Intrinisic and keeping quality. Potassium nutrition exerts a strong influence on acid metabolism in tomato fruit. The acids involved are primarily citric acid and malic acid. Compared to potassium deficient plants, fruit coming from plants well suppled with K are generally higher in total solids, sugars, acids, carotene, lycopene, and have better keeping qualities. Fruit from low K-plants tend to drop prematurely and the taste is flat. The effect of K on quality goes far beyond the level

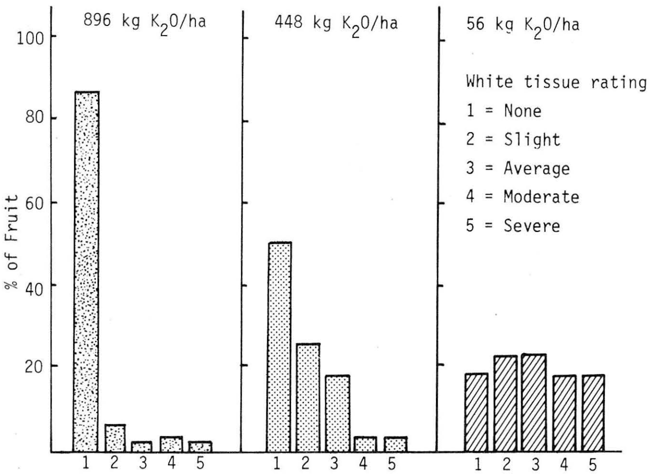

Fig. 2. Amount of white tissue in outer wall of tomatoes around stem scar. Data obtained from 20 vine ripe fruit/plot. Average of 5 replications; spring, 1967. (Wayslip and Iley, 1967).

needed for higher yield. In many cases highest yields are obtained at 150-300 kg K_2O/ha, but highest quality was obtained at 600-800 kg K_2O/ha.

4. Sources of potassium. At low levels of K-use there is little difference to be expected from the various K-sources. At higher input levels it is desirable to have at least half the K in sulphate form. In cases where salt concentration may become a problem (protected culture), potassium nitrate is the prefered source.

CALCIUM and MAGNESIUM

The tomato plant is sensitive to low pH, especially when NH_4N is used as the nitrogen source. A number of physiological and ripening disorders are related to inadequate calcium. Blossom-end rot has frequently been related to low Ca and high Mg levels in the soil (22) or to a high K:Ca ratio (5) or a decrease in Ca caused by ammonium nutrition. Excess calcium over K + Mg seems to be associated with some ripening disorders such as "greenback", yellow-green areas near the calyx to the apex.

Other physiological disorders related to calcium deficiency are certain types of fruit cracking (2). Foster et al (8) found that the (Ca + Mg) : (K + Na)ratio was negatively correlated with the rating of bacterial cancer. Increases in the Na:Ca ratio increased the incidence of *Fusarium oxysporium*. Resistance to fusarium wilt appears partly related to Ca- and Na-pectates in the cell wall. Magnesium deficiency can be induced by high rate of K and/or NH_4-N application. Sprays with 1.5% $MgSO_4$ solution are a fast cure compared with soil application of Mg, which may take a long time to become effective (35). Mori (18) showed that vascular browning was very severe in all treatments low in magnesium, especially in those combinations where ammonia was used as a nitrogen source.

TRACE ELEMENTS

Among trace elements, boron, zinc, and manganese deserve special attention. A positive significant correlation has been observed between boron and flower number, number of aborted flowers, and fruit weight. Boron deficiency causes reduced root growth, swollen hypocotyls and cotyledons, brittle leaves, and necrosis of the shoot apex. Other symptoms are incomplete and irregular leaf expansion, shortened internodes, multiple axilliary branching, dieback of the growing point, and abnormalities in the cellular structure.

Like boron, zinc deficiency is frequently found on high pH soils. Zinc deficiency is aggrevated by phosphorus application. Potassium, on the other hand, appears to promote zinc uptake. Zinc deficiency is characterized by stunted internodes and small, wrinkled leaves showing patches of white tissue.

The tomato plant can tolerate a wide range of manganese levels. Severe deficiency was associated with Mn levels of about 20 ppm in all tissues except the fruit. Toxicity occured in young leaves at levels of 450-500 ppm, and in old leaves at levels of 900-1,000 ppm (32).

CONTRAINTS TO FERTILIZER EFFECTIVENESS IN THE TROPICS

LACK OF HIGH YIELDING, DISEASE RESISTANT VARIETIES

Until the development of the IRRI rice varieties, it was generally assumed that the tropial indica type of rice was less fertilizer responsive than the sub-tropical japonicas. While in rice the plant type had to be changed (to make it more fertilizer responsive), in the case of tomato, heat-tolerance and resistance to disease (like bacterial wilt and mosaic virus) may be critical factors. High yielding varieties adapted to tropical conditions have been developed by some multinational fruit canning corporations, but such seed is not available to the average private grower. The intensive breeding efforts at AVRDC will hopefully change this situation soon.

POOR CULTIVATION TECHNIQUES

1. General. In the healthy tomato plant, source and sink appear to be well balanced. The healthy tomato plant is therefore capable of producing extremely high yields over a short period of time. Tomato plants producing 150 t fruit/ha must be able, during the time of peak requirement, to take up about 22 kg of plant nutrients per hectare and day. This is about eight times the peak need of a rice crop yielding 8 t grain/ha. Such high rates of nutrient uptake are possible only where soil management practices are excellent, to permit optimum development of a healthy root system.

2. Root development and nutrient uptake. Factors that stimulate proliferation of the roots are:

a) A high organic matter content in the soil. Organic matter has a very complex effect, such as improving the storage capacity of available water, improving the air:water ratio in the soil, increasing the exchange capacity of the soil, buffering the release of nutrients into the soil solution, de-toxifying some heavy metals, releasing chemical compounds that stimulate root growth, stimulating the growth of soil micro- and macro-organisms favorable to plant growth, etc.

b) Soil moisture. Under the climatic conditions in the tropics heavy rain is frequently followed by several days of drought. Under conditions of poor soil management this means that at times most of the pore space will be filled with water (oxygen stress) while at other times it will be filled with air (water stress) . Such conditions of alternate drying and wetting severely restrict root development.

c. Soil temperature. Soil temperatures above $39^{o}C$ reduce root expansion and temperatures above $44^{o}C$ are detrimental to root growth and nutrient uptake. A dry soil exposed to the tropical sun may easily reach (surface) temperatures of over $44^{o}C$, thus eliminating the roots from the top 5-10 cm of soil, where otherwise (air:water ratio, organic matter content, etc.) conditions for intense root activity are optimal.

3. The importance of mulching. Mulching is essential for high yields of field grown tomatoes. While some effects of mulching in the tropics are the same as in temperate climates, others differ.

In a cool climate, mulching is practiced, among others, to increase and buffer soil temperature. Black vinyl mulch is best suited for such a purpose. In the tropics one of the effects of good mulch is to decrease surface soil temperature. Rice straw, rice husk, dry grass, etc., are therefore far better mulching agents in the tropics than plastic sheets. In the tropics good mulch has the following overall effects:

a) It reduces soil surface temperatures and it levels diurnal temperature fluctuations.

b) It helps to maintain a good distribution of moisture throughout the profile.

c) It promotes nitrification and helps to maintain a more uniform nutrient content in the soil solution throughout the profile.

d) It promotes a deeper and more even distribution of fine roots throughout the profile (although more roots will be feeding directly under the layer of mulch.)

e) It decreases nutrient losses through leaching and fixation.

f) It permits a better utilization of soil and fertilizer nutrients.

FERTILIZER REQUIREMENTS OF TOMATOES IN THE TROPICS

Fertilizer requirements of the tomato will be determined by the agronomic response of the crop and the price relations between fertilizer prices and tomato fruit prices. Unfortunately, both factors are less predictable in tropical developing countries than in advanced countries of East Asia, Europe, or North America. Quality also, in most cases, is not paid for, and that is probably the reason for the very poor tomato quality found in most vegetable markets of Southeast Asia.

Agronomically, the tomato plant can respond to very heavy rates of fertilizer inputs. The average fertilizer application of 36 outstanding tomato growers in Japan recently surveyed by Mori (18) is shown in Table 4.

Table 4. Chemical fertilizer application rates of 36 outstanding tomato growers in Japan (13).

	Plant nutrient			Yield
	N	P_2O_5	K_2O	
	------	--kg/ha-	-----	-t/ha-
Average of 36 growers	340	410	320	105
Range	70-800	90-930	90-570	
Nutrient uptake	320	105	557	105
Nutrient uptake/t	3.04	1.00	5.30	1

Past application rates and levels of compost and organic matter application probably account for the wide range in the rates of fertilizer application. Average fertilizer application rates in Kanto Plain (one of the major tomato growing areas in Japan) are: 370 kg N, 290 kg P_2O_5, and 350 kg K_2O/ha. The Horticulture Experiment Station in Suweon, South Korea, recommends the fertilizer rates in Table 5. Similar and higher rates are being used in The Netherlands and in Italy.

Compared to other crops, tomatoes require very high nutrient concentrations in the soil solution. The desirable soil and plant

Table 5. Fertilizer recommendations for tomatoes in Korea.[a]

Type of culture	N	P_2O_5	K_2O
	---------	-----kg/ha---	-------
Open field	300	216	328
Protected	340-390	250-290	320

[a]Ref.- Hort. Expt. Sta. Suweon, S. Korea.

nutrient levels are shown in Table 6.

In the tropics very high rates of fertilizer input are rarely warranted on account of the much lower yield levels obtained, the less favorable and highly fluctuating price relations, and because quality is seldom paid for.

Fertilizer rates used for tomatoes in the tropics usually range from: 40-120 kg N, 30-90 kg P_2O_5, and 30-90 kg K_2O/ha.

Fertilizer response and fertilizer efficiency is often unsatisfactory in the tropics because of inadequate soil preparation, poor water management, and varieties that for various reasons cannot make full use of applied fertilizer (Table 7). Although in relative terms the fertilizer response is striking, because of the very low yield fertilizer efficiency is poor.

Table 7. Tomato experiment in North Sumatra.[a]

Fertilizer treatment				Yield	
N	P_2O_5	K_2O	Lime		
-------kg/ha-------				-----t/ha-----	
0	0	0		1.31	100
0	22.5	25.0		1.97	150
67.5	22.5	0		3.31	253
67.5	22.5	25.0		4.49	343
67.5	22.5	50		6.30	481
135	45	25		6.96	531
67.5	45	25	20.000	7.85	599

[a]Ref. - Rep. Dinas Pertanian Rakyat Daerah TKT I, Sumatera Utara, Medan, 1971; Local variety grown on andosol.

The extremely low yield in the control plot (Table 7) indicates poor soil and water management. Yields of at least 3 t fruit/ha should be obtainable without fertilizer on any soil where tomatoes are grown. In many countries the national average yield is below that level so it is difficult to speak about "fertilizer requirements in the tropics" in general terms.

In Nigeria, where the tomato is an important ingredient of all diets in the Savannah area, nitrogen is the most deficient element and optimum rates are 60 kg N/ha and 20-60 kg/ha each of P_2O_5 and K_2O. In forest soils (initial) nitrogen response is small but (initial) (and K) requirement is high. Leaf analysis (5th leaf taken at early flowering) gave a good assessment of nutrient requirements. Critical levels were 0.4% NO_3- N, 0.4% P, and 4% K. Severe deficiency was associated with levels of 0.1%, 0.15%, and 2% for NO_3-N, P, and K, respectively (27).

Table 6. Recommended levels of nutrients for tomatoes.[a]

	Soil		Plant	
	Desirable range	Toxic range	Desirable range	Toxic range
	ppm	ppm		ppm
Phosphorus	60-70	-	0.4%	-
Potassium	600-700	-	6%	-
Magnesium	350-700	-	0.5%	-
Calcium	1000	-	1.25%	-
Nitrogen	(50-100)[b]	-	3 to 5%	-
Boron	1.5-2.5	3	40-60 ppm	100
Manganese	5-20	80	30 ppm	1000
pH	6.5-7.5[c]			
Salt conductivity (S.C.)	80-100			

[a]Ref. 10. [b]Preliminary suggested levels. [c]Depending on severity of manganese problems.

DISCUSSION

In high income countries with a strong and stable demand for high quality tomatoes, fertilizer plays a key role in producing both quantity and quality. Few crops surpass the high yielding tomato in nutrient requirement per unit area. The nutrient requirement can be so high that it is difficult to supply all the nutrients needed without running into problems of excessive salt concentrations.

In the tropics, such problems rarely exist. Tomato yields rarely exceed 25 t/ha, and market economics do not favor a very intensive type of cultivation. Quality is usually not adequately paid for, and fertilizer rates are usually far below the level permitted by the genetic response capability of the plant.

Bacterial and virus disease and inadequate heat tolerance have been serious problems for tropical tomato growers in the past. Much hope is therefore placed on the breeding work done by AVRDC.

In rice-growing tropical Asia, few farmers develop good skills in the proper management of upland soils. The importance of organic matter (mulch) with respect to both water and nutrient availability and efficiency has not received sufficient attention.

Overall we can be very optimistic. As far as yields are concerned, we are still close to the bottom with plenty of possibilities to increase both the quantity and quality of tomatoes in the tropics.

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TEMPERATURE REGULATION OF GROWTH AND DEVELOPMENT OF TOMATO DURING ONTOGENY

L.H. Aung[a]

INTRODUCTION

Temperature represents a working thermal condition essential for the metabolic and cellular functions of the tomato plant. Characterization of the tomato's environment is incomplete without a notation of prevailing temperature conditions. The rates of many physiological processes of the tomato plant are determined by temperature and may be manifested in subsequent morphological changes. The vegetative and reproductive responses are strongly modified by temperature alone, or in conjunction with other environmental factors of light, gas composition, mineral nutrients, and moisture. In this review, temperature is singled out for consideration, since its influence on tomato growth and development is generally the most prominent and dominant (Fig. 1). Other related factors are dealt with to the extent that they provide a clear focus on the temperature responses, or where they cannot readily be separated one from another.

Fig. 1. Temperature modification of the growth and development of tomato cultivars grown under phytotronic conditions (see ref. 9 for details): clockwise from top left: Epoch, Tropic, Fireball, Michigan-Ohio Hybrid.

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SEED GERMINATION

Tomato seed germination, as indexed by the visible outgrowth of the radicle, occurs when provided adequate moisture, aeration, and suitable temperature. The temperatures which favor a high percentage of germination within a prescribed time differ between cultivars, and for seeds within a cultivar. Germination temperatures of 24°C (12) and 18.5°-21°C (66) have been recommended. The difference in the selection of these temperatures may reflect adaptation to local climatic conditions and different production systems, involving different growing media, nutrient status, and cultivars. Many tomato cultivars germinate rapidly and maximally, however, in an optimal temperature range of 26-32°C (48). Temperatures below and above these optimals retard, and near the lower or upper extremes are injurious to, the germination process and subsequent plant development (26, 31).

SEEDLING DEVELOPMENT

Tomato's cotyledonary leaves both store and assimilate food. They develop chloroplasts and increase in size with emergence. Increased cotyledon area is largest when grown at 15.5°C rather than at 18.5°C or 21°C (15). The temperature for optimum dry matter increase of the cotyledons is 18-20°C, which is lower than the optimum of 25°C for shoot growth. The cotyledons of 4-day-old seedlings, however, expanded more in area and showed a greater dry matter increase at 25°C than at 15°C night temperature (25). Tomato seedlings at the 2-leaf stage, when exposed to a brief daily treatment at 3°C or 30°C night temperatures for 4-5 weeks, suffer significant growth reduction (11).

The tomato seedling is most temperature-sensitive soon after cotyledon expansion (Fig. 2). The rate of leaf primordia initiation is hastened and dry matter growth is greater at 25°C constant day and night temperature than at constant 15°C. At 15°C, fewer leaves form than at 25°C. The size of the main shoot apex at 15°C, however, is twice as large as that at 25°C, and the plants initiate flowers sooner (24).

Seedlings of 3 tomato cultivars grown for 7 weeks at a constant temperature of 26°C (8-hr dark and 16-hr light) accumulated more dry matter than plants grown at 20°C or 14°C. At 20°C, the leaves accumulated more dry matter than at 14°C or 26°C. In contrast, the amount of dry matter accumulated in the stem was higher at 26°C than at 20°C or 14°C. Low temperatures of 14°C and 20°C resulted in fewer leaf nodes before the first inflorescence than at 26°C. The number of flowers per inflorescence of plants grown at 14°C was higher than in those grown at 20°C or 26°C, but height was reduced (Table 1).

In older 20-40 cm tall tomato plants, the rate of stem elongation is greater when grown at a fluctuating 26.5°C day and 19-20°C night temperature than at constant 26.5°C day and night temperature, or 19-20°C day and 26.5°C night temperature (58,59). This phenomenon of optimal stem growth from lower night than day temperatures was termed "thermoperiodicity" (59, 60, 61). Although some tomato cultivars show a higher growth rate at alternating high day and lower night temperatures than under a

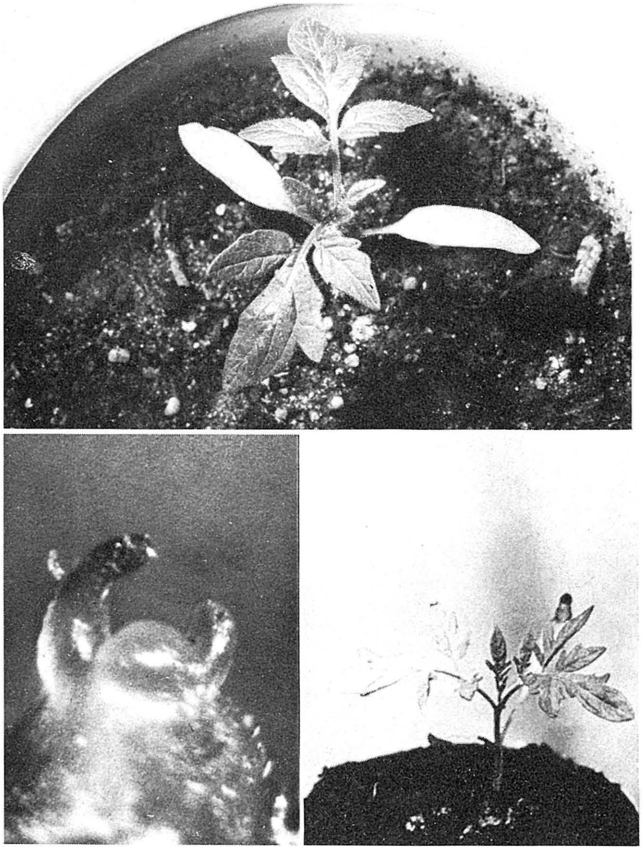

Fig. 2. Tomato seedling at the thermo-sensitive stage of development: Top 2 1/4-leaf stage after cotyledon expansion; bottom, a similar seedling of the same age dissected (left) showing a globular meristematic dome with 2 leaf primordia, and 2 1/2-leaf stage undissected (right) seedling.

Table 1. Developmental responses of tomato seedlings grown under constant temperature regimes[a]

Observations	Day-Night temperature		
	26°C	20°C	14°C
Dry weight (mg)/plant			
Leaves	314	369	175
Stem	184	94	25
Root	95	88	50
Total	593	551	250
Leaf number	15.2	11.3	10.6
Plant height (cm)	83	60	45
Flower number	4.4	6.4	9.6

[a] Reference 29 ; Values are means of 3 cultivars.

constant day and night temperature, there are cultivars which show no significant response to thermoperiods or show a higher growth rate at a constant day and night temperature than at alternating high day and lower night temperatures (Table 2). Also, young tomato plants grow better at a constant day and night temperature than at fluctuating high day and lower night temperatures (25, 58).

Table 2. Effect of thermoperiods on stem elongation rate (mm/day) of tomato cultivars grown under controlled environment[a]

Cultivar	Day/Night temperature			Response
	26.5°C/30°C	26.5°C/26°C	26.5°C/16°C	
Essex Wonder	23.4	27.3	32.2	Yes
Comet Forcing	-	21.6	28.6	Yes
Valiant	17.7	22.4	26.8	Yes
Michigan State	-	23.2	23.6	No
Santa Clara Canner	14.0	19.6	23.6	Yes
Norton Stone	-	19.6	22.9	Yes
Marglobe	15.8	19.4	22.4	Yes
Rutgers	12.3	18.3	18.3	No
Indiana Baltimore	15.0	18.7	20.0	No
Burpee Jubilee	12.0	15.2	21.1	Yes
Temperature Means	15.7±3.9	20.1±3.8	23.5 ± 4.7	
Earliana	24.0	31.9	25.6	No
Marglobe	7.8	13.9	23.1	Yes
Pearson	18.1	26.2	23.2	No
Stone	17.1	30.3	21.8	No
Beefsteak	23.7	29.5	27.6	No
Temperature Means	18.1±6.6	26.4±7.3	24.3±2.3	

[a] Reference 59 ; A Yes indicates cultivar shows thermoperiodicity.

In 3-week-old "Potentate" seedlings grown at a 15.5°C night temperature, Calvert observed stem length increase as the day temperature rose from 15.5°C to 20°C. No increase was seen when the day temperature remained at 15.5°C and the night temperature was raised to 20°C. Thus, stem length was affected only by the level of the day temperature (16). Saito and Ito (43), on the other hand, found that seedlings grown for 50 days after cotyledon expansion showed the greatest stem length and diameter at 30°C day and 17°C night temperatures than at a temperature combination of 30°C day/24°C night or 24°C day/17°C night. The results of these workers are at variance; however, the light conditions, cultural practices, cultivar, and temperature levels selected by Saito and Ito were much different from those of Calvert, which might account for the different results.

When considering the effects of day and night temperatures on tomato stem elongation, it is desirable to sharply delineate the temperature influence from associated factors (29).

AXILLARY SHOOT DEVELOPMENT

The number, size, vigor, and growth pattern of the axillary shoots ("sideshoots", "laterals") of tomato cultivars differ (5). The development of these axillary shoots are altered by mineral nutrients, hormonal chemicals, photoperiod, moisture, and temperature (2, 51, 53; Table 3). Depending upon cultivars and cultural practices, the proportion of

Table 3. Effect of temperature on axillary shoot development of tomato cultivars grown under phytotronic conditions[a]

Observations	Temperature treatment[b] Low & Medium	Medium	Low + High & Medium	HSD (5%)
		cv. Fireball		
Axillary shoot number	6.8	6.0	6.2	2.0
Axillary shoot fresh wt. (g)	51.8	43.8	56.7	20.5
Main shoot fresh wt. (g)	22.8	21.6	21.6	6.9
Axillary % of total	69	67	72	
		cv. Floradel		
Axillary shoot number	3.7	6.7	5.2	1.0
Axillary shoot fresh wt. (g)	50.0	60.1	34.9	16.7
Main shoot fresh wt. (g)	48.0	50.4	55.0	10.0
Axillary % of total	51	54	40	
		cv. Tropic		
Axillary shoot number	2.6	3.0	3.0	1.6
Axillary shoot fresh wt. (g)	40.8	40.6	33.2	13.0
Main shoot fresh wt. (g)	46.3	54.4	50.8	7.7
Axillary % of total	47	43	40	
		cv. Michigan-Ohio Hybrid		
Axillary shoot number	4.4	5.2	5.4	1.3
Axillary shoot fresh wt. (g)	40.8	35.9	23.3	15.0
Main shoot fresh wt. (g)	48.2	47.6	49.2	6.3
Axillary % of total	46	43	32	

[a] Aung's unpublished data.

[b] Values are means of 9 plants; The plants were grown in Redi earth medium, fed with Hoagland's nutrient solution and exposed to 1200 ppm of CO_2 under 9-hr photoperiod with an illuminance of 40 Klux (PAR of 730 $\mu E\ m^{-2}\ sec^{-1}$) from cool white fluorescent and incandescent lamps; Low = 2 weeks at 14°C day/10°C night, Medium = 26°C day/22°C night, High = 4 days at 34°C day/30°C night. HSD refers to Tukey's test at 5% level of probability.

assimilating leaf areas of the axillary shoots in relation to the whole plant can constitute a third or half of the entire plant weight or leaf area. Thus, their contribution to yield may be considerable.

Two additional aspects of the correlative influences of the axillary shoots on the growth of the main stem should be mentioned: (a) the removal of the young axillary buds prior to unfolding enhances flower production and fruit ripening of field-grown tomato (4), and (b) the development of the root system is diminished by pruning the axillary shoots (47).

ROOT FORMATION AND DEVELOPMENT

The root system constitutes an integral part of the plant and is important in contributing to the structural and functional integrity of the shoot (6, 18, 56, 57). Information on the formation, regeneration, and development of roots of tomato cultivars, however, is incomplete.

Field-grown summer tomato has roots which penetrate 1 m deep with a lateral spread of 1-1.3 m (47). In the greenhouse, tomato roots grow at a fairly constant 33 mm/day, penetrate 1m deep, and attain lengths of 1.5 m (55). Thus, despite differences in the growing environmental and cultural conditions, the root systems of field and greenhouse grown adult tomato plants are quite similar.

Reid (42) observed that the ability of tomato stem cuttings to regenerate roots and shoots depends upon and varies with the carbohydrates and nitrogenous substances in the cuttings. In aseptic culture on agar, excised tomato roots were capable of continued growth when supplied with a mixture of inorganic salts, carbohydrates, and yeast extract. The growth of the isolated roots was greatly reduced at 5°, 8°, 10°, and 40°C; grew slowly at 15° and 35°C; and showed optimal growth at temperatures between 20-33°C (62).

Both exogenous and endogenous hormones are associated with tomato rooting (7). An anatomical examination of adventitious root development of "Fireball" explants grown at 26°C day and 20°C night temperatures revealed that (a) root primordia originated from the pericyclic and endodermal regions, and histogenesis of the roots was completed 2 days after initiation; (b) emergence of the roots through the cortex occurred 5 days after initiation; and, (c) the quiescent center, which was absent in preemergent roots, appeared in emergent roots exceeding 0.5 cm in length (13). In intact "Fireball" seedlings grown under similar temperature conditions, the pattern of root initiation in the hypocotyl and primary root occurred acropetally (i.e. from base to apex). Rooting ability differs significantly among cultivars, and such a trait allows plant breeders to select for a more efficient and prolific root system (8).

Exposure of tomato roots or shoots to differential temperature treatments affects the growth responses and chemical composition of the organs. "Tecumseh" seedlings at the 2-leaf stage grown in a nutrient bath at 15.5°C root temperature for 16 days had 2.7 times more dry matter and 1.3 times more phosphorus in the shoot than plants grown at 13.2°C.

The root dry matter and phosphorus content of 15.5°C grown plants, on the other hand, were 3.5 times and 4.6 times greater, respectively, than plants grown at 13.2°C (63). Similarly, shoot weight and height of "Stokesdale" grown at 21°C root temperature for 17 days approximately doubled compared to plants grown at 13°C. Petiole phosphorus and potassium content were increased 34% and 17% respectively, at 21°C (50).

The development of root systems among tomato cultivars differ, and the size they attain is significantly modified by night temperatures. A day temperature of 26.5°C and a night temperature of 16-22°C resulted in the heaviest root system (Table 4).

Table 4. Effect of day and night temperature on root growth of tomato cultivars grown under controlled environment[a]

Cultivar	Root fresh wt. (g)/plant Day 26.5°C Night 30°C	26°C	22°C	16°C	13°C	CV Means
Earliana	30	57	53	53	29	44±14
Marglobe	29	32	72	63	40	47±19
Pearson	23	49	65	72	52	52±19
Stone	40	72	84	89	87	74±20
Beefsteak	55	62	69	74	62	64±7
Temperature Means	35±13	54±15	69±11	70±13	54±22	

[a] Reference 59 .

FLOWERING

Flower differentiation and development of tomato can begin soon after cotyledon expansion. The developmental stage is critical in the seedlings's response to low temperature induction of flower production and early flowering. Generally, seed vernalization at 5°C or less has little or no effect on tomato flowering. In contrast, tomato seedlings are thermo-sensitive and can be vernalized to flower earlier and produce a greater number of flowers on inflorescences. A temperature of 14°C, in contrast to 25°C or 30°C, given to tomato seedlings after cotyledon expansion increases flower number on the first inflorescence of tomato cultivars (32). The low temperature effects are reflected in greater flower numbers, fewer leaves preceding the first inflorescence, and earlier date of anthesis. The commercial significance of the low temperature treatment during the thermo-sensitive stage is (a) earlier flowering and fruiting for market and (b) greater total fruit yield (64; Table 5).

There is a temperature-sensitive period for each inflorescence during which low temperature promotes greater flower production. The sensitive period for the low temperature effect on the first inflorescence of "Kondine Red" is between the 8th and 12th day after cotyledon expansion

Table 5. Low night temperature treatment during the thermo-sensitive stage on early and total fruit yield of 'Fireball' tomato[a]

Observation	24°C day	
	12-13°C	18-20°C
Early marketable yield		
Fruit number	67	58
Fruit weight (kg)	7.08	5.86
Fruit size (g)	106	101
Total marketable yield		
Fruit number	161	140
Fruit weight (kg)	16.75	13.26
Fruit size (g)	104	95

[a] Reference 49 .

(32). In "Spartan Hybrid", the thermo-sensitive period for the first inflorescence is the 2nd week after cotyledon expansion, and for the 2nd inflorescence the 5th week (65). Ten days old "Potentate" seedlings exposed to 15.5°C during the day and 10°C at night show increased flower numbers on the 1st, 2nd, and 3rd inflorescences after the 3rd, 4th, and 5th week of treatment, respectively. Thus, the intervals between the thermo-sensitive phases for the first 3 inflorescences are 1 week apart. "Ailsa Craig" shows significant flower number increases only in the 1st and 2nd inflorescences, and the interval between their sensitive phases is 2 weeks (14).

Differential temperature exposure of tomato seedlings during the thermo-sensitive stage indicates that a shoot temperature of 10-13°C determines the morphological position of the first inflorescence. A root temperature of 10-13°C, on the other hand, controls the number of flowers on the inflorescence (39).

Flower production of "Grosse Lisse" was reduced by phosphorus deficiency imposed prior to flower initiation. Time of anthesis was delayed by 7 days. Kinetin applications at 10^{-5}, 10^{-6}, and 10^{-8}M in the growing nutrient medium reduced shoot growth, but flower numbers were significantly increased (36). Kemp et al. (27) and Wittwer and Dedolph (67) had similarly shown that kinetin reduced tomato growth and delayed time of flowering.

Flowering of tomato is reduced by relatively high temperatures. A high temperature of 26°C day/22°C night under phytotron conditions significantly reduced flower numbers in the first inflorescence of "Epoch" and "Michigan-Ohio Hybrid", and in the 1st and 2nd inflorescence of "Fireball", compared to 22°C day/18°C night or 18°C day/14°C night. The number of days from seeding to anthesis of the 1st flower on the 1st inflorescence of 5 commercial cultivars was also significantly decreased with increasing growth temperature (9).

FRUITING

After the inception of the flower, the ovarian tissues, constituting the fruit organ of the tomato, already possess the majority number of cells which will be reflected in the mature fruit (3, 21). Thus, the growth and nurture of the fruit following pollination and fertilization consist predominantly of cell enlargement accompanied by a massive influx of water, organic and inorganic nutrients, and synthesis of others (20).

Microsporogenesis of the tomato begins with the division of the archesporial cells which give rise to the pollen mother cells. Each pollen mother cell divides to give a tetrad, the latter eventually resulting in four mature microspores with thickened cell walls, the pollen grains. The cell walls of the microspores are rich in callose, and starch is present in substantial amount in the binucleate stage of pollen development and the cells of the microsporangia (10). These findings support observations that carbohydrates are essential for normal anther development, and their deficiency leads to microspore degeneration and pollen sterility (22, 23). The adverse effects of high temperatures on microspores and fruit-set may be partly attributable, therefore, to a diminished supply of carbohydrates essential for normal pollen development and pollen tube growth. High temperatures also induce stylar exsertion beyond the staminal-cone, which hinders pollination (1,52) and retards the development of the pistils. Thus, Smith (46) found that high temperatures existing approximately 3 days prior to anthesis have a detrimental effect on the rate of pistil development. The affected pistils fail to develop beyond the egg stage and are characterized by smaller egg cell, nucleus, and poorly staining cells. Marre and Murneek (34) also demonstrated the importance of carbohydrate on the growth of tomato ovaries. They note that 48-72 hours after pollination or auxin treatment, the developing ovaries actively synthesize or acquire carbohydrates. Leopold and Scott (30) showed that the growth of *in vitro* tomato ovaries have an optimal temperature of 20-22^{o}C, and the addition of 5% sucrose with 10^{-4}M ascorbic acid in the culture medium promotes fruit-set of excised flowers at 30^{o}C. It may be relevant to observe also that the low moisture stress conditions often accompanying high temperatures could generate a high abscisic acid level in tomato (35, 37), which would favor premature senescence and abscission of reproductive organs. Thus, the high temperature modifications: (a) poor development of pollen, (b) lack of pollination, (c) disintegration of embryonic pistil cells, (d) substrate competition and limitation, and (e) hormonal imbalance are all conducive to abscission of tomato ovaries and poor fruit-set and yield.

Tomato cultivars exhibit a wide range of fruiting ability under low (17) and high (45) temperature conditions. Some cultivars capable of setting fruit under low night temperatures are also able to set fruit at relatively high night temperatures. On the other hand, some of the same cultivars which set fruit under low night temperatures were unfruitful at high night temperatures. In general, increasing the night temperatures decreased fruit-set and reduced fruit size. Unfavorable high day temperature is less detrimental on fruit-set than high night temperature. While it is quite well accepted that high temperatures decrease fruiting, it is known that "Moneymaker", grown at 35^{o}C day/18^{o}C night temperatures under controlled conditions, yielded more and heavier fruit than plants grown at 20°C day/15°C night temperatures when provided adequate moisture (2).

Although various attempts have been made using hormonal chemicals to counteract the adverse influence of unfavorable temperatures on tomato fruit-set (33, 38, 40), and with varying degrees of success (or failure), understanding of hormonal aspects of fruit-set and development is still in its infancy (19). Information on endogenous hormonal changes in relation to defined temperature and related environmental conditions affecting specific growth stages of reproductive structures is needed before precise and predictable control of tomato fruiting can be realized.

FRUIT RIPENING

Transformation of the matured green tomato into a red ripe fruit involves many complex sequences of underlying biochemical reactions.

Table 6. Optimal growing temperatures of tomato at different developmental stages

Developmental stages	Optimal temperatures[a]	Reference
Seed germination	26-32 °C	48
Cotyledon expansion	16-20 °C	15
Seedling apex enlargement	15°C	24
Seedling growth	25-26°C	25, 29
Stem elongation	30°C day/17°C night	43
	27°C day/19-20°C night	58, 59
Axillary shoot growth	35°C day/18°C night	2
	26°C day/22°C night	Table 4
Root growth:		
Intact seedling	26-32°C	
Older plants	27°C day/13-22°C night	59
Excised *in vitro*	20-33°C	62
Leaf initiation	25°C	15, 24
Leaf node reduction	10-14°C[b]	32, 65
Flower formation	13-14°C[b]	32, 65
Anthesis	13-14°C[b]; 26 C day/22°C night	9, 32
Pollen formation	20-26°C	10
Pollen germination	22-27°C	1
Pollen tube growth	22-27°C	1
Stylar extension	30-35°C	1, 46
Fruit-set:		
Intact plant	18-20°C	17, 45, 58
Excised *in vitro*	20-22°C	30
Fruit ripening	24-28°C	54

[a] It should be borne in mind that the temperature responses are modulated by light intensity, mineral nutrient and moisture levels.

[b] Low temperature given to seedlings for short duration of 2 weeks or less followed by growth at higher temperatures.

In the process of ripening, the green chlorophyll pigments are degraded, and the yellow-orange carotenoid and red lycopene pigments are synthesized. The biosynthesis of these pigments are light and temperature dependent (28, 41, 44). Carotene and lycopene development is promoted by red light and inhibited by far-red, indicating the process is under phytochrome control. Vogele (54) demonstrated that "Bonny Best" and "Marglobe" fruit maintained at 24-28^{o}C developed a deep orange-red coloration, but became yellow colored when kept at 32-36^{o}C. At 40^{o}C or higher the fruit remained green and failed to ripen.

EPILOGUE

The ultimate goal in regulating tomato's vegetative growth and flowering by providing an optimal growing environment is to achieve earlier and more abundant high quality fruit. However, such a goal is only partly realized because (a) basic understanding of vegetation, reproduction, and their interrelationships is incomplete, and (b) optimal growing environmental conditions during different growth stages of the tomato are seldom met even under controlled greenhouse or phytotron conditions. Recognition and, where feasible, correction of the limiting internal and external factors of tomato development can go a long way to assist in realizing higher fruit yield. Perhaps it is fair to say that we have learned a great deal about how to use temperature (Table 6), but we are still unable to explain fully how it influences growth and development.

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TOMATO FRUIT-SET AT HIGH TEMPERATURES

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INTRODUCTION

Tomato yield is mainly determined by the number of plants per unit of land area, the number of flowers produced per plant, average fruit-set percentage, and average fruit size. Fruit-set percentage is one of the key yield componenets to decide the yield in areas of marginal production (55). By definition, fruit-set occurs in a plant which has its female parts and develops seed within a pericarp. This enclosing pericarp tissue is the site in which pollen grain must germinate after pollination, the pollen tube must grow through this tissue to reach the ovule, which forms the fruit after fertilization, and finally the fruit must remain within the plant and grow. Therefore, the absence of abscission of reproductive organs, which may take place at any time before, during, or after anthesis, does not have the same meaning as fruit-set (19).

Environmental factors such as light intensity, temperature, and moisture stress greatly affect each process of fruit-set in tomato, and subsequently fruit-set percentage and yield (3, 15, 17, 36, 37, 54, 56, 60, 63). High temperature in the tropics is particularly unfavorable for fruit-set, limiting tomato production. (1, 9, 10, 58). Since generative development is not much influenced by high soil temperatures, more attention is paid to the effect of air temperature in this paper.

TEMPERATURE REQUIREMENTS FOR FRUIT-SET

Although tomato plants can grow under a wide range of temperatures, fruit-set is limited to a somewhat narrow range. Fruit-set is usually poor when the temperature is either relatively low or high. Watts (59) found that fruit-set is greater at 24^{o}C than 16^{o}C. Went (61, 62) reports that the critical factor in setting tomato fruit is the night temperature, the optimal range being 15^{o}-20^{o}C. Fruit failed to set at 13^{o}C or below. When the average maximal day temperature is above 32^{o}C, and the average minimal night temperature is above 21^{o}C, fruit-set is low (41). Also, high light intensity accompanied by high temperatures is harmful to fruit-set. Reducing the light intensity by shading

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increases fruit-set significantly at high temperature; but, when the temperature is satisfactory, reducing the light intensity has no beneficial effects. Light intensity affects the internal temperature of the reproductive organs. Later, Schaible (49) also noticed that tomato fruit-set is generally poor when the night temperature exceeds 23°C.

Howlett (25) points out that both night and day temperatures are important factors limiting tomato fruit-set. Sugiyama et al. (54) attributes poor fruit-set and yield to high day temperature. Ranges between 30°-45°C cause a marked reduction of fruit-set, although no visible injury to vegetative growth is observed (32, 33). Growing temperatures below 30°C are recommended for fruit-set and yield.

Cultivar differences in the ability to set fruit at high temperature were first reported by Went (60). Subsequently, it has been possible to select cultivars capable of setting fruit under relatively high temperature (11, 12, 18, 44, 45, 49, 52, 57, 58). Others have dealt with differences between genotypes at high temperature, which should increase understanding of the specific mechanisms of sensitivity or resistance to the abscission of reproductive organs or arrest of fruit growth by heat stress (1, 9, 11, 16, 22, 39, 44, 46). This review does not attempt to preclude the possibility that one factor is affected chiefly by changes in day temperature and another by night temperature, however, both are considered simultaneously, since high day temperature is usually associated with high night temperature in the humid tropics.

PRE-ANTHESIS AND ANTHESIS STAGES

FLOWER FORMATION

The developmental stage of a seedling is critical to flower formation under high temperatures. Flower production decreases with increased temperature up to 27°C, regardless of any heat-tolerance in terms of fruit-set ability (16). A 26°C day/27°C night at the early growth stages reduces flower numbers in the first cluster, but days to the first anthesis are also decreased with increased growing temperature in the early growth stages (14). In contrast, work at AVRDC found that days to the anthesis of the 1st cluster of both heat-tolerant accession L-125 and heat-sensitive accession L-123 are not affected when the high temperature (33-38°/21-26°C) are imposed for a 2-week interval at any time after the cotyledon expansion.

We observed the macroscopic appearance of the first cluster in both L-123 and L-125 at 3 weeks after the cotyledon expansion of control plants, and high temperature of increasing duration at this stage decreased flower numbers (Fig. 1). These results imply that heat sensitivity is maximal during the macroscopic appearance of the cluster, and abortion of flower buds can take place before their anthesis. Hewitt and Curtis (24) attributed this to a depletion of the carbohydrates by increased respiration. It was later found that heat-tolerant tomato cultivars at high temperature (mean max. of 39°C) tended to maintain a high net photosynthetic rate as well as fruit-set (9).

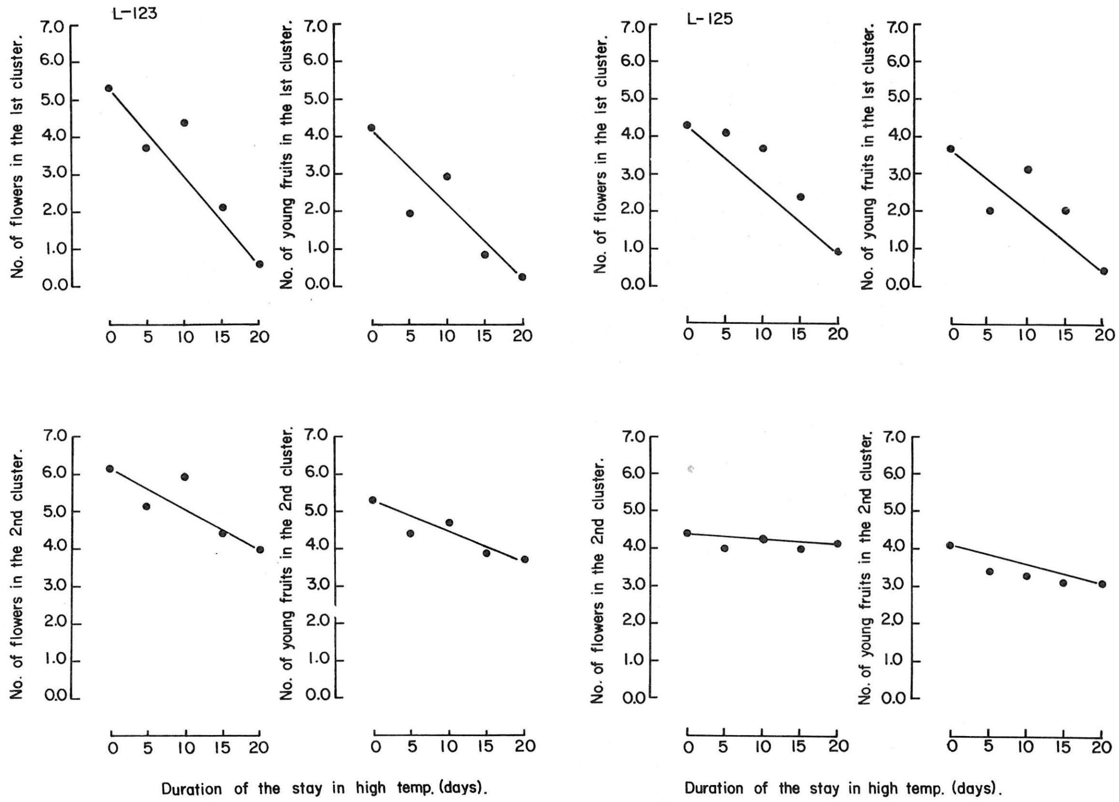

Fig. 1. Effect of high temperatures (33-38^{0}C day/ 21-26^{0}C night) started from the macroscopic appearance of the inflorescence in tomato accessions L-123 and L-125; AVRDC, 1978.

POLLEN GRAIN AND OVULE FORMATION

Under normal temperature conditions (30°/15°C), meiosis stages of macro- and microspore mother cells take place about 8-9 days before anthesis (28). This phase is the most sensitive to heat injury, a phenomenon noted when the plant is at 40°C or above for several hours. Heat treatment at this phase caused:

1) pollen tetrads to degenerate, and pollen grain to empty, and

2) macrospore mother cells in the ovule to degenerate and their developmental stage to be delayed (28). Heat injuries to both macro- and microspores decrease with the advancing stage of flower buds before anthesis (28,53). High temperature at 3-1 days before anthesis or on flower buds younger than the meiosis stage do not cause any morphological disturbance of pollen grains and ovules. Hand pollination with pollen at normal temperature increased the percentage of fruit-set for flowers which had been treated 7-5 days before anthesis to 60%, but failed to increase the fruit-set of flower buds treated at other stages (34). These results suggest that high temperature affected both pistil and stamen in the flower buds 9 days before anthesis, while it affected mainly stamen in the buds 7-5 days before anthesis.

The numbers of sterile pollen, tested by staining or germination, increase with high temperature before anthesis (12, 16, 23, 39, 54). Sugiyama et al. (54) attribute the low fruit-set at high temperature (40°C) before anthesis mainly to a reduction of fertile pollen; however, Charles and Harris (16) suggest that a lower percentage of viable pollen plays only a minor part in causing low fruit-set at 27°C. Work at the AVRDC shows pollen obtained from the high temperature grown heat-tolerant tomato plants (L-125) tends to have more viable grains than heat-sensitive L-123 (Table 1). Levy et al. (39) report that pollen grains obtained from high temperature grown heat-tolerant "Hotset" have higher viability than those of heat-sensitive "Hosen-Eilon". Elahmadi (22) found differences among genotypes for high temperature not only on pollen viability but also on ovule viability.

Table 1. Pollen germination and pollen tube growth of tomatoes grown in relative high temperature.[a]

Acc. no.	Pollen germination	Pollen tube length
	-%-	(μ)
L-123	16	382
L-125	77	470
LSD 0.05	7	66

[a]Mean maximum temperature for 10 days before the collection of pollen was 30°C, and pollen was incubated at 25°C for the test.

STAMEN STRUCTURE

Levy et al. (39) suggests that splitting of the antheridial cone due to high temperature is a mechanical barrier to self-pollination. This characteristic was not found in heat-tolerant "Hotset" at 36°-39°C day/16°-20°C night, whereas in heat sensitive "Hosen-Eilon" its frequency reached 40% of all flowers, which would eventually drop before fruit-set.

The opening of pollen lobes is associated in part with formation of the endothecium - a subepidermal cell layer of the pollen sac, with special thickening in the walls except for the external tangential one. This endothecium formation is normal in heat-tolerant "Saladette" at high temperature (32°C day/27°C night); consequently the opening of the anthers also is normal (46). However, endothecial thickening of heat-sensitive "Roma VF" did not occur at high temperature and resulted in loss of pollen dehiscence, whereas flowers of "Roma VF" under low temperature developed normal endothecia and dehiscence. In a study of several genotypes with the ability to set fruit at high temperature, pollen production was reduced and dehiscence impaired in all genotypes at high temperatures, regardless of heat tolerance (22).

STYLE ELONGATION

Tomatoes are self-pollinated at a rate of 98% or more (39), and one characteristic reducing fruit-set under high temperature is the style elongation relative to the antheridial cone (1, 45, 47). Self-pollination would be prevented or reduced when the stigma extends beyond the mouth of the antheridial cone. A strong relationship was found between style elongation and flower drop - the lower the stigma level, the higher the fruit-set - within a line at high temperature (10, 39, 45, 46). Levy et al. (39) found that no fruit was set by flowers with the style protruding more than 1 mm out of the antheridial cone due to high maximum temperatures of 36-39°C. An inheritance study of fruit-set and style elongation at high temperature concluded that style elongation is a prime factor contributing to low fruit-set at high temperature (45).

On the other hand, no style elongation was observed in several cultivars (16), although fruit set was reduced due to high temperature at 27°C. The low fruit-set was attributed to high temperature raising the stigma and plugging the tube of the antheridial cone, where it was less likely to receive pollen. A great variability in style elongation between cultivars was shown under high temperature (35). Later work confirmed the wide genotypic variation in style elongation at high temperature (10, 39, 46). The frequency of such distorted flowers ranged from 0-100% in heat-tolerant "L-246" (KL-2) and in heat-sensitive "L-95" (Venus), respectively, when grown under the mean maximal and minimal range of 41°-24°C (Table 2). Similar results occurred with heat-sensitive and heat tolerant-hybrids (39). Rudich et al. (46) found that the stigma was thrust through the mouth of the antheridial cone (+0.15 mm) of heat-sensitive "Roma VF" at a day temperature of 40±1°C, whereas the style of heat-tolerant "Saladette" at high temperature was shorter, and the stigma stayed within the antheridial cone (-1.1 mm). Mechanical pollination using a brush (10), or hand pollination using normal temperature pollen,

Table 2. Effect of temperature on style elongation and fruit-set rate of tomatoes.[a]

Type	AVRDC acc. no.	Varietal name	41 - 24°C Style exserted	41 - 24°C fruit-set	32 - 24°C Style exserted	32 - 24°C fruit-set
Heat-tolerant	L-246	KL2	0	42	0	57
	L-2991	PI 290856	0	44	0	55
	L-232	Nagcarlan	63	24	0	42
Mean			21	36	0	51
Heat-sensitive	L-96	Saturn	45	30	11	37
	L-205	Techumseh	53	19	10	26
	L-203	Floradel	83	4	20	19
	L-95	Venus	100	0	20	61
Mean			70	13	15	36

[a]Adapted from Ref. 10.

improved fruit-set at high temperature; probably because it distributed pollen to otherwise inaccessible stigma. However, production did not always match that of normal temperature.

Study of the heritability of style elongation reveals a high value of inheritance (39, 45). Therefore, the practical possibilities for selecting heat-tolerant lines with normal styles under high temperature has been suggested (39).

POST-ANTHESIS STAGE

POLLEN GERMINATION

Many studies have investigated the effect of temperature on in vitro pollen germination and pollen tube growth of those pollen grains obtained from plants grown under favorable environmental conditions (1, 13, 23). Generally, pollen grains germinate and pollen tubes elongate well at 20°-30°C, and temperatures above 35°C decrease in vitro pollen germination and pollen tube growth. Exposures to temperature above 35°C for one or more hours greatly decrease in vitro pollen germination and pollen tube growth (13, 23, 32). No apparent differences between heat-tolerant and heat-sensitive cultivars in terms of temperature effect on pollen germination and pollen tube growth were found (13).

Exposure to temperatures above 34°C at the time of in vivo pollen grain germination causes a decrease in the in vivo germination percentage and in the rate of pollen tube development into the style and thus prevents fertilization (1, 20, 30, 50, 51). The optimal temperature for in vivo pollen germination and pollen tube growth is near 20°C (16, 51). On the other hand, the decrease in pollen germination with increasing temperature up to 27°C is generally much less than the decrease in fruit set. Also, heat-tolerant "BL 6807", which has the biggest decrease in germination with increasing temperature, has the best fruit set; whereas, heat sensitive "PR 6915" and "BL 6803", which has the smallest decrease, has the poorest fruit set (16). It would appear, therefore, that the reduction in pollen germination and pollen tube growth may not be the sole cause of reduced fruit set under certain high temperature conditions.

Hand pollination using high temperature (35/25°C) and normal temperature (22/18°C) pollen showed that although pollen produced at high temperature is viable, its effectiveness in producing fruit does not match that of normal temperature pollen (1). The reason was attributed to the retarded rate of growth of the pollen tubes produced at high temperature, which resulted in inadequate food stored in the pollen grain. Another possibility is that the poor germination or slow growth of the pollen tube is attributed to lack of a "stigma factor" normally present in the stigma or style (40), although it has not been identified. It was thought that if a "stigma factor" was present in tomato pistils, the pollen germination and pollen tube growth would be affected by the stigmatic exudate. Work at AVRDC showed that pollen of heat-sensitive L-95 incubated at 28°C in a medium containing aqueous stigmatic extract of heat-tolerant L-226 grown at high temperature germinated better than it did in a stigmatic extract of L-95 grown at high temperature (Table 3). It also was shown that indole-3-acetic acid (IAA) promoted germination and tube growth of pollen grains of either heat-tolerant or heat-sensitive cultivars grown at high or normal temperature conditions (Table 4).

Table 3. Effect of aqueous stigma exudate on tomato pollen germination and growth.

Acc. no.	Type	Medium	Germination	Pollen tube length
			-%-	-µ-
		Control[b]	8	42
L-95	Heat-sensitive	L-95[c]	31	68
		L-226[c]	44	183
		Control[b]	10	75
L-226	Heat-tolerant	L-95[c]	2	50
		L-226[c]	41	170
LSD 0.05			5	12

[a]Mean maximum temperature of 10 days before pollen collection was 31°C, and pollen was incubated at 28°C for 1 hr for the test.t.
[b]20% sucrose + 100 ppm H_3BO_3. [c]20% sucrose + 100 ppm H_3BO_3 + stigma exudate from acc. no. indicated.

Table 4. Effect of IAA and GA_3 on pollen[a] germination and growth of tomatoes grown in growth chamber or greenhouse.

Acc. no.	Medium	Germination		Pollen tube length	
		Growth chamber[b]	Greenhouse[c]	Growth chamber	Greenhouse
		%		μ	
L-123	Control	16	1	10	7
	IAA (0.25 mg/l)	32	14	29	25
	GA_3 (0.5 mg/l)	16	18	21	16
L-125	Control	12	1	9	9
	IAA (0.25 mg/l)	44	12	40	20
	GA_3 (0.5 mg/l)	26	7	39	9

[a]Pollen was incubated at 30°C for 1 hr. [b]Temp. (20/20°C). [c]Temp. (35/21°C).

Gibberellin A_3 (GA_3) also had a slightly promotive effect, but not as much as IAA (13). Whether any of the these plant hormones are a stigmatic factor or are involved in heat sensitivity needs to be studied.

FERTILIZATION AND SEED FORMATION

Flowers at one to three days after anthesis were sensitive to high temperature and almost all flowers failed to set fruit under high temperature (40°C) at this stage but not under high temperature at 5-8 days after anthesis (34). The more advanced the stages of fertilized flowers treated with high temperature, the more heat-resistant the fertilized flowers were. Later, Iwahori (29) also observed that pollen grains began to germinate 3 hrs after pollination on the stigma and fertilization took place 20-30 hrs after pollination, which occurred about 3 days after anthesis. The fertilized ovules which had been treated with high temperature 18 hrs after pollination did abscise, which was mainly attributed to the retardation or stoppage of pollen tube elongation. When flowers were treated with high temperature 24-56 hrs after pollination, degeneration of endosperm and retardation or proembryo development were observed. On the other hand, flowers of the plants held at high day temperature of 30°C or high night temperature of 24-30°C developed fewer locules (48).

There is a positive correlation between the number of seeds and fruit weight within varieties (21, 56) and among varieties (26). The environmental conditions positively affected these two characters, and the cause of the decrease of either,usually is accompanied with that of the other (27). The effect of temperature on the number of seeds per fruit and the fruit-set percentage was studied at AVRDC. Generally, the fruit-set and the number of seeds per fruit were higher at low temperature than at high temperature, and most heat-tolerant cultivars tended to have a higher number of seeds at high temperature (10).

GROWTH REGULATORS AND FRUIT-SET AT HIGH TEMPERATURES

Fruit-set and fruit development are usually associated with the endogenous plant hormones produced by pollen, style tissue, or seed through the normal processes of pollination, fertilization, and seed formation (42). After fruit-set, fruit growth follows cell division and enlargement promoted by the endogenous plant hormones produced by seeds through seed development (4, 5, 7, 8, 30, 42). In general, auxins and cytokinins are abundant and reach their peak during early development of cell division (4, 5, 7, 8, 30, 43). Gibberellin levels are more prominent during cell enlargement (4, 5), whereas abscisic acid and ethylene increase gradually during maturation (4).

Few attempts have been made to relate the changes in hormonal activity occurring in the flower, its fruit-setting process, and early growth of fruit as they are affected by environmental factors. Iwahori (31) reported that the highest level of endogenous IAA-like substance appeared 7 days after anthesis, when the ovary began to grow. The high temperature (40°C) treatment for 4 hrs 0-3 days after anthesis resulted in disappearance of this high level of endogenous IAA-like substance in those fruit which did not abscise from the plants but had their growth arrested. Also, almost all auxin activity was detected only in the seeds. Accordingly, in the high temperature treated ovary of a tomato flower, fertilization will not take place, and this would result in failure to produce the auxin (47), which is assumed to trigger fruit development (38).

No reports have discussed the effect of high temperature on endogenous growth regulators other than auxins as related to fruit-set. However, work at AVRDC found cultivar differences in the number of adventitious roots formed due to ethrel application. The number of roots formed was inversely related to heat-tolerant fruit-set, although some exceptions were observed (13). How this sensitivity to ethrel application is related to heat-tolerance needs to be clarified.

The importance of endogenous growth regulators in controlling abscission of reproductive organs has been known (38). Work at AVRDC (13) indicates that pedicels of newly set or large fruits with reproductive organs removed resist abscission better than those pedicels with their flower buds open or with fertilized flowers removed (Table 5). This result suggests that the high level of certain endogenous growth regulators in later stages of the fruit-set process may prevent the abscission of reproductive organs. Furthermore, heat-tolerant L-125 tends to have a low abscission percentage regardless of when its reproductive organs are removed. On the other hand, exogenous application of IAA or GA4/7 prevents the abscission of pedicels without reproductive organs, and application of ethrel promotes abscission of pedicels without reproductive organs (Fig. 2)

The exogenous application of natural as well as synthetic auxins has brought about improved fruit-set which otherwise failed to develop after receiving high temperature treatment (13, 34, 35, 47). Fruit-set of flowers treated with high temperature at anthesis recovered after exogenous application of a synthetic auxin, pará-chlorophenoxyacetic acid (CPA), whereas flower buds treated with high temperature failed to

Table 5. Abscission rate of pedicels with their reproductive organs removed at the time of heat treatment.[+]

	Open flower	Small fruit (0.2 - 1.5 cm)	Large fruit (1.5 - 2.5 cm)
	%		
Heat-tolerant[++]			
L-125	22[e3]	15[e]	17[cd]
L-226	97[ab]	73[abc]	75[a]
L-232	94[abc]	40[d]	19[bcd]
L-2972	98[abc]	63[bcd]	21[bcd]
L-3690	81[cd]	60[bcd]	37[bc]
Heat-sensitive[+++]			
L-123	98[ab]	62[bcd]	9[d]
L-146	88[bcd]	46[cd]	22[bcd]
L-166	100[a]	87[ab]	45[b]
L-386	100[a]	92[a]	40[bc]
L-387	76[d]	82[ab]	45[b]

[+]Unpublished results of Kuo et al., 1978. [++]Ref. 57.
[+++]Means with different superscripts are significantly different ($P<0.05$).

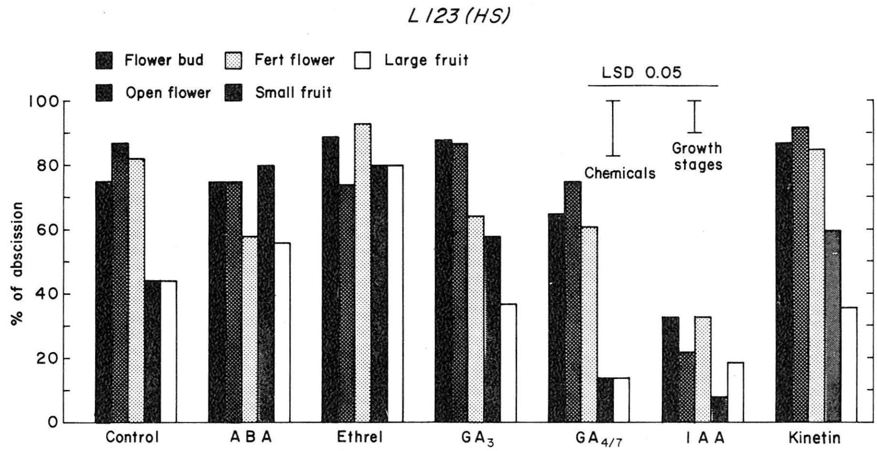

Fig. 2. The effect of growth regulators on the abscission of tomato pedicels with their reproductive organs removed in tomato accession L-123; AVRDC, 1978.

respond to CPA, and did not set fruit (30). Exogenous application of benzyladenine (BA) with CPA before high temperature treatment either at flower bud or anthesis showed a remarkable preventive effect to heat injury (30). Abdalla and Verkerk (2) found that the growth retardant cycocel (CCC), and $GA_{4/7}$ reduced flower drop and increased fruit set and development at 35° day/25°C night. Later, Abdul et al. (6) confirmed that the application of CCC improved fruit-set at high temperature. These results strongly suggest the control of fruit-set may involve more than a single hormonal factor. The possible involvement of other endogenous plant hormones in relation to heat-tolerance is open for further study.

CONCLUSION

Poor fruit-set at high temperature, usually above 30°C, is not due to a single factor but the causes are many and diverse. Each physiological phenomena may account for some reduction in fruit set. On the other hand, the damaging effect on several heat-tolerant cultivars was consistently lower for some physiological or morphological parameters analyzed. These also support the view that reduction or absence of fruit-set at high temperature is not the consequence of a single malfunctioning factor but a simultaneously impaired complex of physiological processes.

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DISCUSSION SESSION II

Villareal: What form of nitrogen source is best for tomato and why?

Uexkull: Nitrogen sources are of minor importance when input rates are low. At higher rates (above 100-120 kg N/ha) nitrate forms are often superior to the ammonia form. High concentration of ammonia in the rhizosphere restricts root growth and can be toxic. Nitrate forms deserve preference over ammonia under the following conditions:

1. High rates of nitrogen use.
2. Soils high or low in pH.
3. Soils low in organic matter.
4. Soils with poor aeration.
5. Conditions of extreme drying and wilting.

On "very good" soils, high in organic matter with good soil texture and structure, nitrification can be very rare and on such soils ammonia forms can be safely used, even at high rates.

Sunarjono: At high temperatures, around 40^{o}C, the tomato pollen did not germinate. You showed that by exposing tomato plants 5 days before and 5 days after anthesis the percentage of fruit-setting was increased sharply. Does it mean that the fertilization of the egg cells took place between exposures?

Kuo: The data you refer to was cited from Sugiyama et al.(1966). They exposed tomato plants with various stages of flower buds, flowers, and fertilized flowers to 40^{o}C for three hours on each of two successive days. Their results revealed that flower buds 9-5 days before anthesis and flowers at 1-3 days after anthesis were highly susceptible to high temperature. They also showed that hand pollination with normal pollen on heat treated flowers after anthesis failed to increase fruit-set. Therefore, the conclusion to be drawn is that high temperature prevents fruit-set via the limitation of fertilization.

Sunarjono: What do you mean by fertilization?

Kuo: Fertilization is not a single event. It involves pollen germination, pollen tube growth and pollen tube reaching the ovule. Together, all those processes constitute fertilization.

Aung: When we refer to fertilization, I think we have to consider the amount of seeds involved. You are not talking of a single seed or an ovule being fertilized. You are talking of many seeds. The number of seeds reflect the number of ovules that are fertilized. Some varieties can have 150-200 or more ovules fertilized so that when you try to study the time of fertilization or the fusion of the egg cell and the male nucleus, you have a pretty tough problem. The second point is how many ovules need to be fertilized to set a fruit? We can argue that for a good fruit to set and attain a marketable size would require at least a minimum number of seeds, say 15 to 20. In terms, however, of examining the time of fertilization, it would difficult, considering the number of ovules and the location in the tomato fruit.

TOMATO DISEASES

BACTERIAL AND FUNGAL DISEASES OF TOMATO

Charles Y. Yang[a]

PROBLEMS OF TOMATO GROWING IN THE TROPICS

Even though tomatoes can be grown reasonably well in the drier and cooler parts of the tropics, tomato production in the hot, wet, lowland tropics is often hampered by diseases and pests (21). Reduction in the quality of tomato crops may be caused by various diseases either during growth in the field (64) or during post-harvest activities such as transit, storage, and marketing (41). Effective disease control requires preventive measures and host plant resistance. The use of disease resistant varieties is the most effective and inexpensive means of control; however, chemical fungicides and bactericides may be used to effectively control many tomato diseases. The germplasm of the wild relatives of tomato afford a potential genetic resource for many desirable characteristics including disease resistance (17, 45, 53, 54, 56, 73). Known sources of resistance to most tomato diseases are currently available as catalogs or lists (24, 30, 60, 62, 65, 67).

SCREENING TOMATOES FOR DISEASE RESISTANCE

The Asian Vegetable Research and Development Center (AVRDC), along with many other research instituations in the world, maintains a large germplasm collection of cultivated and wild tomatoes. A vigorous, large-scale breeding and screening program for disease resistance has been initiated to identify and develop disease resistance utilizing the genetic potential of this germplasm. Since 1974, many tomato accessions which possess resistance characters to major tropical tomato diseases such as bacterial wilt, gray leaf spot, leaf mold, powdery mildew, late blight, TMV, and rootknot nematodes have been identified, selected, and utilized in the breeding programs to improve tropical tomato production (7, 8, 9, 10, 11, 12, 43).

DISEASES CAUSED BY BACTERIA AND FUNGI

Fifty-one pathogens, composed of bacteria, fungi, viruses, and nematodes, can attack tomato plants and cause disease. Detailed accounts

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of the symptomology, geographical distribution, disease cycle, and control measures of the individual tomato diseases can be found in several publications (14, 23, 32, 34, 38, 41, 42, 64). In this paper, 5 bacterial and 29 fungal diseases of tomato are listed and referenced in Tables 1-3; however, only the more important bacterial and fungal diseases that occur in the tropical and subtropical regions will be individually described.

Table 1. Tomato diseases caused by bacteria.

Disease	Causal organism	Reference
Bacterial wilt	*Pseudomonas solanacearum*	35,58,61
Bacterial canker	*Corynebacterium michiganense*	6
Bacterial spot	*Xanthomonas vesicatoria*	27
Bacterial speck	*Pseudomonas tomato*	19
Bacterial soft rot	*Erwinia carotovora*	72

Table 2. Tomato diseases caused by fungi.

Disease	Causal organism	Reference
Fusarium wilt	*Fusarium oxysporium* f. *lycopersici*	69
Verticillium wilt	*Verticillium albo-atrum*	18
Damping-off	*Pythium ultimum*; *p. aphanidermatum*; *Rhizoctonia solani*	2
Black leaf mold	*Cercospora fuligena*	8,29,57
Leaf mold	*Cladosporium fulvum*	3
Gray leafspot	*Stemphylium solani*	4,68
Septoria leafspot	*Septoria lycopersici*	5,31
Powdery mildew	*Erysiphe polygoni* *Leveillula taurica*	8 51
Early blight	*Alternaria solani*	52
Late blight	*Phytophthora infestans*	15
Southern blight	*Sclerotium rolfsii*	25
Stem rot (blight)	*Sclerotinia sclerotiorum*	22

Table 3. Tomato fruit diseases caused by fungi.

Disease	Causal organism	Reference
Buckeye rot	*Phytophthora capsici* *Phytophthora* spp.	59
Ghost spot	*Botrytis cinerea*	26
Gray mold rot	*Botrytis cinerea*	71
Nailhead spot	*Alternaria tomato*	49
Phoma rot	*Phoma destructiva*	46
Soil rot	*Rhizoctonia solani*	28
Alternaria rot	*Alternaria tenuis*	40
Anthracnose	*Colletotrichum phomoides*	36
Cladosporium rot	*Cladosporium herbarum*	41
Fusarium rot	*fusarium* sp.	47
Helminthosporium rot	*Helminthosporium carposaprum*	39
Phomopsis rot	*Diaporthe phaseòlorum* var. *sojae*	70
Pleospora rot	*Pleospora lycopersici*	50
Pythium rot	*Pythium aphanidermatum*	41
Rhizopus rot	*Rhizopus stolonifer*	13
Ring rot	*Myrothecium* sp.	63
Sour or watery rot	*Geotrichum candidum*	20

1. BACTERIAL WILT CAUSED BY *PSEUDOMONAS SOLANACEARUM*

Bacterial wilt is known by many common names, including southern bacterial wilt, Granville wilt of tobacco, Moko disease of bananas, and brown rot of potato. This disease is a serious obstacle to production of tomatoes in many tropical and subtropical areas. The pathogen, *P. solanacearum*, is most destructive during warm (30-35°C), wet weather. Since the bacterium needs abundant moisture for optimum development, disease severity increases with decreasing soil drainage. This pathogen can attack plants in over 25 botanical families; many of them cultivated crops such as tomato, potato, tobacco, pepper, peanut, eggplant, banana, and soybean. The losses caused by this pathogen are incalculable.

The lower leaves of infected tomatoes may droop and the whole plant may appear stunted before wilting occurs. Affected plants rapidly wilt and die without yellowing of the leaves. The vascular system becomes brown, and development of adventitious roots along the stem may be enhanced. Slimy bacterial material may exude from the bundles when the stem is cross-sectioned. If cut stem sections are suspended in water for a few minutes, a milky string of bacteria will flow from the cut surface.

The advanced stages of the disease are indicated by a brown decay of the pith and extensive hollowing of the stem. Leaf spotting and fruit do not occur. The rapidity of wilting and death, the absence of foliar yellowing, and the pith decay and hollowness distinguish this wilt disease from the Fusarium and Verticillium wilts.

P. solanacearum is primarily a soil-borne plant pathogen. Its distribution and the diseases it causes are poorly understood, and the pathogenic and physiological variations within the species are enormous. Also little is known of the ecological factors that affect the bacterium's longevity in soil or its disease potential in different soils. It is quite embarassing and disturbing to find that after 82 years and more than 1,400 research papers published (35) since the appearance of E.F. Smith's first monographic treatment in 1896 (61), we still experience heavy crop losses all over the world because we lack effective control measures and adequate knowledge of the biology and ecology of this destructive pathogen.

Investigations on *P. solanacearum* have been hampered by the lack of information on the many different strains of the pathogen in the tropics and subtropics. Identification of specific strains of the pathogen is esential in programs designed to test host germplasm. The numerous hosts affected by this pathogen, its wide geographic distribution, the intrinsic complexities of strain differentiation, and many confusing and diversified classification systems at subspecies-level are the crucial factors limiting the research progress on *P. solanacearum*. In addition, the inherent complexity and diversity of the soil environment and the wide host range of the pathogen make it difficult to determine the soil management or cultural practices necessary for effective control.

The major challenges and opportunities for progress are in breeding for resistance to *P. solanacearum*. Resistance for the bacterial wilt pathogen has been found in *L. pimpinellifolium* (P.I. 127805A) by several workers (1), but this resistance is not adequate at the hot temperatures found at altitudes below 608 m in the tropics. Commercial varieties, such as "Venus" and "Saturn," developed with high levels of resistance for a given location, may not survive in other geographic areas either because of the presence of different strains of the pathogen or because the resistance is variable under different environmental conditions (44). Unless the strain situation within a specific crop can be clarified and the genetics of resistance can be defined, progress on improvement of bacterial wilt resistance in tomato will continue to be slow.

Inoculation procedures for disease resistance screening have been standardized (8,9). The tomato germplasm collected at AVRDC has been systematically screened under enhanced disease conditions in both the field and greenhouse. To date, at least 27 tomato accessions have been selected from the more than 2,000 screened. Many of these selections have demonstrated a moderate to high degree of resistance to bacterial wilt in the field, and their resistance is being incorporated into the current breeding materials in order to broaden the genetic background for resistance to *P. solanacearum* (9, 10).

2. FUSARIUM WILT CAUSED BY *FUSARIUM OXYSPORIUM* F. *LYCOPERSICI*

Fusarium wilt is an important field disease of tomato in many warm regions of the world. In cooler locations, it is also an important disease of tomato under glass.

The leaves of the diseased plant turn yellow and wilt gradually. These symptoms start on the lower leaves, affecting the leaflet unilaterally, spread to the top, and eventually the whole plant dies. The xylem tissues of the stem turn dark brown. The roots also become infected, but there is no decay on the infected roots. Severely infected plants die before the end of the growing season. The disease is more severe on light, acid soils in hot areas. Two physiological races of the fungus are known to differ in pathogenicity toward tomato cultivars.

The only practical means to control Fusarium wilt is the use of resistant varieties of tomato, and, many resistant tomato varieties are available commercially. Varieties that are resistant to race 1 include Manapal, Heinz 1370, Campbell 28, Tropi-Red, Mars, Ohio W-R29, Anahu, Saturn, Manalucie, Nemared, Napoli, Roma VF, and Chico III. The cultivars Walter and Florida MH-1 are resistant to both races 1 and 2.

3. DAMPING-OFF CAUSED BY *PYTHIUM ULTIMUM, P. APHANIDERMATUM,* OR *RHIZOCTONIA SOLANI*

Damping-off is a soilborne disease that is distributed throughout the world. It causes decay of seed or seedlings, or causes young plants to collapse and die. It usually occurs in small patches in the seedbeds. Seedlings are extremely susceptible to damping-off for 2 weeks after they emerge; as the stem hardens and increases in size, the injury no longer occurs.

Damping-off can be controlled by treating plant beds either with Dexon or Captan as a preplanting soil treatment, or with PCNB as a soil drench immediately after seeding.

4. LEAF MOLD CAUSED BY *CLADOSPORIUM FULVUM*

One of the common and destructive diseases of greenhouse tomatoes, it also frequently occurs on field grown tomatoes in tropical regions. The destructiveness of leaf mold on susceptible tomato plants is dependent on moisture and temperature. Infection can occur at an optimum temperature range from 21-26^{o}C, with relative humidity above 95%.

Usually, symptoms of leaf mold develop first on the oldest leaves closest to the ground. They appear on a leaf as small, light-colored spots which turn to a light yellow followed by the browning, drying, and death of the cells in the infected area. Under severe diseased conditions, the infected spots coalesce and the foliage is rapidly killed. The dense patches of buff-colored mold on the under surface of the infected leaves are the fungal conidia which are disseminated by air currents. The fungus primarily attacks leaf blades, but it can also develop on petioles, blossoms, and stems.

Leaf mold is a disease in which physiological specialization of the causal organism is a prime factor (16, 48). To date, at least 12 races of the pathogen have been described on the basis of differential host reactions (37), and more can be expected at any time. A single dominant gene, Cf_2, derived from wild tomato *L. pimpinellifolium*, conveys immunity to five races of the pathogen (65). The following varieties have good resistance to most races of the fungus: Tuckcross M.O. and V. Tuckcross 520, Ohio Hybrid O, Manalucie, Manapal, Vantage, Veegan, Vinequeen, and Waltham Disease Resistant Hybrid.

Another foliage disease, the black leaf mold or black leafspot caused by *Cercospora fuligena*, is very prevalent and sometimes destructive on tomatoes grown in the lowland tropical regions (8, 29, 57). The symptoms of this disease are so close to those of the leaf mold that it is often diagnosed as the Cladosporium leaf mold disease without further distinction. However, under favorable field conditions, the Cercospora leaf mold develops a rather dark black patch of spore mass on the underside of the affected leaves instead of the yellow buff patches so typical of the leaf mold. There is no tomato variety known to resist the black leaf mold disease.

Resulting from 873 screenings in the past 5 years at AVRDC, 11 tomato accessions have been proven to have a high degree of resistance to the leaf mold disease caused by *Cladosporium fulvum*. They are L21, L94, L203, L221, L265, L295, L302, L304, L336, L337, and L341.

5. GRAY LEAF SPOT CAUSED BY *STEMPHYLIUM SOLANI*

Gray leaf spot is a very common and destructive disease of tomatoes in warm and moist tropical and subtropical regions. The disease differs from early blight and nailhead spot by not affecting the fruit. Symptoms commonly appear either in the seedbed or on plants seeded directly in the field. Lesions are most common on leaflets, occasionally on petiole or stem, but never on fruit. Small, brown to black specks appear, scattered or abundant, circular or elongate, and slightly sunken and, as the spot enlarges, the center becomes grayish brown and shiny. The necrotic centers may drop out, leaving a shot-hole effect. When the spots reach their maximum diameter, about 4 mm, the entire leaf turns yellow, dies, and drops. The disease usually progresses from old, lower leaves upward. Warm, moist weather favors disease development and when this occurs, all the leaves except those near the tips may be killed and few fruit are produced. The conidia of the pathogen are carried by air currents.

Gray leaf spot can be controlled by spraying maneb or other dithiocarbamates on the seedbeds. A number of commercial tomato varieties are highly resistant to this disease: Chico III, Floradel, Tropic, Walter, Manapal, Marion, Indian River, Tecumseh, Campbell's 17, and Chico Grande.

Over 2,000 tomato accessions and close to a thousand crosses were screened at AVRDC's experimental farm, 11 accessions and 4 crosses possess strong resistance to gray leafspot (9).

6. SEPTORIA LEAFSPOT CAUSED BY *SEPTORIA LYCOPERSICI*

Septoria leafspot, one of the most destructive foliar diseases, can cause complete defoliation during periods of warm temperatures with frequent rains or heavy dews. The disease is world-wide. It appears on leaves and stems at any stage of plant growth. The lower oldest leaves show the first symptoms. Infected leaves develop water-soaked spots. The spots are circular; they have gray centers and blackish borders. As the spots develop, they become surrounded by a distinct yellow halo. When conditions are favorable (22-26^{o}C), fungus fruiting bodies appear as small black specks, pycnidia, in the center of the spots. Spores ooze out of these pycnidia in pink, gelationous masses during wet weather, and are spread by splashing rain to new leaves. Leaves with 10 or more spots soon turn yellow and drop off, exposing the fruit and permitting heavy sunscald injury. The disease occasionally attacks the stems and blossoms, but rarely attacks the fruit.

Although a high level of resistance to Septoria leafspot has been identified in variety Targinnie Red, a few P. I. accessions, and germplasm collections of *Lycopersicon hirsutum* and *L. peruvianum* (5, 56), no commercial variety with this resistance is available. Maneb and Zineb may be used as a chemical control for Septoria leafspot.

7. POWDERY MILDEW CAUSED BY *ERYSIPHE POLYGONI*

This disease is common on tomato grown during cooler and less humid seasons in some subtropical regions. Conidia are produced in chains on conidiphores that arise from mycelia on the host surface. They are disseminated by air currents. In countries of the Mediterranean basin, the powdery mildew of tomato is reportedly caused by *Leveillula taurica*.

At AVRDC, 3 tomato accessions, i.e. L17, L30,and L40, out of 1,963 screened in the field, have been identified as resistant to powdery mildew. In the field, powdery mildew of tomato can be effectively controlled by fungicides such as Milcurb Super.

8. EARLY BLIGHT CAUSED BY *ALTERNARIA SOLANI*

Early blight, also known as Alternaria leafspot, is the most common leafspot disease of tomatoes throughout the world. It produces a circular spreading spot, which has dark edges and is usually brown to black in the center. These spots frequently merge, forming irregular blotches. Concentric rings often appear in the brown center, giving the disease another name "Target Spot."

The early blight pathogen produces toxic materials within the leaf, causing large areas to turn yellow and the leaf to fall, even though there are only a few necrotic spots. Dark masses of conidia are produced around the margin of the spot, where they are easily dislodged by the wind. The fungus sometimes attacks the fruit, causing large, sunken areas of a black, velvety appearance at the stem end. Infected fruit frequently drop. Large spots often appear on the stems of seedlings at the ground level, causing the partial girdling known as collar rot.

Prevention of seedling infection is very important in controlling early blight. Seed dressing with thiram is an effective control measure. The disease can be controlled in the field by spraying with maneb or other dithiocarbamates. Currently no commercial tomato variety is highly resistant to the early blight fungus; however, Floradel, Manalucie, and Southland are considered moderately resistant.

9. LATE BLIGHT CAUSED BY *PHYTOPHTHORA INFESTANS*

Late blight of tomatoes is caused by *Phytophthora infestans*, a fungus which also causes late blight of potatoes. The disease causes severe defoliation, marked damage of the tomato plants, and a destructive rot of both the mature and immature fruit. Cool nights and moderately warm days with abundant moisture favor the rapid development and spread of late blight. During severe epidemics this leaf blight may destroy an entire crop. In the warm regions the late blight fungus remains alive on *Solanum* hosts.

The characteristic foliar symptoms of the late blight are irregular, greenish-black patches first appearing on the older leaves. They rapidly enlarge and become brown and papery. Water-soaked, brown streaks may also develop on the infected stems. During moist weather or under heavy dew, a white, downy fungus growth often develops near the margin of the diseased tissue on the under surface of the leaves or on the stem lesions. Stem lesions appear as water-soaked brown areas that may girdle and kill the plant. Severely diseased plants often break along the stem lesions and cause lodging. Infection of the fruit can occur at any growth stage, and lesions appear as large, green to brown, water-soaked blotches. These lesions commonly appearing on the upper half of the fruit, are firm in texture with occasional zonate markings. Often soft rot organisms invade blighted fruit and cause rapid fruit disintegration.

The common tomato races of the pathogen damage both tomato and potato equally. The potato races, however, affect potatoes more severely than tomatoes. Several passages of a potato race through tomato or potato plants may alter its racial character. The differences in late blight resistance shown by commercial tomato varieties may well be the reflection of the complications facing tomato breeding programs when dealing with a destructive pathogen with many physiological races. Currently, the varieties New Hampshire Surecrop, New Yorker, Nova, and W. Virginia 63 have a high resistance to the common tomato races of late blight fungus.

To date, screening under the most epiphytotic conditions for late blight, AVRDC's plant pathologists have identified 32 tomato accessions and 31 crosses highly resistant to the disease. These results came from screening 4,023 accessions and 946 crosses. The best resistant selections, i.e. accession L1197 and cross CL607-7-1-0, are being used for resistance to late blight in AVRVC's tomato breeding program.

10. SOUTHERN BLIGHT CUASED BY *SCLEROTIUM ROLFSII*

Besides tomatoes, southern blight affects more than 100 different host plants. This disease is common and widespread in subtropical and tropical regions. General drooping of the leaves, easily confused with bacterial wilt or Fusarium wilt, is the first above-ground symptom. Brown decay of the stem's cortical tissues at the ground level is also evident, and it is usually covered by a whitish mycelial mat interspersed with many small, light-brown spherical shaped sclerotia. The wilt continues until the plant dies. If fruit near the ground are invaded, a rapid decay follows, and the fungus appears generally on the surface. The shape, size, color, and formation of the sclerotia of the southern blight pathogen can be used diagnostically to distinguish it from a very similar tomato disease, stem rot caused by *Sclerotinia sclerotiorum*. The sclerotia of the latter pathogen are mostly formed inside the hollow cavities of the infected stem, and are comparatively larger, black, hard, and irregularly shaped. Sanitation is the best protection against the southern blight.

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Tomato plants are clip-inoculated with bacterial wilt inoculum at AVRDC.

TOMATO VIRUSES

Nobuyuki Oshima[a]

K.M. Smith (19) described 14 tomato viruses and 1 Mycoplasma disease (Table 1).

Sturgess (20) reported a "leaf shrivelling virus disease" of tomato caused by a strain of potato virus Y, yellow shrivel, due to a complex consisting of the strain and the aucuba strain of tobacco mosaic virus (TMV), and tomato fern-leaf shrivel due to a complex of the strain and cucumber mosaic virus (CMV).

A strain of tobacco leaf-curl virus on tomato was reported by Nariani (10) in Delhi. Beet curly-top virus also causes the disease usually known as tomato yellows and, previously, as western yellow blight of tomato (19).

In Japan, 6 viruses occur in tomato plants: TMV, CMV, double virus streak, tomato spotted wilt virus, tobacco leaf-curl virus, and sometimes potato virus Y; and some Mycoplasma diseases. TMV, CMV, and double virus streak are common. Tomato spotted wilt virus and tobacco leaf-curl virus occur in limited prefectures.

Among these viruses, the most important disease of tomato is tomato mosaic disease caused by TMV. More than 90% of the viruses isolated from mosaic tomato plants in Japan are TMV in which the tomato strain of TMV is about 90% or more. Sometimes tomato plants are infected by the necrotic strain of TMV which causes severe necrosis in leaf, stem, and fruit, but it occurs very rarely. Loss of yield by the mosaic disease is from 20-30% commonly, but sometimes more than 50%.

Recently many tomato growers want to use the attenuated virus in their fields. Attempts to cross-protect tomato crops with an attenuated tomato strain of TMV was carried out by Oshima et al. (13) in 1963. They obtained higher total yields from tomato plants inoculated with their strain L_{11}, which had been made by growing a tomato strain, TMV-L, at 35°C for 14 days in sections of a tomato stem. $L_{11}A$, which Japanese tomato growers use at present, was selected from L_{11} by several passages through local lesions of *Nicotiana glutinosa* and tomato plants in the field. This attenuated strain is an almost symptomless strain and

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Table 1. Tomato viruses or virus diseases and Mycoplasma (19).

Name	Transmission		Virus particle	
	Mechanical	Vector	Shape	Size (nm)
Tomato aspermy virus	+	Aphid	Isometric	38
Tomato aucuba mosaic (due to a strain of TMV)	+	-	Rod	15 x 300
Tomato black-ring virus	+	Nematode, Seedborne	Isometric	30
Tomato bunchy-top virus	+			
Tomato bushy stunt virus	+		Icosahedron	30
Tomato double virus streak (TMV and PVX)	+		TMV - Rod PVX - Flexible rod	15 x 300 12 x 515
Tomato fern leaf disease (CMV or some strains of TMV)	+	CMV - Aphid	CMV - Isometric TMV - Rod	30 15 x 300
Tomato ringspot virus	+	Nematode, Seedborne	Isometric	27
Tomato shoestring virus	+			
Tomato spotted wilt virus	+	Thrips	Spherical	68 - 102
Tomato top necrosis virus	+		Spherical	26
Tomato yellow-leal curl virus		Whitefly		
Tomato yellow-net virus	+	Aphid		
Tomato yellow-top virus		Aphid		
Tomato big bud disease (Mycoplasma)		Leafhopper		

stable without producing severe strains by mutation (4). But recently the cultivars having the Tm-1 gene resistant to TMV became infected by a virulent strain, Pelham's 1 type strain, and another attenuated strain, $L_{11}A$ 237, was made by successive passages of $L_{11}A$ through TMV resistant GCR 237 tomato (Tm-1/Tm-1) for the protection of such cultivars (15).

These attenuated viruses, applied as diluted sap from infected tomato leaves to which 600 or 800 mesh carborundum is added, are inoculated to tomato seedlings at the 1 or 2 leaf stage with a motive or hand sprayer. Ogihara et al. (14), in Chiba prefectural Agricultural Experiment Station, investigated the nature of the protection afforded by $L_{11}A$, cultivating different tomato cultivars in a plastic greenhouse contaminated by TMV, and raised higher yields in $L_{11}A$-infected tomato plants than in the non-treated plants. The effects of $L_{11}A$ on yield differed according to the tomato cultivars, the season of cultivation, and the year (Table 2).

Table 2. Effects of inoculation of the attenuated strain (ratio of yield).[d]

Form of culture	Cultivar	Attenuated virus ($L_{11}A$) inoculated (Standard ratio)	
Retarding[a]	House-Homare	132	1970
Semi-forcing[b]	"	129	1971
Over-wintering[c]	Kochi-First	196	"
"	Toko-K	456	"
"	House-Homare	155	"
"	Kyoryoku-Goko	179	"

[a]Oct-Dec; [b]Mar-Jun; [c]Jan-May; [d]Chiba Prefectural Agricultural Experiment Station.

In 1968, Rast (18) isolated an almost symptomless mutant, M II-16, with good protective qualities by exploiting the mutagenic action on the tomato strain of TMV. This strain is manufactured commercially and has been applied to a high proportion of glasshouse grown tomato crops in the Netherlands and United Kingdom.

Many commercial cultivars having resistant Tm-1 or Tm-2^2 genes were introduced and some of them are grown commercially. However Oshima and Motoyoshi (16), studying tomato resistance to TMV strains, observed the adaptive changes of TMV strains following passage through various types of resistant tomatoes, GCR 237 (Tm-1), GCR 236 (Tm-2), and GCR 254 (Tm-1, Tm-2). Motoyoshi and Oshima (9) also studied phenotypic expressions of different genes controlling resistance to TMV in tomato in the protoplast system using otherwise isogenic breeding lines. Genes Tm-2 and Tm-2^2

were not expressed and did not prevent TMV-L, a common strain of TMV, from infecting and multiplying. By contrast, homozygous gene Tm-1 was able to express its effect in protoplasts as well as in leaf discs; no virus progeny were detected by fluorescent antibody staining or by infectivity assay up to 3 days after inoculation with TMV-L. Protoplasts and leaf discs homozygous for Tm-1, however, became infected with TMV-CH2, a tomato strain able to overcome the effects of Tm-1 in intact plants (Table 3).

CMV is another important virus in Japan and occurs commonly, especially in the open fields. The virus seems to be transmitted mainly by the aphids, *Aphis gossypii* and *Myzus persicae*. Many wild plants near the tomato fields are infected with CMV and probably become sources of infection from which aphid vectors transmit the virus. CMV produces the diseases known as "fern leaf", but the symptoms on tomatoes are affected by air temperature and different strains of CMV.

Sometimes tomato plants were affected with the necrotic strain of CMV, but in Japan such a strain occurs rarely. Recently very interesting facts were discovered concerning the necrotic strain of CMV. Vuittenez and Putz (24) reported that field tomato plants in large regions of the French Alsace were stricken with a severe necrotic disorder of epidemic proportions in 1972, and almost the entire field tomato harvest in that part of France was annihilated. In 1974, conclusive evidence was given by Putz et al. (17) that the disorder was viral etiology and somehow associated with CMV infection. However, in 1977, Kaper et at. (5) found that in addition to the three CMV genomic RNA's 1, 2, and 3 and RNA 4 (the nucleotide sequence which also occurs in RNA 3), CMV-S virions, a necrotic South African strain of CMV, contains a fifty RNA component which is not part of CMV's divided genome. The tomato plants inoculated with CMV-RNA 1+2+3 and RNA 5 exhibited necrotic symptoms, but the plants inoculated with CMV-RNA 1+2+3 showed mild mosaic only.

Kuniyasu <u>et al</u>. (7), Vegetable and Ornamental Crops Research Station, carried out inoculation tests of several cultivars to select breeding materials having resistance to TMV and CMV. The experimental resuts showed that M-R 9, M-R 12, Ohio 60712, and L-253 cultivars (among 11 cultivars) showed only sight mottling while "Fukuju No. 2", a TMV susceptible cultivar, was severely affected. The degree of resistance of these cultivars was affected by many factors, including inoculation methods, plant stage, and environment.

Tomato yellow dwarf disease in Japan was reported from tomato fields among the mountains in Nara prefecture in 1973 (11,12). This disease seems to have been occurring in the prefecture for a fairly long time, and recently was confirmed in northern parts of Osaka and Wakayama prefectures also. In these regions, tomato fields suffered badly from the disease, and sources of virus were supposed to be in wild plants. The diseased plants showed curling, yellowing, twisting, and rolling of the leaves, a dark green color along the leaf veins, and stunting of the plants.

The outbreak of this virus fluctuated between years. For instance, it occurred in 100% of tomato plants in one district of Nara prefecture in 1974, but in the next year only in 3.4% (Table 4).

Table 3. Percentages of infected protoplasts of different genotypes inoculated with different TMV strains.[a]

Expt. inoculation buffer	Strain of virus	Tomato line and genotype				
		GCR 26 +/+ +/+	GCR 237 Tm-1/Tm-1 +/+	GCR 254 Tm-1/Tm-1 Tm-2/Tm-2	GCR 236 +/+ Tm-2/Tm-2	GCR 267 +/+ $Tm\text{-}2^2/Tm\text{-}2^2$
1. 0.01 M-potassium phosphate, pH 6.7	L	19	0	0	41	17
2. 0.05 M-tris-HCl, pH 8.0	L	41	0	-	-	-
	OM	44	0	-	-	-
	CH_2	70	63	-	-	-
3. 0.01 M-potassium phosphate, pH 6.7	L	28	0	-	-	-
	OM	16	0	-	-	-
	CH_2	41	59	-	-	-
4. 0.05 M-tris-HCl pH 8.0	L	-	-	0	35	-
	OM	-	-	0	20	-
	CH_2	-	-	54	37	-

[a]Ref. 9. Percentages of infected protoplasts were estimated by fluorescent antibody staining of protoplasts sampled 48 hr after inoculation.

Table 4. Outbreaks of yellow dwarf disease in 1974-1976 in Uda-gun of Nara prefecture.[a]

Region surveyed	Site	Plants infected 1974	1975	1976
		------------%------------		
Sone-Mura	A	0.5	1.1	1.0
	B	2.0	0.8	0.3
	C	3.0	0.4	0.5
Oouda-Cho		5.5	3.0	11.7
Sinbara-Cho (1)	A	100.0	3.4	14.0
	B	24.0	0.8	4.0
Sinbara-Cho (2)	A	-	17.0	-
	B	-	25.0	-
Branch Station of Nara Prefectural Agri. Expt. Sta.		50.0	9.7	20.2

[a]Ref. 11.

Solanaceous plants grafted with the affected plant showed symptoms like those caused by tobacco leaf-curl virus, and the whitefly, *Bemssia tabaci*, transmitted the disease. The preparation purified from diseased tomato leaves contained small isometric particles, 15-20 nm in diameter. Very similar particles were also observed in purified preparations from tobacco leaves infected with tobacco leaf-curl virus. From these results the causal virus of tomato yellow dwarf disease was concluded to be identical or closely related to tobàcco leaf-curl virus. Sometimes viruses isolated from affected tomato plants showed different symptoms on tobacco plants and, consequently, it is necessary to reveal whether these viruses belong to the same virus or not, and also especially to reveal the differences between this virus and tomato yellow leaf-curl from Israel (1), yellow mosaic from India (23), a virus-like disease which causes stunting and yellowish rugose foliage symptoms from Nigeria (3), tomato yellow mosaic from Venezuela (2) which was reported to be mechanically transmitted to several species of the family *Solanaceae* recently (22), and "mosaico dourado do tomateiro" from Brazil (8).

Tomato spotted wilt virus was isolated for the first time from tomato plants of Nara Prefecture in 1972 although already this virus had been isolated from imported dahlias in 1965 (6). The virus induced stem and veinal necrosis, necrotic spots, necrotic or yellowish wilt, severe malformation, and necrosis of fruit in tomato greenhouses or fields (21).

By the sap inoculation test, 30 species in 8 families were found susceptible to the virus. The symptoms were pronounced necrosis in many susceptible plants, especially of *Solanaceae*. The virus was transmitted by the thrips, *Thrips tabaci*. In crude sap prepared with 0.1 M phosphate buffer (pH 7.0) or distilled water, the thermal inactivation points of the virus were between 45-50^{0}C or 35-40^{0}C, the dilution end points were between 10^{-5} - 2 x 10^{-5} or 10^{-4} - 2 x 10^{-4}, and the longevities in vitro were between 10 - 15 hr or 5 - 10 hr, respectively. Virus particles observed in a leaf dip preparation from diseased plants were found to be spherical, 70-90 nm in diameter, presenting an outer layer structure. In ultrathin sections of infected leaf cells of tomato, clusters of spherical virus particles 70-90 nm in diameter were frequently observed in cytoplasm enclosed in vesicles (6).

Besides the above-mentioned viruses, some yellows-type diseases caused by Mycoplasma of potato witches' bloom, aster yellows, and gentian witches' bloom have occurred in tomato plants in the northern parts of Japan, but the outbreaks were in the limited areas and not so important. The vector is the dark leafhopper, *Ophiora flavopicta*.

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PRINCIPAL INSECTS WHICH ATTACK TOMATO IN THE TROPICS AND THEIR CONTROL

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INTRODUCTION

This article is a review of the research that has been done in Thailand and neighbouring countries. The focus is on the major insect pests which have been found causing serious damage to tomato. When compared to the damage caused by diseases, insect problems seem to be the lesser. However, there are a few insect species that can cause serious damage to tomatoes grown in a tropical environment. The scarcity of research documents makes this report far from complete. For this reason, this article is open for further discussion.

From the emphasis of published and unpublished resources surveyed, it is apparent that the major tomato insects of concern to researchers in the tropical countries are sucking insects and fruit borers. More attention has been paid to fruitworm. However, sap sucking insects may become important when they are involved in virus transmission.

APHIDS

There are two species of aphids commonly found on tomato:

1. Cotton Aphid, (*Aphis gossypii* Glover). In the Philippines (4) it causes serious damage when occurring in great numbers. High populations greatly reduce plant vigor. In Thailand, apart from tomato, this aphid also attacks a wide range of solanaceous plants besides cotton.

2. Green-peach Aphid, (*Nyzus persicao* Sulzer). In Thailand this species is common on vegetable crops and found throughout the country. It can transmit virus diseases of tomato such as tomato yellow top and tomato aspermy. Recent tests indicate that this species cannot transmit leaf curl disease in Tailand (8).

Control Measures. Since these two aphids can feed on a very broad range of plants, host plant relationships during the growing season must be taken into consideration before the planting date can be planned. Chemical application of fenitrothion, diazinon, or malathion has been recommended (4).

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WHITE FLY

The significance of whitefly on tomato was pointed out when virologists of the Division of Plant Pathology, Department of Agriculture, successfully transmitted leaf curl virus from infected plants to normal plants by using the whitefly (*Bemisia tabaci* Genn.) as a vector. The disease has been recorded to cause serious reduction of tomato yield in many areas of Thailand (8). Although *B. tabaci* has not yet been recorded on tomato in Thailand, it is listed as a major pest of tobacco (5), and it is known to transmit tobacco leaf curl virus (1). It seems that the whitefly has a broad range of host plants under tropical conditions. Nene (3) has listed above 75 plant species as hosts, including over 7 *Solanum* crops and tomato.

Control Measures: Virologists who work toward the control of leaf curl disease on tomato are asked to pay more attention to ways of protecting tomato plants from whitefly attack. Recommendations for chemical treatments on soybean and urdbean are (3):

1. 0.1% Endosulfan + 0.1% Metasystox (oxydemetonmethyl) + 2% of orchard oil.

2. 01.% Malathion + 0.1 % Metasystox + 2% of orchard oil.

Another method of chemical control is through soil treatment by granular systemic insecticides, such as carbofuran or aldicarb. One application at transplanting should be effective. Tobacco growers in Thailand have successfully used this to protect from tobacco leaf-curl virus.

FRUITWORM

The insect that commonly attacks tomato is the fruitworm (*Helicoverpa armisere* Hubner), commonly known as cotton bollworm or corn earworm. In Thailand, this worm has been a major pest of tobacco, corn, cotton, soybean, vegetables, and legumes. It is also reported as a major problem in India (6) and the Philippines (2,4). Investigation on the damaging habits and chemical control of the worm was carried out for the first time in 1975 (7). Adult females lay a single egg normally on young leaves or flowers. Damage can be found on young leaves and flowers by small larvae. Mature larvae bore a hole into the fruit and rotting is caused by bacteria or fungi. Damage to the fruit has been as much as 30%. Outbreaks are normally found during dry season when host plants are more abundant. Tomato grown near tobacco is normally subjected to more damage. Seasonal abundance of this pest can be found in Mar to Apr in northern Thailand.

Control Measure. Experiments were conducted at Maejo Field Crop Station, Chiangmai, Thailand, during Feb-May 1975 (7) to study the potential of certain insecticides for tomato fruitworm control. Field evaluations, using randomized complete block experimental designs, were conducted in 15 m^2 plot with 5 replications of each treatment. A total of 8 treatments, including control plot, were evaluated for tomato yield. First application was started at first flower set, followed by weekly spray intervals. Insecticide effectiveness was based on percent control on marketable fruit. Yield results are shown in Table 1. Methomyl at the rate of 0.6 kg a.i./ha, Acephate at 0.7 kg a.i./ha, and Monocrotophos at 1.2 kg a.i./ha were among the best treatments followed by Endosulfan 0.6 kg a.i./ha, Methomidophos 0.6 kg a.i./ha, and Leptophos at 1.2 kg a.i./ha.

Table 1. Relative efficiency† of chemicals against tomato fruitworm at Maejo Experiment station;Thailand,1975.

Treatment and formulation	Rate	1st harvest††		2nd harvest††	
		Fruit damaged	control	Fruit damaged	control
	-kg a.i./ha-	-------------------%---------------------			
Methomyl 90% SP	0.6	2.33 a (900)	91.67	3.30 c	89.14
Monocrotophos 56% WSC	1.2	0.52 a (960)	98.00	2.10 a	93.03
Diazinon 40% WP	1.2	3.05 a (929)	88.60	8.10 c	73.35
Leptophos 50% WP	1.2	0.72 a (827)	97.31	3.50 abc	88.48
Endosulfan 35% EC	0.6	2.01 a (984)	92.49	5.10 abc	83.22
Acephate 75% SP	0.7	0.97 a (897)	96.37	2.70 ab	91.11
Salithion[R] 40% EC	0.6	2.73 a (892)	89.80	7.10 bc	76.64
Methamidophos 600 LC	0.6	2.33 a (910)	91.30	5.10 abc	83.22
Diflubenzuron 25% WP	0.6	7.38 b (952)	72.45	14.70 b	51.64
Control (Untreated)		26.79 c (900)		30.40 1	

†Values followed by the same letter are not significantly different at the 5% level of error based on Duncan's multiple range test. ††Total tomatoes examined for 5 replications are indicated in (parentheses) otherwise 100 tomatoes for each replication were taken for check. [R]Proprietary product.

In consideration of the hazards of toxic residues from those promising products tested, Methomyl and Acephate were later recommended for use as tomato fruitworm control in Thailand. In the Philippines (4) Methomyl and Acephate are also suggested, as well as Fenitrothion and Tetrachlorvinphos.

CONCLUSION

It is apparent that among the principal insect pests attacking tomato in the tropics, tomato fruitworm (*H. armigera* Hubner) has received foremost attention and was found to be the most important insect so far. However, some sap sucking insects, such as aphids and whitefly, should receive further attention, especially whitefly (*B. tabaci*) which has become a vector of tomato leaf curl disease.

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NEMATODES ATTACKING TOMATO AND THEIR CONTROL

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INTRODUCTION

There are over 60 species representing 19 genera of plant parasitic nematodes that have been reported to attack tomatoes. Average losses in tomato crop yields due to nematodes are estimated at about 10-15% and, of these, the root-knot nematodes (*Meloidogyne* spp.) probably contribute at least 4%. Among the nematodes affecting tomatoes, the root-knot nematodes are undoubtedly the most destructive and well studied. Of the 37 *Meloidogyne* species described, 7 were reported to infect tomatoes but, of these, only *M. arenaria, M. incognita,* and *M. javanica* are the most common and destructive on tropical tomatoes. *M. incognita* was reported by Ducusin and Davide (12) to have caused 85% yield loss of the rainy season variety 2029 when inoculated at planting, and 40% when inoculated at flowering. In the coastal plains this species reduced tomato yields 85%, compared to 20-30% in the highlands (1). Taylor and Sasser (57) reported that root-knot nematodes multiply logarithmically for several generations during the growing season. They calculated that even if only 5% of the average of 500 eggs produced by each female would survive and reproduce, the numbers will be 25, 625, 15,625 and 390,625 in four generations in the tomato cropping season. It is certain, therefore, that population increase is tremendous on a susceptible crop and under favorable conditions.

Besides the root-knot nematodes, the other destructive endoparasitic species are probably the reniform (*Rotylenchulus reniformis*) and the lesion (*Pratylenchus* spp.) nematodes. Some of the ectoparasites that could be equally destructive are *Helicotylenchus* spp., and *Tylenchorhynchus* spp.

SYMPTOMS

Nematodes affecting tomatoes attack mainly the root system. Infections caused by *Meloidogyne* spp. and *Nacobbus aberans* are characterized by root swellings, often called knots or galls, that contain the enlarged,

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saccate female nematodes. The symptoms caused by the other nematode species are distinguished by the absence of feeder roots, stubby roots or extensive root pruning, and general root decay. The damage to the root system, therefore, reduces uptake of water and nutrients from the soil, resulting in stunted growth and low yields. During hot or dry weather, affected plants wilt readily because of a very shallow root system.

NEMATODE SPECIES ATTACKING TOMATO

Some 65 species belonging to 19 genera of plant parasitic nematodes are reported (8, 17, 20, 26, 33, 43, 44, 45, 47, 48, 56, 62) to attack tomatoes in the tropics (Table 1). Eleven species of *Helicotylenchus* have been identified; followed by 9 species of *Tylenchorhynchus*; 8 of *Pratylenchus*; 7 of *Meloidogyne*; 4 each of *Criconemoides, Longidorus,* and *Xiphinema*; 3 of *Trichodorus*; 2 each of *Ditylenchus, Hoplolaimus, Nacobbus,* and *Scutellonema*; and one species each for the other genera. Among these 19 genera, *Meloidogyne* is the most destructive on tomatoes and possibly followed in importance by *Rotylenchulus reniformis, Pratylenchus* spp., *Helicotylenchus* spp., and *Tylenchorhynchus* spp. The other genera may be considered as minor pests of tomato.

DISSEMINATION

The nematodes affecting tomatoes may either be present in the fields over long periods or they may be introduced or spread through infested transplants, farm implements, and animals during farm operations water such as surface run-off or floods; or by strong winds. Plant parasitic nematodes have also been spread by farmyard manure placed in tomato furrows underneath the planting rows.

ROOT-KNOT NEMATODES

TAXONOMY

The root-knot nematodes belong to the genus *Meloidogyne* Goeldi, 1887. Taylor and Sasser (57) listed 37 species of *Meloidogyne* and 7 species were reported to infect tomato (Table 1). The International *Meloidogyne* Project reported that the 4 species which cause serious damage on tomatoes occur throughout the world with *M. incognita* as the most common (59%), followed by *M. javanica, M. hapla,* and *M. arenaria* with 28%, 8%, and 4%, respectively (Table 2). Besides the morphological characters used for species identification (13), such as larval measurements or the posterior cuticular pattern of adult females, Taylor and Sasser (57) developed the North Carolina Differential Host Test to identify the above four species, as well as four races of *M. incognita* and two races *M. arenaria* (Table 3).

Meloidogyne species deposit their eggs in a gelatinous matrix, formed at the posterior end of the adult female, that holds the eggs together forming an "egg mass". More than 1,000 eggs have been recorded in one egg mass, although average counts range from 300-400.

Table 1. Nematodes attacking tomatoes.

Belonolaimus gracilis Steiner, 1949
Criconemoides duplicivestitus Andrassy, 1963
C. ferniae Luc, 1959
C. lobatum Raski, 1952
C. solivagus Andrassy, 1963
Ditylenchus destructor Thorne, 1945
D. dipsaci (Kuhn, 1857) Filipjev, 1936
Dolichodorus heterocephalus Cobb, 1914
Helicotylenchus cavenessi Sher, 1966
H. crenacauda Sher, 1966
H. dihystera (Cobb, 1893) Sher, 1961
H. dihysteroides Siddiqi, 1972
H. elegans Roman, 1965
H. erythrinae (Zimmerman, 1904) Golden, 1956
H. microcephalus Sher, 1966
H. microlobus Darling & Thorne, 1959
H. multicinctus (Cobb, 1893) Golden,1956
H. pseudorobustus (Steiner, 1914) Golden, 1956
H. varicaudatus Yuen, 1964
Hemicycliophora arenaria Raski, 1958
Hoplolaimus aorolaimoides Siddiqi, 1972
H. indicus Sher, 1966
Longidorus africanus Merny, 1966
L. attenuatus Hooper, 1961
L. elongatus (de Man, 1897) Thorne & Swanger, 1936
L. maximus (Butschli, 1874) Thorne & Swanger, 1936
Meloidogyne acrita (Chitwood, 1949) Esser, Perry & Taylor, 1975
M. acronea Coetzee, 1956
M. arenaria (Neal, 1889) Chitwood, 1949
M. hapla Chitwood, 1949
M. incognita (Kofoid & White, 1919) Chitwood, 1949
M. javanica (Treub, 1883) Chitwood, 1949
M. thamesi (Chitwood, 1952) Goodey, 1963
Nacobbus aberrans (Thorne, 1935) Thorne & Allen, 1944
N. serendipiticus Franklin, 1959
Paratylenchus projectus Jenkins, 1956
Pratylenchus brachyurus (Godfrey, 1929) Filipjev & Steckhoven, 1941
P. coffeae (Zimmerman, 1898) Goodey, 1951
P. neglectus (Rensch, 1924) Chitwood & Oteifa, 1952
P. penetrans (Cobb, 1917) Chitwood & Oteifa, 1952
P. pratensis (de Man, 1880) Filipjev, 1936
P. scribneri Steiner, 1943
P. vulnus Allen & Jensen, 1951
P. zeae Graham, 1951
Radopholus similis (Cobb, 1893) Thorne, 1949
Rotylenchulus reniformis Linford & Oliveira, 1940
Scutellonema cavenessi Sher, 1963
S. lobiatum Siddiqi, 1972
Trichodorus christiei Allen, 1957
T. minor Colbran, 1956
T. proximus Allen, 1957
Tylenchorhynchus brassicae Siddiqi, 1961
T. capitatus Allen, 1955
T. claytoni Steiner, 1937
T. curvus Williams, 1960
T. dubius (Butschli, 1873)
T. huesingi Poetzold, 1958
T. nudus Allen, 1955
T. nanus Allen, 1955
T. rhopalocercus Seinhorst, 1963
Xiphinema americanum Cobb, 1913
X. basiri Siddiqi, 1959
X. diversicaudatum (Micol., 1927) Thorne, 1939
X. index Thorne & Allen. 1050

Table 2. World frequency of *Meloidogyne* spp. identified by the differential host test.[a]

Species/Races	Population No.		Population %	
M. incognita	260		59	
Race 1		164		37
Race 2		57		13
Race 3		26		6
Race 4		13		3
M. javanica	125		28	
M. hapla	36		8	
M. arenaria	19		4	
Race 1				
Race 2				
Other species	4		1	

[a]Correspondence from J.N. Sasser, Principal Investigator, International *Meloidogyne* Project, May 31, 1978.

Table 3. North Carolina *Meloidogyne* differential host test identification.

Meloidogyne species/races	Differential host plant cultivars[a] Tobacco	Cotton	Pepper	Watermelon	Peanut	Tomato
M. incognita						
Race 1	-	-	+	+	-	+
Race 2	+	-	+	+	-	+
Race 3	-	+	+	+	-	+
Race 4	+	+	+	+	-	+
M. arenaria						
Race 1	+	-	+	+	+	+
Race 2	+	-	-	+	-	+
M. javanica	+	-	-	+	-	+
M. hapla	+	-	+	-	+	+

[a]Tobacco cv NC95; cotton cv Delta Pine 16; pepper cv California Wonder; watermelon cv Charleston Gray; peanut cv Florrunner; tomato cv Rutgers; + = ratings of 4 or more; - = ratings of 0, 1.0, or 2.0.

The egg develops immediately after deposition into the first larval stage, molts within the egg, and hatches as second-stage infective larva. After finding its host, it penetrates the root, usually just above the root cap, settles near the region of elongation and feeds and molts three more times. After the fourth molt, the adult female becomes flask-shaped,while the male becomes cylindrical. Adult males, although equipped with stylet, are not known to feed, but the females, in the feeding process, develop "giant cells" about the head region, stimulate hyperplasia, and eventually form a distinct gall. Adult females are about 0.4-1.3 mm long x 0.3-0.7 mm wide. In the Philippines (5, 65), at 25-29°C *M. incognita* females attained the egg-laying stage 15 days after larval inoculation of tomato seedlings and a majority produced egg masses 18-20 days after inoculation. Field observations show that *Meloidogyne* females continue to produce eggs for 2-3 months.

M. incognita, M. javanica, M. arenaria, and sometimes *M. hapla* reproduce by mitotic parthenogenesis (i.e. with no meiosis during oogenesis and the somatic (2n) number of chromosomes is maintained during maturation of the oocytes). The basic chromosome number of the genus is 18,but populations of *M. hapla* with haploid chromosome numbers n = 15, 16, and 17 have been found. The somatic numbers for *M. javanica* are 2n = 43, 44, 46, and 48; *M. arenaria* has 2n = 36 and 3n = 54; and *M. incognita* has 2n = 41-44 (59).

INTERACTIONS WITH OTHER PATHOGENS

1. With Bacterial Wilt. *Meloidogyne* infections predispose tomato plants to faster and more severe bacterial wilt, caused by *Pseudomonas solanacearum* E.F. Smith. Thus, David (6), using "Marglobe" tomato, reported 25% wilting of plants after 1 wk and 75% after 2 wks following inoculation with *P. solanacearum* alone, compared to 75% wilting after 1 wk and 100% after 2 wks following inoculation with the *M. incognita - P. solanacearum* combination. Napiere (3) showed that under both natural and artificial inoculation experiments, wilting developed 1-3 wks earlier on plants inoculated with the *P. solanacearum - M. incognita* combination than with *P. solanacearum* alone. In wilt-resistant cultivars, survival was lower by 33-63% in plants inoculated with the bacterium-nematode combination over those inoculated with bacterium alone (Table 4). The combined effects of the two pathogens decreased the yields by 16.5-23.1%, compared to those inoculated with the bacterium alone. Similarly, Halim (18) reported that wounding of tomato roots by *M. acrita* significantly increased the incidence of bacterial wilt in both susceptible and resistant varieties.

2. With Fungi. Orion and Krikun (35) reported that resistance of the tomato cultivar, "Gilat 38", was not affected with the inoculation of *M. javanica* and *Verticillium dahliae* but, in the susceptible variety, "Rehobot 13", wilt symptoms and vascular discoloration were increased after inoculation with the nematode-fungus combination. Where *Rhizoctonia solani* was inoculated after *M. incognita* had invaded the tomato roots and formed galls and giant cells, the severity of infection was increased (16).

Table 4. Percent survival of tomatoes inoculated with *Pseudomonas solanacearum* (PS) and *Meloidogyne incognita* (MI).

Treatment	Survival after 60 days				
	Yellow Plum	Venus	VC 48-1	VC 11-1	1169
	%				
PS	0	67	89	78	89
PS + MI	0	33	26	37	41
PS + MI after 1 wk	0	30	26	41	48
MI + PS after 1 wk	0	52	37	26	48
MI	100	100	100	100	100
Control	100	100	100	100	100

ECOLOGY

Due to the influence of temperature, the predominant *Meloidogyne* spp. in the tropics are *M. incognita, M. javanica,* and *M. arenaria; M. hapla* is limited to higher elevations. Peacock (39) reported that larvae and eggs of *Meloidogyne* spp. die in dry soil but can survive so long as there in enough moisture to maintain the soil air at nearly 100% humidity. It was also shown that root-knot nematodes survive, hatch, and reproduce over a pH range of 4.0-8.0, and that optimum pH for egg hatch of *M. javanica* was between 6.4-7.0, and inhibited below pH 5.2 (61). It is generally observed that while *Meloidogyne* spp. are found in a large variety of soil types,maximum damage occurs on plants grown in light sandy soils and very little on heavy clay soils.

CONTROL

1. Resistant varieties. Resistance to *Meloidogyne* spp. may be due to a single major gene (vertical resistance) or to a number of minor genes (horizontal resistance). Plants with vertical resistance are either immune or hypersensitive (i.e. the larvae are killed after they start to feed or when no giant cells are formed; 46). In resistant varieties, galling and giant cells are rare, infection sites are necrotic, and few larvae develop and produce eggs in contrast to susceptible varieties where all infection sites are galled and contain giant cells, no necrosis, larval penetration in large numbers, and mature females occur in 16-21 days. In " Hawaii 5229", resistance to *M. incognita* is monofactorial and completely dominant and the same gene controls resistance against *M. acrita, M. arenaria,* and *M. javanica* (64). However, varieties "Nematex", "Small Fry", and "Cold Set" each possess a single gene for resistance, dominant in Nematex and Small Fry but recessive in Cold Set (49). Fassuliotis (15) reported that all resistant tomato cultivars possess the Mi gene and that they all derive their resistance from a cross "Michigan State Forcing" x *Lycopersicon peruvianum* (PI. 128657). This Mi gene for resistance, however, was shown to operate only at temperatures below 28^{o}C (11, 21). Tomato cultivars reportedly resistant to the 4 common *Meloidogyne* species in the tropics are given in Table 5 (2, 10, 15, 24, 30, 41, 53, 54, 64).

Table 5. Tomato cultivars resistant to the common tropical *Meloidogyne* spp.

Meloidogyne arenaria:	Atkinson, Hawaii 5229, Manalucie, Nematex, VFN-8, 66 N, 569 N - 10
M. acrita:	Gawaher (Giza 1), Hawaii 5229
M. hapla :	P.I. 270435 *L. peruvianum*
M. incognita:	Anahu, Anahu R, Atkinson, Beefeater, Beefmaster, Betterboy, Big Seven, Bigset (H), Bonus (H), Bw-21-F1, Calmart, Coldset, Florida-Hawaii Cross, Gawaher (Giza-1), Gilestar, Hawaii 7322, Hawaii 5229, Hawaii 7746, Hawaii 7747, Hawaii 55, Healani, Kalohi, Kewalo, Kolea, Manalucie, Merbein Canner, Merbein Early, Merbein Mid-season, Merbein Monarch, Monte Carlo, Nematex, N-52 (H), Nemared, Pelican, Peto 662VFN, Puunui, Red Glow (H), Ronita, Rodeplaat Albesto, Rossol, Small Fry, Sunburst, Terrific (H) Tuckercross K, Vine Ripe, VFN Bush, VNF-8, VNF368, PI 270435 *L. peruvianum*, 66 N, 569 N - 10.
M. javanica:	Anahu, Atkinson, Gawaher (Giza-1), Hawaii 5229, Healani, Kalohi, Nematex, VFN-8, Manalucie, 66 N, 569 N - 10, *L. peruvianum* strains LP_1, LP_2, LP_3.

2. Chemical. Nematicides have long been used for the control of root-knot and other nematodes affecting tomatoes, and yield increases of 4-68% have been reported (7, 12, 51). However, these chemicals are expensive and may require special equipment. Hence, in tomatoes, their use is calculated to reduce the nematode population only to a point where maximum profit can be obtained. The most economical and efficient way of using nematicides for tomatoes is to fumigate infested seedbeds or nursery beds with methyl bromide, for example, at the rate of .49 kg/10 m^2. In heavily infested fields, apply the nematicides by the row method, which reduces the nematicide required by 50-75%/ha. Table 6 shows some of the common nematicides available in the world market that have been used effectively against root-knot and other tomato nematodes.

3. Cultural Practices.

a) Crop rotation. For crop rotation to be effective in the control of root-knot nematodes, the species and races of *Meloidogyne* affecting tomatoes must first be identified, the rotation crops must be immune or highly resistant, and weeds, where many *Meloidogyne* species can reproduce, must be controlled. While resistant tomato varieties are now available, they are not yet as profitable as the commercial, but susceptible, varieties. Hence, rotation should be planned so that the nematode population is at its lowest level before the susceptible varieties are planted. In a field infested with races 1 or 2 of *M. incognita, M. arenaria, M. javanica,* or *M. hapla,* cotton is recommended as a rotation crop. However, if the nematode species present is not *M. hapla* or Race 1 of *M. arenaria,* a

Table 6. Some nematicides found effective against root-knot and other tomato nematodes.[a]

Common name	Chemical name	Formulation/Classification
A. Fumigants:		
1. DD Mixture	1,3-dichloropropene & 1,2-dichloropropane	Liquid EC/Nematicide
2. DBCP	1,2-dibromo-3-chloropropane	Liquid EC or Granular/Nematicide
3. EDB	ethlene dibromide	Liquid/Nematicide
4. Natham	sodium methyl-dithio-carbamate	Liquid/Nematicide
5. MBr	methyl bromide	Gas/Nematicide
B. Non-fumigants and systemics:		
6. Aldicarb	2-methyl-2-(methylthio)propionaldehyde O-(methylcarmoyl oxime)	Granular/Nematicide/Insecticide
7. Carbofuran	2,3-dihydro-2,2-dimethyl-7-benzofuramyl methylcarbamate	Granular/Nematicide/Insecticide
8. Ethoprop	O-ethyl S,S-dipropyl phosphorodithioate	Granular/Nematicide/Insecticide
9. Triazophos	1-phenyl-3-(O,O-diethyl-thinophosphoryl) 1,2,4-triazole	Liquid EC, Granular/Nematicide/Insecticide
10. Fensulfothion	o,o-diethyl o-(p-methyl-sulfinyl)phenyl) phosphorothioate	Granular/Nematicide
11. Oxamyl	methyl-N,N-dimethyl N-(methyl-carbamyl) oxy)-1-thioxamidate	Granular, Liquid EC/Nematicide/Insecticide

[a]Ref. 7, 12, 22, 28, 36-38, 51, 54, 57, 60.

susceptible tomato crop can be followed by peanuts, which are immune to all known races of *M. incognita*, to *M. javanica*, and to Race 2 of *M. arenaria* (50, 57). Cereal crops, such as rice or corn, are also effective rotation crops. Netscher (34) reported strawberry as a good substitute for peanuts, while Navarro and Barriga (32) recommended planting *Tagetes* or *Crotalaria* after tomato.

b) Summer fallow. Deep plowing of infested tomato fields during summer, accompanied by applications of farmyard manure but without irrigation, was reported to be effective in controlling root-knot and other nematodes affecting tomatoes (9, 58). Plowing at intervals of 2-4 wks exposes the eggs and larvae to desiccation, and many in the upper soil layers are killed (57).

c) Addition of organic manures. Chicken manure, applied at 7.8 t/ha, reduced root-knot nematode infection in field tomatoes by 50-55%, and increased the yield by 43% (3, 12). Although the actual factors responsible for killing the nematodes are not known, it is generally believed that the application of organic manures increases the build-up of nematophagous fungi, predaceous nematodes, and other soil organisms that affect the populations of plant parasitic nematodes.

OTHER NEMATODES

More than 60 other species of plant parasitic nematodes have been reported on tomatoes but many of these have not yet been studied in detail. The following species probably contribute to losses in tomato yields. The control measures given for the root-knot nematodes may also apply to these nematodes.

Reniform Nematodes. *Rotylenchulus reniformis* is one of the most common widely distributed nematodes in the tropics. It has a wide host range with a high reproductive potential on tomato and other suitable hosts. Its population density, even on acidic soil with pH 4.5, is usually very high. The damage is more serious to tomato seedlings than to older plants. It reduces both top and root growth, is capable of causing significant yield reductions with populations as low as 100/pot, and it inhibits population increase of *M. incognita* or *M. javanica* when these nematodes are together (25, 40, 52, 63). It was shown that *R. reniformis* is mainly a phloem feeder and that infested tissues show hypertrophy, hyperplasia, and giant cells (55). All the common tomato cultivars in Egypt were reported by Oteifa and Osman (36) to be susceptible, except VFN-8 which was moderately resistant. A strain of *Lycopersicon pimpinellifolium* (P.I. 375937) was reported by Robois et al. (42) to have consistently shown a high degree of resistance among 10 cultivars tested.

Root-lesion Nematodes. Table 1 shows 6 species of *Pratylenchus* affecting tomatoes. Among these, however, *P. penetrans* is probably the most important and well studied. All lesion nematodes are migratory endoparasites and cortical feeders. They destroy and kill plant cells during feeding, causing lesions or necrotic areas. Although populations of *Pratylenchus* are usually not as high as *Meloidogyne* or *Rotylenchulus*, they are equally effective in suppressing root and shoot growth. Slabaugh

(56) reported 56% growth reduction in tomatoes while Miller (29) gave 20-66% compared with 67% in *M. incognita*. When *P. penetrans* and *M. incognita* coinhabit tomato roots, the population densities and pathogenic effects of both nematodes are depressed compared to monoculture populations (14).

Nematodes of Lesser Importance. Not much is known about many of the lesser nematodes reported as parasites of tomatoes given in Table 1. *Tylenchorhynchus* spp., *Helicotylenchus cavenessi, H. microlobus, H. pseudorobustus,* and *Paratylenchus projectus* destroy feeder roots and cause lesions on large tomato roots, resulting in chlorosis, stunted growth, and reduced yields (20). *Helicotylenchus nannus* was reported by Libman et al. (27) to be almost as effective as *M. hapla* in predisposing infection and developing bacterial wilt. Similarly, all parts of germinating tomato seeds, hypocotyls, and root tips of grown plants were shown by Jensen (20) to be attacked by *Dolichodorus heterocephalus*, resulting in poor seedling emergence, retardation of growth, necrotic lesions, and stubby root conditions. Tomato roots affected by *Trichodorus christiei, T. minor, Longidorus elongatus,* and *L. attenuatus* lack root cap or region of elongation, and also show stubby characteristics. In addition, *L. elongatus* and *L. attenuatus* serve as vectors of tomato black ring virus. *Hemicycliophora arenaria* and *Xiphinema diversicaudatum* cause galls on secondary and feeder roots. Galls caused by the latter are characterized by curly-tip, which is due to the imbalance in cell proliferation on one side of the affected root (19).

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DISCUSSION SESSION III (MORNING)

Reynard: I read a report that the cultivar Nematex has shown resistance to bacterial wilt in some tests in the Philippines? Has this been supported by your tests?

Yang: I don't recall Nematex as being resistant to bacterial wilt in our confirmation tests.

Sunarjono: I would like to make a suggestion. After looking into your success in screening for bacterial wilt, I looked into resistance to other diseases, particularly late blight. As you know, in our country (Indonesia) this is the most serious tomato disease in many areas. I suggest that you please conduct screening in our country so that you can get more valuable and fundamental results on resistance to late blight.

Muthukrishnan: What is the frequency of leaf curl occurrence in southern Taiwan? For example, in southern India it is the predominant virus disease affecting most tomato cultivation.

Yang: We are not working on leaf curl virus resistance. It is not a very serious disease of tomato here.

Volin: We have been suggesting individual pesticides or fungicides to control pests and disease. An integrated control combines pesticides and fungicides. Have you worked on that?

Yang: We are not working on chemical control of pathogens or insect pests with tomato. The most popular fungicide being used by the farmers for foliar disease is Dithane.

Johannessen: Have you used Difolatan or Bravo for your tomato culture?

Yang: On tomato, the answer is no. However, we did try Difolatan to control downy mildew on Chinese cabbage and found that it caused phytotoxity at the manufacturer's recommended dosage.

Johannessen: We have seen herbicide leaf injuries sometimes. We use Difolatan and Bravo widely on tomato in California and they greatly minimize black mold.

Yang: Does black mold occur mostly in the field-grown stage of tomato cultivation?

Johannessen: It occurs at different times. If tomatoes have sunburn and the plant is weakened, it occurs quite commonly. It appears on exposed surfaces in the cooler season. It also occurs commonly after rain when there is a lot of fruit cracking. Except for water mold, which follows a heavy rain, black mold is our most serious problem.

Wilson: Have the causative agents of leaf curl virus been identified?

Oshima: The causative agents of leaf curl virus have been identified by comparison with the standard virus which is kept in our institute.

Caldwell: After using attenuated TMV-virus, the more virulent type 1 strain CS2 appeared in tomato plants carrying the Tm-1 gene. Could the widespread inoculation of the avirulent strain have provided the opportunity for selection of type 1 mutant occurring at a very low rate in the population, as has occurred with the MII-16 avirulent strain in England? Are there plans to use a cultivar with all 3 genes for TMV resistance (rather than only TM-1), since this would require an unlikely triple mutation of the virus pathogen for resistance to be overcome, and thereby would protect all 3 genes for resistance?

Oshima: Japanese attenuated virus did not give rise to such a virulent form because the method by which the attenuated virus was made is different from the method in The Netherlands. Our strain was made by heat-treatment, and the Netherland strain (MII-16) was made by the mutagenic action of nitrous acid. Attenuated strains of TMV which I made by the action of nitrous acid also resulted in mutation to the severe strain. I think seed companies plan such triple-resistant cultivars, but I don't know what genes their cultivars bear because Japanese companies do not publish it. In my experiments with hybrid tomatoes bearing two or three TMV-resistant genes they were more resistant against TMV strains than tomatoes bearing only one TMV-resistant gene.

Villareal: What are the prevalent races of *M. incognita* in tropical Asia?

Valdez: We still do not know. The information from Dr. Sasser about the means of distinguishing these races through differential hosts came only about 3 months ago, therefore, we have not worked this out. The main problem, however, in tropical Asia is that there are very few nemotologists, probably only one or two in each country. I hope there will be many more take up nematology so the problem you raised can be answered.

Stevens: Do you know if the Mi gene confers resistance to other genera of nematode that are important on the tomato?

Valdez: No. Mention in some literature indicated that the Mi gene is an important source of resistance to root-knot nematode. But whether it can confer resistance to other genera of nematodes, I am not aware.

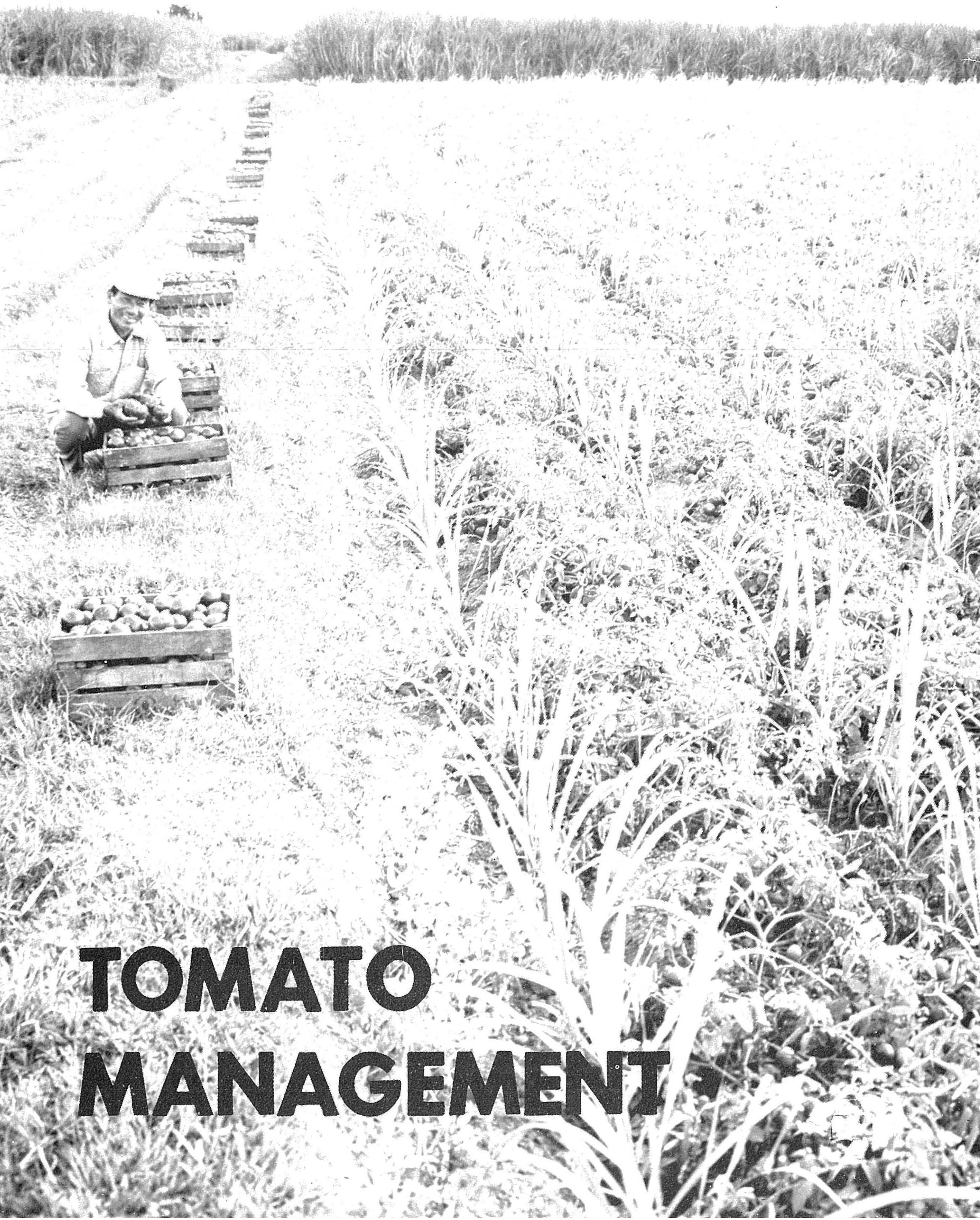
Sunarjono: Organic manures can control root knot nematodes in tomatoes. Experimental results in our country indicated that stable manures increased the population of nematodes. What kind of organic manure can be used and how do you apply it?

Valdez: Chicken manure is the most extensively used organic manure in the Philippines. Our repeated surveys show that nematode counts were very low in areas where it is most used. It is not definitely known whether chicken manure has this nematode reducing action. We think that chicken manure is a good medium for the multiplication of nematophagus fungi which trap the nematodes, thereby reducing the population.

Ruelo: In my integrated control work I used nematode-trapping fungus and used chicken manure as its substrate. It had a physiological effect on the tomato which I suspected made the plant tolerant to nematode attack. Whenever chicken manure substrate was used, the tomato plants showed vigorous growth and good yield.

Olifernes: In the interest of plant quarantine, may I know if *Heterodera* spp. also attack tomatoes? If so, do we have the nematode already around our fields previously planted to white potato and now planted to tomatoes in the Philippines?

Valdez: Not all *Heterodera* spp. will attack tomatoes, but the potato golden nematode, now known as *globodera*, will aso attack tomatoes. This nematode is not yet known to be present in the Philippines.


TOMATO
MANAGEMENT

EFFECT OF EXCESSIVE WATER, CULTIVAR, COMPOST, AND BENZYL ADENINE (BA) AND PERFORMANCE OF TOMATO PRODUCTION ON TWO SOIL TYPES

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INTRODUCTION

Tomato, a popular vegetable in Asia, is a source of income to small farm operators and contributes to the nutrition of the consumer (8). However, tomato supply during the hot, wet season and, hence, the contribution to Asian nutrition from tomato are limited. Because the supply is limited, the price is high and the economic potential increases. In Taiwan the supply drops from over 5,450 t/mo in Mar to 227 t/mo in Jul with reported farm-gate prices of US$55/t in Feb and US$474/t in Jul (Fig. 1) (11,12).

During the hot, wet season in the lowlands, high rainfall and consistently high temperatures cause low yields due in part to poor fruit set, high disease incidence (especially bacterial wilt, *Pseudomonas solanacearum*; 1), and excessive water. Improved cultivars that resist local strains of bacterial wilt have been released (4,14).

Based on data from 73 countries, approximately 67% of the land in the tropics experience annual rainfall greater than 1000 mm (7). Tomato, like most vegetable crops, requires well-drained soil to maintain soil oxygen levels adequate for growth and development (15). Stolzy et al. (9) demonstrated that photosynthesis in tomato was reduced 50% in 8.5 hrs when oxygen in the soil was replaced with N_2 in a gas mixture. The growth rate of tomato is reduced sharply when soil oxygen concentration levels remain below 10% for one month (6). The heavy rainfall experienced in many areas of Taiwan increases southern blight (*Sclerotium rolfsii*). Studies conducted in central Taiwan (5) indicate that the oxygen concentration in the soil atmosphere was reduced to approximately 4% in the top 15 cm of soil when 200 mm of rain fell during 5-day periods. At concentrations of 2%, tomato plants wilted severely and yields were reduced.

To define hot-season conditions for tomato production, we required that the mean minimum temperature not fall below 22°C. After comparing

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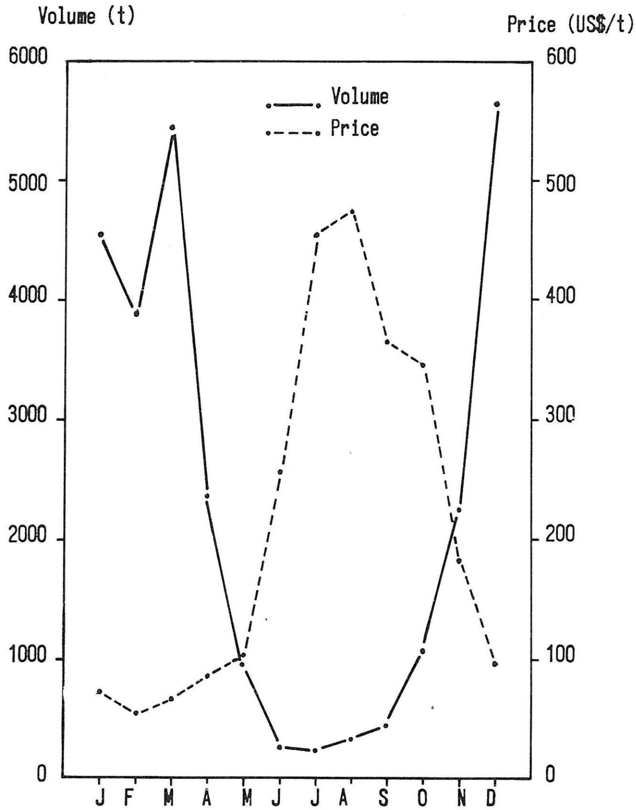

Fig. 1. Fresh market tomato transaction volume and farm gate prices; Taiwan, 1977 (11, 12).

statistics (13) with weather data (10), we determined that this requirement is met in Taiwan only in Changhua, at least during the first two months (Aug and Sep) of planting. During this time the rainfall decreases rapidly from 211 mm in Aug to 59 mm in Sep. By Oct, the minimum temperatures are below 22°C and the rainfall continues to decrease to create good weather conditions for tomatoes. Rainfall is probably the major factor which determines if an area can produce tomatoes under hot-season conditions, and the rainfall in Changhua probably represents a lower limit.

Other areas in Taiwan which have similar temperatures, (e.g., Tainan county, where AVRDC is located), do not grow tomatoes in Aug (Fig. 2). Over a 20 yr period, rainfall in Yungkang, 12 km south of AVRDC, averaged 343 mm in Aug and 179 mm in Sep (Fig. 3). Further south, Tainan City averages higher precipitation with similar temperatures.

Because improvements in disease resistance as well as in fruit setting ability under high temperatures are now being made available in new cultivars, extending lowland tomato production seasons into the rainy months when tomatoes bring highest prices becomes a possibility if proper wet season management is developed.

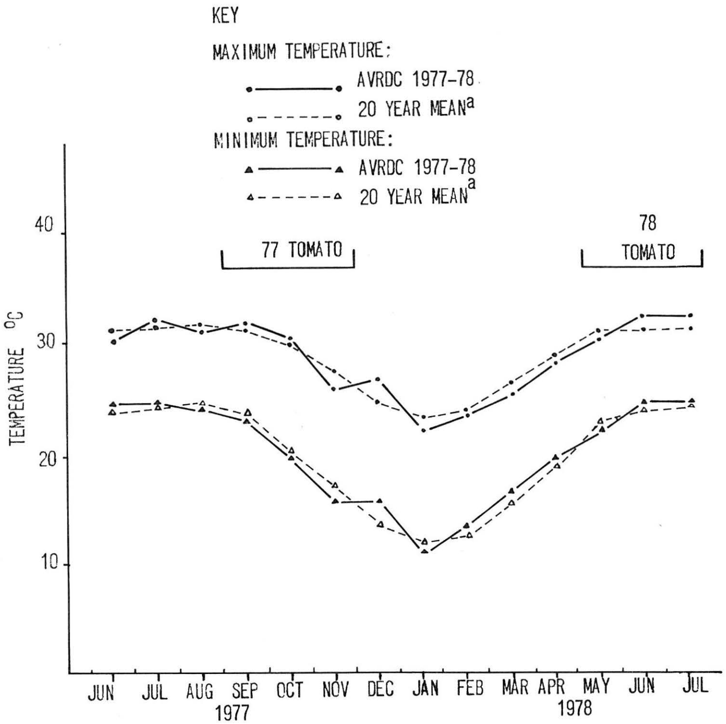

Fig. 2. **Maximum and minimum mean monthly temperatures(°C) for July 1977 – July 1978 at AVRDC.**

[a] Data for Yungkung weather station, located 12 km south of AVRDC (10).

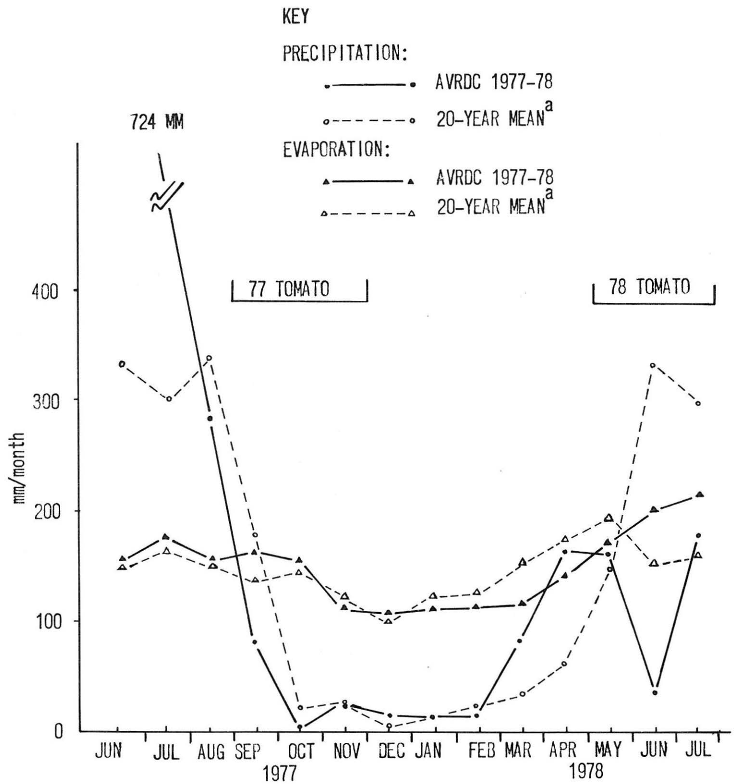

Fig. 3. Monthly precipitation and evaporation at AVRDC, July 1977-July 1978.

[a] Data for Yungkang weather station, located 12 km south of AVRDC (10).

Initial studies in management at AVRDC (2,3) indicated that cultural management practices should include raised beds, (30 cm) with compost (20-40 t/ha) in the center, prepared by buffalo and followed with an application of rice straw mulch (5-10 t/ha) to prevent soil erosion and soil compaction. For determinate tomato lines, staking or trellising did not promise to increase yields significantly over simple mulched plots. Mulch adequately serves to separate the fruit from the moist soil when the fruit is harvested at the mature green stage. Physiological experiments in the greenhouse suggested that benzyl adenine (BA) might ameliorate the effect of excessive water (3).

MATERIALS AND METHODS

After considering the cultural management practices, we selected certain factors about which we needed economic data in addition to yield data. We conducted a set of summer tomato production trials at AVRDC in 1977 and 1978 to determine the effect of these factors on the performance and net benefit of summer tomato production. Each summer the trial was repeated in two locations - at AVRDC on loam and at nearby Shanshang on sand. The soil analysis is shown in Table 1. Main plot treatments were arranged factorially. One main plot factor was with (to represent the wettest locations and/or the wettest months) and without excessive water; and the second was with and without BA. Based on results of the late-wet season plantings, we replaced the BA treatment with a locally available commercial foliar spray, BASF Fetrilon-Combi, containing 4% Mg, 1.5% Mn, 1% Fe, 0.5% Cu, 0.5% Zn, 0.3% B, and 4.3% S, and applied at the rate of 1 part Fetrilon-Combi to 1000 parts water by spraying until run-off at 1,3,6, and 9 weeks after transplanting. Subplot treatments were cultivars -- CL11d and White Skin (WS). CL11d sets fruit well under high temperatures. WS requires spraying with a fruit-setting hormone and staking, pruning, and tying. These operations add to the production costs. Sub-subplot treatments were compost -- with (20 t/ha) and without.

Table 1. Soil properties of loam (AVRDC) and sand (Shanshang) plots.

pH	E.C. (mmho/cm)	Organic matter (%)	Total N (%)	K_2O (ppm)	P_2O_5 (ppm)	Sand	Silt	Clay
						------	(%)	------
Loam								
6.1	0.90	0.84	0.05	281	124	38	35	27
Sand								
5.2	0.03	0.68	0.04	188	104	92	6	3

By measuring means of yield and calculating net benefits for each treatment, we tested the following hypotheses concerning treatment effects:

1. AVRDC's CL11d produces a higher yield and net benefit than WS.

2. Applying compost to the bed center increases yield and net benefit.

3. Excessive water reduces yield and net benefit.

4. A tomato production system on sand produces higher yield and net benefit than one on loam during the rainy season.

5. BA increases yield and net benefit.

If any of these hypotheses proved acceptable, we also hoped to gather limited quantitative estimates of the effect.

In 1977, tomato seedlings were transplanted on Aug 27 during the late hot, wet season and harvested weekly between Nov 3-29. A similar experiment in May during the early hot, wet season was destroyed by a typhoon. A second planting in Jul was destroyed by a second typhoon. In 1978, transplantings were made on May 2 and 3 at Shanshang and AVRDC, respectively, and harvested weekly in Shanshang between Jun 29 - Jul 26. Cultural practices recommended by AVRDC for the tropical rainy season were followed except in the treatments requiring deviations from recommendations. WS was staked and CL11d was not. WS was sprayed with a fruit-setting hormone (Tomatotone, 0.15% F-chlorophenoxy acetic acid) every week. All beds were prepared by buffalo, the method preferred under wet conditions. Bed height was a relatively high 30 cm raised bed. In the Aug, 1977 plantings, excessive water treatment consisted of 200 mm of furrow irrigation water applied Oct 6 and Nov 7. This additional water plus the late wet season rainfall approximated the average high rainfalls experienced during the early wet season at AVRDC. In the May, 1978 plantings, excessive water treatments were 200 mm of furrow irrigation water applied Jun 28 after the second flower cluster, and Jul 6 after the third harvest. The compost treatment consisted of placing 20 t/ha of rice-straw compost under the center of the bed at formation. Compost was from winter mushroom production and analysis included 0.56% N, 0.15% P_2O_5, and 0.23% K_2O. BA treatments consisted of spraying 50 ppm BA on foliage until run-off 24 hrs after excessive water treatment. Approximately 5 t/ha of rice straw mulch was applied at planting time to produce a 2-cm thick layer. About 5 t/ha more was applied 6 weeks later.

We recorded cost of materials and labor required for operations (i.e. applying compost, staking and pruning, applying fruit-setting hormone, and harvesting).

In addition to collecting agronomic and economic data from our experiments, we gathered similar data from AVRDC contract farmers, two local farmers who plant various crops including tomato on AVRDC land and use their traditional management practices.

RESULTS

OVERVIEW

Out of 6 plantings in 1977, 4 were destroyed by typhoons. Of the first 2 plantings in May 1978, one yielded one harvest, the other, 4, before succumbing to southern blight.

YIELDS

Cultivar. The yield of CL11d averaged 38 and 31 t/ha or 1.4 and 1.5 times the average of WS on loam and on sand, respectively (Tables 2 and 3). This is a highly significant increase in yield over the farmers' cultivar. There was a significant interaction between cultivar and compost. WS responded more to the addition of compost than did CL11d. The 1978 yields were much lower, but once again CL11d's yield represented a highly significant increase over WS. The yield of CL11d was 3 times that of WS.

Table 2. Means of yield (t/ha) by treatments — water*, cultivar**, and compost** — for summer tomato production on loam at AVRDC and sand at Shanshang, 1977.

Loam 32							
Excess Water 26.7				No Excess Water 38.0			
CL11d 28.5		WS 24.9		CL11d 46.6		WS 29.5	
Compost	No Compost	Compost	No Compost	Compost	No Compost	Compost	No Compost
31.1	25.8	30.6	19.2	50.8	42.4	34.5	24.5
Sand 26							
Excess Water 24.3				No Excess Water 28.3			
CL11d 28.7		WS 19.9		CL11d 34.3		WS 22.3	
Compost	No Compost	Compost	No Compost	Compost	No Compost	Compost	No Compost
37.1	20.2	25.6	14.2	43.4	25.2	28.7	15.9

Table 3. Means of yield (ton/ha) by cultivar, water, and compost treatments on loam and sand, 1977.

	Excess water*		Compost**		
Loam					
Cultivar**	Yes	No	Yes	No	Means
WS	25	29	33	22	27
CL11d	28	47	41	34	38
Means	27	38	37	28	32
Sand					
Cultivar**	Yes	No	Yes	No	Means
WS	20	22	27	15	21
CL11d	29	34	40	23	31
Means	22	28	34	19	26

INTERACTIONS: CULTIVAR X WATER* ON LOAM AND CULTIVAR X COMPOST* ON SAND

Compost. Application of compost caused a highly significant increase in yield. Yields for composted plots were 37 and 34 t/ha, or 1.3 and 1.8 times those plots not receiving compost in bed center on loam and sand, respectively (Table 3). These increases were highly significant. Again, the 1978 trial resulted in the same significant differences between means for composted and non-composted plots (Table 4).

Table 4. Means of yield (t/ha) by compost and cultivar treatments on sand, 1978.

Cultivar	Compost Yes	Compost No	Cultivar means **
CL11d	6.2	3.4	4.8
WS	2.1	1.0	1.6
Compost means**	4.2	2.2	3.2

INTERACTION: CULTIVAR X COMPOST*

Water. Excess water caused highly significant reductions in yield, as expected. According to Table 5, sand as compared to loam had, under normal conditions, slightly higher oxygen concentrations. And 24 hrs after excess water, sand exhibited a smaller drop in percent of oxygen. Composted plots averaged higher oxygen concentration in loam at 4 and 24 hrs after treatment. Also, excess water caused highly significant wilting on loam but not on sand (Table 6). The addition of compost caused a highly significant reduction in number of wilted plants. Temperatures at 5 and 15 cm depths were the same in composted and non-composted plots. We concluded that, in the loam plantings, compost reduced the drop in oxygen concentration caused by excess water.

Table 5. Oxygen concentrations (%) in loam and sand profiles 24 hrs after application of 200 mm of water.

Treatments		Depth				
Water	Compost	0-10 cm	10-20 cm	20-30 cm	30-40 cm	Average
			Loam			
NO	NO	19	17	16	15	16.8
NO	YES	21	19	14	15	17.4
YES	NO	0	0	13	15	6.8
YES	YES	0	6	12	15	8.3
			Sand			
NO	NO	21	20	19	16	19.0
NO	YES	21	20	18	17	19.1
YES	NO	21	20	14	10	16.3
YES	YES	20	18	14	13	16.3

Table 6. Means of percent of plants wilted 7 days after first 200 mm excess water treatment, silt 1/, 1977.

Compost	Excess Water Yes	Excess Water No	Compost means**
YES	15	4	10
NO	28	10	19
Water means**	22	7	15

1/ Sand planting had on the average less than 1 percent of plants wilted.

Soil. Yields on loam were generally higher than those on sand. Reduction in yield due to excessive water was less on sand. Increase in yield due to compost was greater on sand (Table 7). This suggests that, under rainy conditions, sand will provide better drainage and aeration but fertility levels must be increased to compensate for lower initial soil fertility and for greater leaching of nutrients from the soil.

Table 7. Means of yield (t/ha) by water and compost treatments for loam and sand, 1977.

Compost	Excess Water Yes	Excess Water No	Compost means**
Loam			
Yes	31	43	37
No	23	33	28
Water means*	27	38	32
Sand			
Yes	31	36	34
No	17	21	19
Water means*	24	28	26

BA and Fetrilon-Combi. BA failed to have a significant effect on yield in the late-wet 1977 season. Because yields were generally lower on sand, we tried using Fetrilon-Combi in the early-wet 1978 planting season. It had no effect on the yield.

NET BENEFIT

Cultivar. Net benefit was calculated as revenue less variable costs, where revenue equals plot yield times farm-gate price. The costs associated with cultivar WS for staking, pruning, tying, and spraying with fruit-setting hormone averaged US$1167/ha; with compost, US$132/ha. Labor and water for excess water treatment was not considered. The price of WS in Nov 1977 was US$264/t. Local wholesalers offered US$130/t for CL11d. The price difference was due to (1) the appearance of CL11d and (2) CL11d not being known on the market. Whether CL11d is capable of commanding a future price comparable to WS depends on the consumer's acceptance of its appearance and flavor. Fruit size may be a factor in consumer acceptance. Individual fruit weight of WS was 1.4 times that of CL11d on loam and on sand for the Aug planting, a highly significant difference (Table 8); but there was no difference in fruit size for the May planting. Although the yield of the Aug planting of CL11d averaged 1.5 times that of WS, which required an additional cost of over US$1000/ha to produce, the net benefit of WS was 1.3 times that of CL11d on loam (Table 9). The difference in net benefit due to cultivar was not significant on sand in Aug. However, in May, when yields were lower overall due both to 3.7 times the precipitation and to higher temperatures, the net benefit of CL11d was 4 times that of WS (Table 10).

Table 8. Means of average fruit weight (g), by cultivar, water, and compost treatments on loam and sand, 1977.

	Excess Water**		Compost*		
Loam					
Cultivar**	Yes	No	Yes	No	Means
WS	48	52	52	48	50
CL11d	32	40	37	35	36
Means	40	46	45	41	43
Sand					
	Excess Water**		Compost[ns]		
Cultivar**	Yes	No	Yes	No	Means
WS	40	43	43	40	41[a]
CL11d	27	33	30	30	30
Means	34	38	37	35	36

[a] 1978 means were 31 and 29 for WS and CL11d, respectively.

Compost. We concluded that compost more than pays for itself. In 1978, the application of compost increased net benefit by US$1800 and by US$2600 on loam and on sand, respectively (Table 11), highly significant increases. Also, compost increased net benefit significantly in 1978 early-wet season. There was a significant interaction between cultivar and compost. Both cultivars benefited from compost, but WS benefited much more that did CL11d.

Water. Excess water caused highly significant reductions in net benefit in the late-wet season plantings, but not in the early-wet season. As with yield, reduction in net benefit due to excess water was less on sand (Table 12). The addition of compost reduced the bad effects of excess water in both soils.

Table 9. Means of net benefit (US$/ha) by treatment -- water[a/], cultivar[b/], and compost[c/] -- for summer tomato production on loam at AVRDC and sand at Shanshang, 1977.

Loam 5200							
Excess Water 4300				No Excess Water 6100			
CL11d 3500		WS 5200		CL11d 5800		WS 6400	
Compost	No Compost	Compost	No Compost	Compost	No Compost	Compost	No Compost
3700	3200	6600	3700	6300	5300	7600	5100
Sand 4000							
Excess Water 3700				No Excess Water 4300			
CL11d 3500		WS 3800		CL11d 4200		WS 4500	
Compost	No Compost	Compost	No Compost	Compost	No Compost	Compost	No Compost
4500	2400	5300	2400	5300	3100	6100	2800

a/ ** for loam and sand. b/ * for loam, NS for sand. c/ ** for loam and sand.

Table 10. Means of net benefit (US$/ha) by cultivar, water, and compost treatments on loam and sand, 1977.

Cultivar*	Excess Water** Yes	Excess Water** No	Compost** Yes	Compost** No	Means
Loam					
WS	5200	6400	7100	4400	5800
CL11d	3500	5800	5000	4300	4600
Means	4300	6100	6100	4300	5200
Sand					
WS	3800	4500	5700	2600	4200
CL11d	3500	4200	4900	2800	3800
Means	3700	4300	5300	2700	4000

Table 11. Means of net benefit (US$/ha) by compost and cultivar treatments for sand, 1978.

Sand			
Cultivar	Compost Yes	Compost No	Cultivar means**
CL11d	1207	717	962
WS	292	192	242
Compost means**	749	454	602

INTERACTION: CULTIVAR X COMPOST*

Table 12. Means of net benefit (US$/ha) by water and compost treatments for loam and sand, 1977.

	Excess Water		Compost means**
Loam			
Compost	Yes	No	
Yes	5200	7000	6100
No	3500	5200	4300
Water means**	4300	6100	5200
Sand			
Compost	Yes	No	
Yes	4900	5700	5300
No	2400	3000	2700
Water means**	3700	4300	4000

Soil. Net benefit for plots on loam were generally higher than that for plots on sand.

BA and Fetrilon-Combi. Because BA and Fetrilon-Combi failed to have effects on yield, we concluded that they would not be effective in increasing net benefit.

COMPARISON OF TOMATO PRODUCTION SYSTEMS

We selected the production system which included compost, CL11d, and no excess water for comparison with other tomato production systems in Taiwan. For that system, the average yield in the late-wet season was 51 t/ha. Labor costs were calculated with current wages at AVRDC, which are lower than those in major vegetable producing areas. According to AVRDC survey data, the other fresh market tomato production systems spent more on staking, fertilizers, and pesticides, and more on labor and used more labor. The AVRDC contract farmers who plant processing tomatoes in Oct have expenses comparable to those involved in growing the determinate CL11d (Table 13).

DISCUSSION

CONCLUSIONS

Cultivar. CL11d outyields WS; but because of the current price difference, WS is more profitable than CL11d at the end of the hot, wet season, if planted on loam. CL11d is more profitable during the hot, wet season. Selection of a cultivar determines the tomato production system used. An indeterminate cultivar like WS requires more material and labor. If labor continues to increase in cost, or becomes unavailable, CL11d or a similar cultivar will prove more profitable than WS under all conditions.

Compost. Application of 20 t/ha of compost in bed center is a

Table 13. Production budget for summer tomato for AVRDC and local management systems.

Item	AVRDC[a]	Changhua[b]	Taipei[bc]	Nantou[bc]	Processing[d]
Yield (ton/ha)	51	69	40	26	53
Price (US$/ton)	130	100	370	330	33
Revenue	6,630	6,939	14,939	8,451	1,753
Expense (US$/ha)					
Material	941	2,486	1,623	3,377	388
Labor	884	5,009	5,355	4,888	793
Other	0	538	204	180	188
Total	1,825	8,033	7,182	8,445	1,369
Net return (US$/ha)	4,805	- 1,094	7,774	6	384

[a] Crop management data, CL11d planted with compost August 25, 1977.
[b] AVRDC survey data, 1977.
[c] Upland.
[d] AVRDC contract farmers winter 1977-1978.

relatively low price input which increases yield and net benefit by 30%- over 90%.

Water. Compost, and choice of soil, and perhaps cultivar can ameliorate the effects of excess water.

RESEARCH DIRECTIONS

Cultivar. CL11d is superior in heat-tolerance and yield to WS but fails to command as high a farm-gate price. We need to determine if this difference is due to characteristics such as fruit size, taste, color, etc., or because CL11d is an unfamiliar commodity. If the latter, can a program introduce such a cultivar successfully to the consumer? If the former, the breeders need to develop a cultivar which, in addition to superior heat-tolerance in its fruit-setting ability and yield, includes desirable fruit size, taste, or whatever is lacking.

Compost. Of the management practices examined here, clearly placing compost in bed center is worthwhile. There is a need to identify appropriate and economical methods of correcting low fertility due to leaching in the wet season or due to choice of soil.

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ROLE OF TOMATO IN MULTIPLE CROPPING

Kuang-chi Su[a]

INTRODUCTION

Tomato is one of the most popular vegetables in Taiwan. Although wild tomato was first found on this island long ago, the improved commercial cultivars were introduced from Japan in 1895, and the tomato research and extension programs have been carried out by our experiment stations since 1909. Tomato acreage in Taiwan has increased steadily from 500-600 ha in the 1940's to 8,146 ha in 1976 and 199,391 tons of total production - 60% fresh-market and 40% processing tomatoes. Most of the fresh market tomato is grown winter to spring on paddy fields, and the processing tomato is grown mainly on the upland fields of southern Taiwan. Increasing demand in local and foreign markets and the success of improved varieties and cultural practices have encouraged skilled farmers to plant summer and autumn fresh market tomato in the cool highlands or on shifting paddy rice fields. Recently, a strong export market has encouraged rapid expansion of processing tomato rotated with sugarcane or sweet potato in the southern highlands.

This report will introduce Taiwan's present tomato crop seasons and cropping patterns, and discuss the problems of adopting tomato in multiple cropping systems.

TOMATO SEASONS AND CROPPING PATTERNS IN TAIWAN

The crop seasons are based on the fruit producing periods: spring (Feb-Apr), summer(May-Jul), autumn(Aug-Oct), and winter(Nov-Jan). The transaction volumes and average prices of fresh market tomato in the different seasons are shown in Table 1.

<u>SPRING TOMATO</u>.

Sowing : Early Oct

Transplanting : Early Nov

Harvesting : Mid-Jan - Early Mar or Mid-Apr

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Table 1. Transaction volumes of tomato and average prices in different seasons; Taiwan, 1972-77.[a]

Crop	Transaction volume		Average price
	-1000 t-	-%-	-US$/kg-
Spring	8.8	41.15	0.066
Summer	2.0	9.54	0.152
Autumn	2.2	10.12	0.233
Winter	8.4	39.19	0.109

[a]Ref. 4.

Most fresh market tomato is produced in spring. Japanese or locally bred medium to large tomato cultivars ("Hokan 3", "Nongyou 505") are commonly planted. Since the cool dry weather makes tomatoes grow without too much difficulty, high yields of good quality tomatoes (which bring low market prices) are characteristic.

There are two patterns for fresh market tomato (Fig. 1): double cropping on rice fields, and single cropping on rice fields. In the double cropping system, tomato is transplanted after the rice harvest or relay-interplanted before harvesting the 2nd rice crop. The harvest is terminated before transplanting the 1st rice crop. The spring tomato harvest may be prolonged to mid-Apr and the time of good market prices. In such cases, the rotation pattern will change as follows: 2nd rice crop (Jul-Oct) spring fresh market tomato (Nov-mid-Apr) - cucumber, kidney bean, or cabbage (mid-Apr-Jun). This cropping pattern is the same as the single rice and tomato pattern. So, these two patterns can be applied according to the favorable market price.

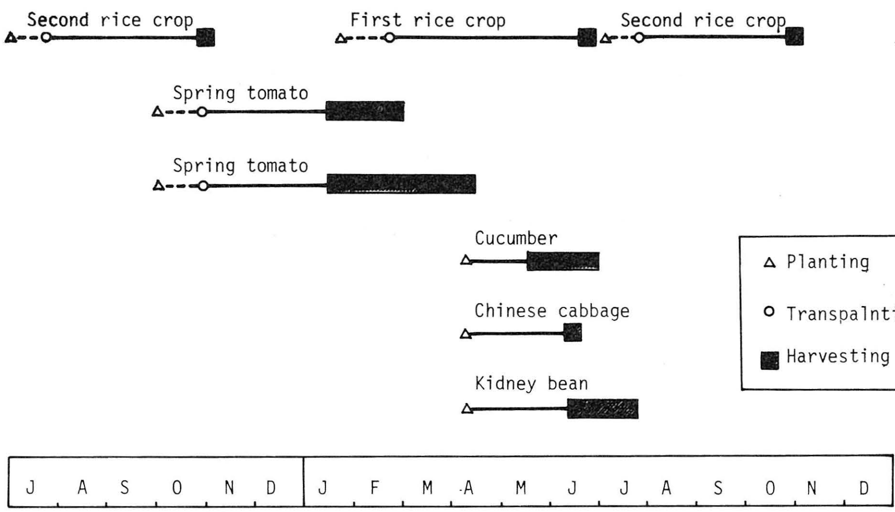

Fig. 1. Spring tomato cropping patterns in Taiwan.

SUMMER TOMATO.

	Lowland	Highland
Sowing	: Mid-Feb - Early Mar	Late Mar
Transplanting	: Mid-Mar - Early Apr	Late Apr
Harvesting	: Early May or Early Jun - Late Jun or Early Aug	Early Jul - Late Aug

Summer fresh market tomato is mainly distributed on the highland paddy fields. As it is difficult to grow tomato in the lowlands during the hot-wet summer, farmers in the cool highlands replace paddy rice with summer tomato for increased income. Heat-tolerant and disease-resistant cultivars, "Paisu", "Nongyou 4","Kyokuko", are normally planted. After one year of the summer tomato (late Apr - late Aug) - corn, cabbage, sweet potato (Sep-Dec or next Feb) pattern, the field will be put back to double cropping rice for 2 or 3 years in order to control soil borne diseases (Fig. 2). However, summer tomato is also planted on the lowland paddy fields in Changhua, but the planting time is about one month earlier than in the highlands. Because of high temperature and excess moisture during the fruit setting period, the application of plant growth regulators is required for the above-mentioned cultivars in the lowlands. The hormones, para-chlorophenoxy acetic acid (Tomatotone) or 2,4-D, are sprayed on the flower clusters at flowering. Besides, mono-cropping on paddy fields, some summer tomato is interplanted on the perennial leek fields by the specialized vegetable growers in Changhua county.

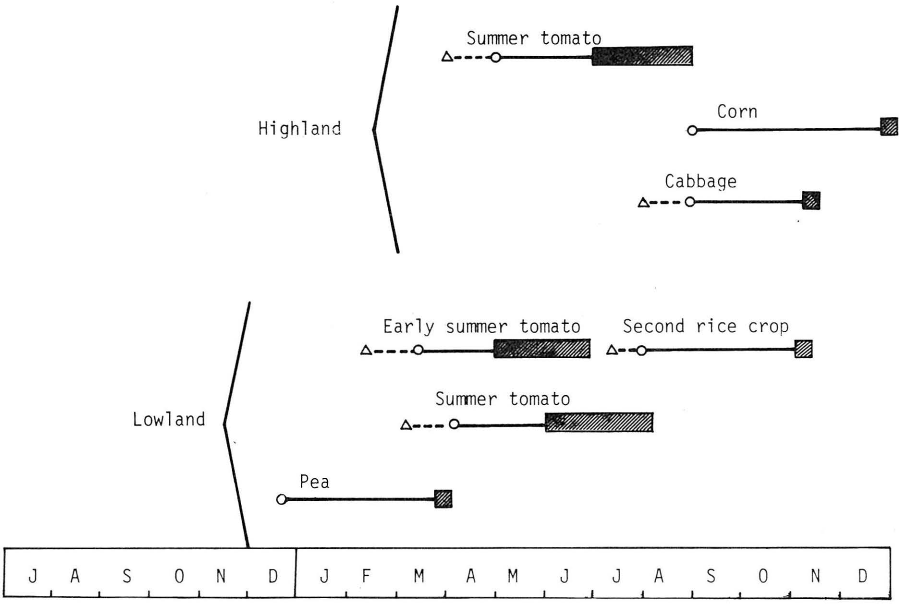

Fig. 2. Summer tomato cropping patterns in Taiwan.

AUTUMN TOMATO.

	Lowland	Highland
Sowing :	Late May - Mid-Jun	Late Jun
Transplanting:	Mid-Jun - Mid-Jul	Late Jul
Harvesting :	Mid-Aug or Mid-Sep - Early Nov	Late Sep - Mid-Nov

In contrast with summer tomato, the autumn tomato is adversely affected by high temperature and/or excess moisture before fruit-setting. Special cultural practices with plant growth regulators are used in autumn. Instead of planting the 2nd rice crop, autumn tomato is grown on lowland and highland paddy fields as mentioned above (Fig. 3). Sometimes, the harvesting period continues to next Jan on the lowlands whenever the price is high. Newly developed determinate cultivars by AVRDC can be transplanted in mid-Jun and have a short harvesting duration, about 35 days from mid-Aug to early Sep.

The most common cropping patterns with autumn tomato are first rice crop (Feb-Jun) - autumn tomato (Jun-early Nov or prolonged to late Jan), and first rice crop (Feb-Jan) - autumn tomato (Jan-Oct) - winter vegetables (Nov-Feb). Autumn tomatoes, row interplanted simultaneously with other vegetables such as green pepper and cauliflower, are planted on raised beds in Changhua. The field should be put back to paddy rice after one or two years of tomatoes in order to restore soil fertility and control diseases.

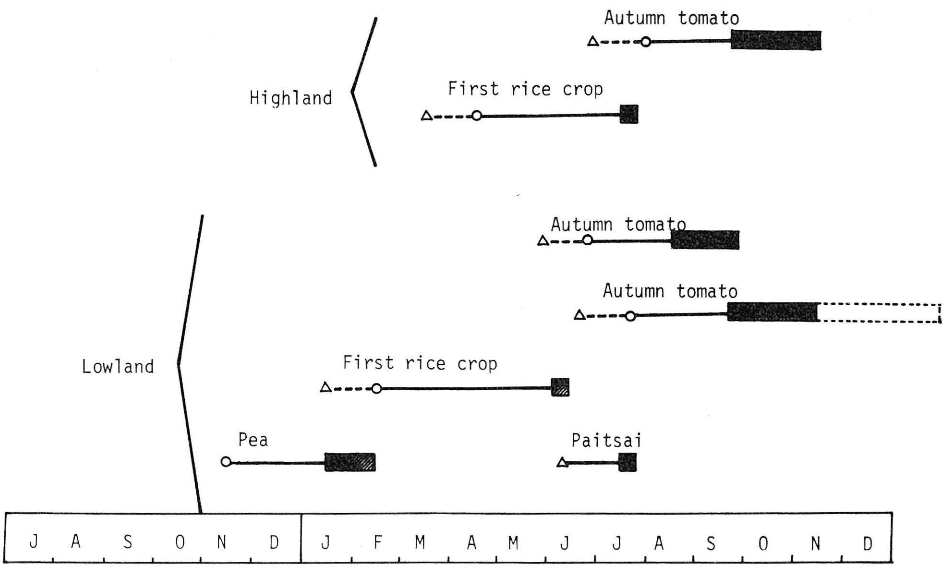

Fig. 3. Autumn tomato cropping patterns in Taiwan.

WINTER TOMATO.

	Fresh market	Processing
Sowing	: Mid-Aug	Late Jul - Late Sept
Transplanting	: Mid-Sep	Late Aug - Early Nov
Harvesting	: Mid-Nov - Late Jan or Mid-Mar	Early Dec - Mid-May

Tomato is not grown in the highlands during winter due to low temperatures. The period of fruit setting in winter is subject to relatively low temperatures (15-20^{o}C). In order to obtain large, high quality fruit, the Japanese cultivars "Hokan No. 1-2", "Kyokuko", and "Hikari", or the local cultivars, "Nongyou 707" or "505", are planted extensively.

For fresh market tomato, the production areas are distributed on the paddy fields of central Taiwan. Following the first rice crop or summer vegetables, tomatoes are planted in mid-Sep and are a substitute for the second rice crop. Following the harvesting of first rice or summer vegetables, the winter tomatoes are transplanted on the double rice cropping area instead of planting a second rice crop. Therefore, the cropping pattern is first rice (Feb-Jun) - summer vegetables (Jul-Aug) - winter tomato (Sep-Jan). The tomatoes will be harvested from mid-Nov to late Feb or extended to mid-Mar, when the market price is good (Fig. 4).

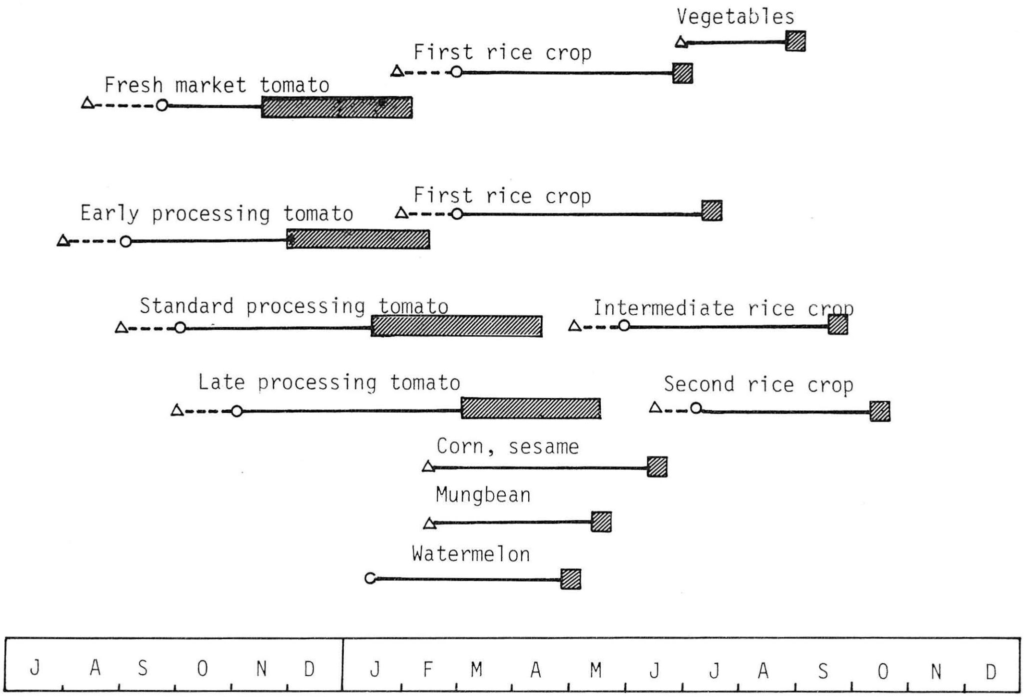

Fig. 4. Winter tomato cropping pattern in Taiwan.

In the 3 year rotation area, the cropping patterns for processing tomato are: (1) first rice (late Feb to late Jun) - early processing tomato (Sep to mid-Feb), (2) intermediate rice (late May to mid-Sep) - standard processing tomato (early-Oct to mid-Apr), and (3) second rice (early Jul to mid-Oct) - late processing tomato (early Nov to mid-May). However, in the upland area of southern Taiwan the farmers grow processing tomato as a mono-crop rotated with other upland crops, such as corn, mungbean, sesame, or watermelon, or interplant between rows of sugarcane. For extending the supply of raw materials to tomato processing factories, the planting time may be adusted from early Sep to early Nov. As a result, the processing tomato harvest will extend 6 months (Dec to May) compared with 3 months for the standard crop season (mid-Jan to mid-Apr). The cultivars, "Morioka No. 7", "Roma", "TK 2", "Chico No. 3", and newly developed AVRDC strain, CI 11-0-2-2-0-3, are commonly planted by farmers.

ROLE OF TOMATO IN MULTIPLE CROPPING SYSTEMS

The cool-dry weather from Oct to Mar is favorable for tomato production concentrated in the winter-spring season. The development of heat tolerant, disease resistant cultivars, and improved cultural practices will enable commercial production of tomato year-round.

The normal growing period of tomato is about 4 months. Pruning and training the indeterminate cultivars, shortening by topping at the low flower clusters, or adopting determinate cultivars will extend the harvest duration from 45-60 days to 120-150 days. This means that tomatoes can be programmed as either a long duration or short duration crop in sequential cropping.

Different crop seasons and durations increase the possibility of introducing tomatoes to multiple cropping at the point when maximum return can be obtained. Farmers commonly shift the first rice crop to the summer tomato or the second rice crop to the winter tomato, and extend the harvest duration of winter tomato from Nov-Jan to Nov-Mar or Apr.

INTENSIFICATION THROUGH INTERCROPPING

Tomatoes are commonly interplanted between rows of long duration crops (e.g. sugarcane on the uplands or leek on intensive vegetable farms).

According to the Taiwan Sugar Research Institute (5), interplanting yielded not only about 40 t/ha of tomatoes but also a 2-10% increase in sugarcane resulted when residual stems and leaves were plowed back into the field.

On leek vegetable farms, the fresh market tomato is transplanted to the ridges of raised beds with stakes covering the furrow (Fig. 5a). Yield is commonly 30-40 t/ha. There is no difference in leek yield between intercropping and mono-cropping leek.

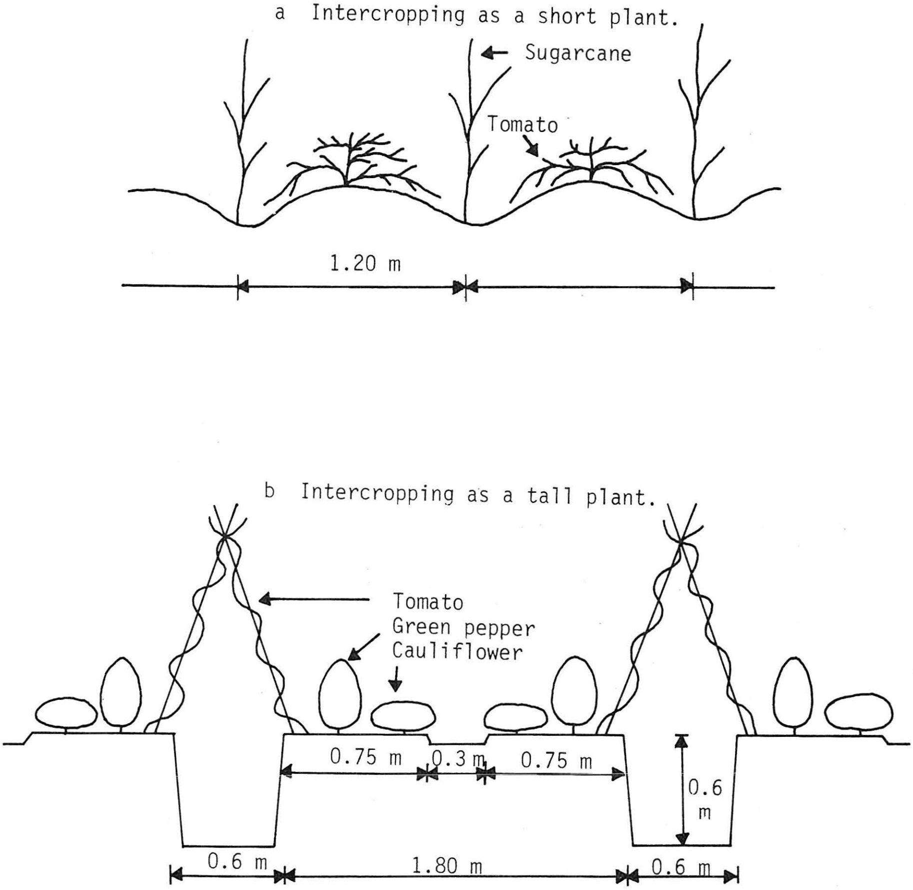

Fig. 5. Tomato intercropping.

Continuous vegetable production on the raised bed with furrows for in-paddy drainage is usually adopted on the fully irrigated areas in central Taiwan. Summer tomatoes are planted on both edges of the raised beds and staked, pruned, and trained. One row of green peppers (medium) and one row of cauliflowers are grown simultaneously to establish a better structure (Fig. 5b).

To avoid delaying the planting of subsequent crops, relay-interplanting of tomato 2 weeks before the rice harvest has been adopted by farmers. Now, with the release of the early-maturity rice cultivars, "Tokyo No.1", this kind of labor-intensive planting is seldom observed. On the other hand, relay-intercropping on raised beds in intensive vegetable farms is commonly adopted.

Vine vegetable crops, such as peas, asparagus beans, kidney beans, etc., are interplanted 2 weeks before the end of tomato harvest to utilize the stakes already set. Other vegetables, such as cabbages or cauliflowers, are also relay-interplanted before the end of the tomato harvest.

INTENSIVE MANAGEMENT AND FAMILY LABOR

Tomato is one of the most labor intensive crops in Taiwan (1-4). It requires about 5000 man-hrs/ha to produce fresh market tomatoes in winter. This is about 8 times the labor needed in the first rice crop, and about 4 times the labor of competitive vegetables such as cauliflower or cabbage.

Since management of fresh market tomatoes needs skilled labor in staking, pruning, training, or harvesting every one or two days, labor is distributed evenly throughout the growing period. Tomato growing will not require a concentration of labor in a short period. Such an intensive and even labor distribution enables the family labor to be fully utilized. The components of labor are almost entirely family labor, and hired labor forms only 8% compared with the total (Table 2).

Table 2. Labor components for various vegetables in Taiwan, 1977.[a]

	Labor requirement				Gross	Total	Net	Farm
	Total	Self	Hired	Harvest	return	cost	return	income
	hrs/ha				US$/ha			
Fresh tomato	4,815	4,415	400	1,467	4,857	4,657	200	3,000
1st Rice	602	366	236	110	1,486	1,234	252	544
Soybean (w)[b]	470	226	244	101	706	682	24	158
Corn (w)	543	371	172	170	799	797	2	223
Watermelon (s)	1,277	1,043	234	157	1,826	1,379	447	1,069
Cabbage (w)	1,265	1,101	154	698	1,760	1,786	-26	761
Pea (w)	1,407	1,407	-	299	1,764	1,572	192	961
Cauliflower (w)	1,597	1,420	177	1,420	2,244	1,976	268	1,191

[a]Ref. 4. [b]w = winter, s = summer.

However, extensive management, short harvest time, and long intervals between harvesting periods (every 7-15 days) for the processing tomato will reduce labor requirements to 1,750 man-hrs/ha and increase the dependence on hired labor to 51%.

The even distribution of intensive seasonal labor for tomatoes will absorb more family labor than other crops and increase the family farm earnings. Therefore, adopting the tomato in multiple cropping patterns will be most suitable for small-scale farmers with surplus family labor.

HIGH RETURN AND CONTINUOUS CASH INCOME

The net income of winter fresh market tomatoes is US$200/ha (4). This value is not the most profitable among the annual crops grown in Taiwan. The farmer's earnings from family labor are included in the net return and the farm income amounts to US$3,000/ha. This farm income is significantly higher than that of other crops, including rice, other field crops, and vegetables.

Since the fresh market tomatoes set fruit over a period of 2-4 months and harvest is every 1-2 days, the grower can get continuous cash income for several months. Such an advantage will encourage small-scale farmers to adopt the tomato in a multiple cropping pattern. On the other hand, by intercropping tomato with sugarcane, farmers can get extra income in the early growing stages of sugarcane instead of no income on sugarcane monoculture for 18 months.

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PROCESSING TOMATO PRODUCTION IN TAIWAN

Chen Zong-Woo[a]

THE CLIMATE OF TAIWAN

Taiwan is an island with a subtropical climate. It is cool and dry, and has little rainfall from Nov to Apr, whereas it is hot, very rainy, and subject to typhoons from May to Oct. Thus, the vegetable growing period, including that of tomato, is naturally concentrated in the period from Nov to Apr. This is in contrast to some of the major tomato production areas in other countries. In addition, there are some climatic differences between north and south Taiwan. North of the Tropic of Cancer there is more rainfall in the winter season; south of the Tropic of Cancer, the climate is more suited for production of high quality tomatoes. The main production area is shown on Figure 1. The mountainous region is characterized by fog and high humidity which retards red pigment development in the winter season. Thus, this is not a good area for tomato production.

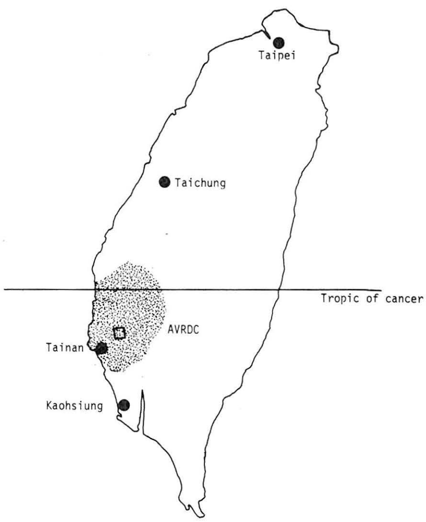

Fig. 1. Main tomato production area in Taiwan.

[a]Tainan District Agriculture Improvement Station, Taiwan.

CULTIVATED VARIETIES

Over 80% of the processing tomatoes grown in Taiwan are "TK-7". This variety was introduced into Taiwan from Japan by the Kagome Corporation. Other varieties grown in Taiwan include "Roma", "TK-2", etc. Only a small area is planted with these. The earliest cultivated varieties are "Roma", "H1370", and "Red Top". The processing tomato industry has grown rapidly in the past few years. The efforts of plant breeders have not been able to keep pace with the sudden expansion. Moreover, each processing plant has its own buyers and markets. In order to meet the standard of quality demanded by their buyers, each processing plant has introduced many varieties to meet their particular needs. It is estimated that about 1000 processing tomato varieties have been introduced in the past decade. Because of climatic differences between Taiwan and the original area from which these varieties were introduced, however, only a few can be used without modification. In order to improve this situation, government institutes and private corporations are continuously introducing new varieties.

PLANTING SEASON

Processing tomato is planted from mid-Aug to the end of Oct. In order to assure a steady supply of tomatoes to processing plants, planting times are divided into early, middle, and late stages (Table 1). There are slight differences among the three planting times which affect yield and quality. The optimum sowing time is from the beginning of Sep to the beginning of Oct.

Table 1. The effects of planting time on tomato yield and quality.

Sowing[a]		Harvest	Yield	Color	Growth	Damage[b]
			-t/ha-			
early	early Aug-early Sep	Nov-Jan	50-60	fair	good	Rain
medium	early Sep-early Oct	Dec-Mar	80-100	excel.	excel.	Frost
late	early Oct-late Oct	Jan-Apr	70-90	good	excel.	Sun scald

[a]Transplanted after 3 wks. [b]Possible damage other than pests.

SOIL

In Taiwan, farmers plant tomato on sandy loam, clay loam, and loam soils. To reduce root knot nematodes, farmers plant tomato after paddy rice. The most popular soil for tomato is loam. Soil fumigation is not done except in tomato nurseries.

METHOD OF CULTIVATION

The small size of farms in Taiwan limits the mechanization of agriculture. For this reason, most field operations, except land preparation, are done by human labor.

Transplanting after starting the seedlings in nurseries. Direct seeding cannot utilize land efficiently. It also adversely affects growth and fruit color and causes shooting because of high plant density and the high humidity of Taiwan.

Distance between rows and plant spacing. Plants are generally planted on 1.0-1.4 m wide rows with 0.3-0.5 m between hills, depending on variety. "Red Top" and "North-East" are determinate varieties and are planted at a 1.0 m x 0.3 m spacing. "TK-7" uses a 1.2 m x 0.5 m spacing; "Roma" and "H 1370" use a 1.4 m x 0.5 m spacing. Of course, soil fertility is also an important factor in choice of correct plant spacing.

Four types of planting systems widely used (Fig. 2).

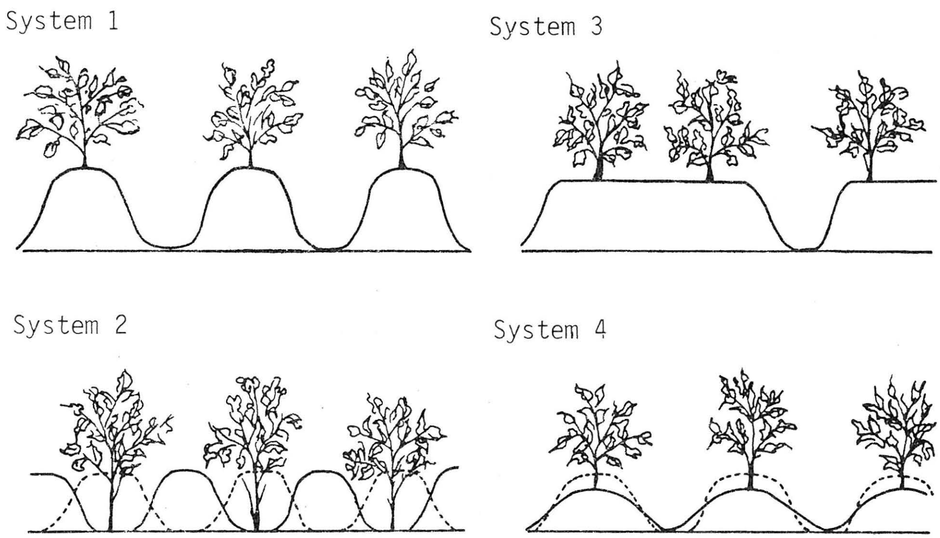

Fig. 2. Four types of tomato planting systems widely used in Taiwan.

1. Build the bed first to a height of 20-25 cm (the same as for sweet potato). Plant seedlings in the center of the bed, one row per bed. After transplanting, water each seedling individually. Such watering continues until establishment. This method is the simplest of the four. Used in early plantings, it has the advantage of providing good drainage, but one hand-weeding is required.

2. Plow and plant in the furrow first, at a furrow depth of about

10-15 cm. Then transplant the seedlings to the center of the furrow. Hill up the plants 3-4 weeks after transplanting, thus changing the original furrow into a bed, and the original bed into a furrow. The advantages of this planting method are that irrigation is easily done and that intertillage may be done at the time of hilling-up. The disadvantage of this method is that plants are often injured by the hilling-up. This method should also be avoided with early tomatoes because it does not afford good drainage.

3. Make a raised planting bed 2.4 m wide. Plant 2 rows on each bed. This method uses rice straw mulch and is good for late planting because it minimizes sun scald.

4. Combination of the first and second method. Build beds of medium height (5-10 cm height) and then hill up to full height 3-4 weeks after transplanting. Side dressing, intertillage, weeding are done at the time of hilling-up.

FERTILIZER APPLICATION

Fertilizer rates are shown in Table 2.

Table 2. Fertilizer application for processing tomato.

Fertilizer	Total quality	Basal	Side dressing		
			1st	2nd	3rd
	kg/ha				
Compost	20,000	20,000	-	-	-
N	400	100	100	100	100
P_2O_5	150	150	-	-	-
K_2O	100	30	20	30	20

INTERCROPPING

Interplanting processing tomato with small varieties of sugarcane is a special method used in Taiwan with much success. Sugarcane is grown for sugar production. The area planted to sugarcane in Taiwan is very large. For intensive utilization of land, pre-stage sugarcanes are interplanted with processing tomato. If a determinate-type processing tomato is selected for interplanting, neither the growth nor the yield of either the sugarcane or the tomato is adversely affected. Tables 3 and 4 show the yields of sugarcane interplantings with the processing tomato variety "Red Top".

CROP MANAGEMENT

Extensive management techniques are used in processing tomato production in Taiwan. Less labor is used than with fresh market tomato, which is staked. Some of the special management practices include:

Table 3. Yield of processing tomato grown under monoculture compared with processing tomato intercropped with sugarcane.

Variety	Culture	Avg. wt. of single fruit	Avg. yield
		-g-	-t/ha-
Roma	Tomato Monoculture	45.5	57.8
Red Top		46.6	47.3
San Marzano		42.3	53.4
Roma	Tomato x Sugarcane Intercrop	44.8	41.5
Red Top		46.3	44.2
San Marzano		42.9	42.7

Table 4. The effect of interplanting with processing tomato on the yield of sugarcane.

Sugarcane culture	Tomato variety	The growth condition of sugarcane at the end of tomato harvest		Sugarcane yield	Index
		Plant height	tillages		
		-cm-	-no-	-t/ha-	
monoculture (N CO)	-	89	8	127.3	100
Interplanted w/ tomato	Roma	80	7	109.7	86
	Red Top	85	7	120.6	95
	San Marzano	83	5	110.4	87

(1) Flower and fruit fall

(2) Phenomenon of over growth

(3) Growers who plant early have to pay attention to rainfall and field drainage, select varieties more resistant to wet conditions, and build high planting beds.

(4) Growers who plant in mid-season have to pay attention to fruit worm damage at the beginning of fruit setting (Nov-Dec), and frost and pest damage during fruit growth.

(5) Growers who plant late have to pay attention to pests (Jan-Feb) and sun scald (after Mar).

HARVEST

The harvest period extends from Nov-Apr, with the best quality and the highest yield obtained from Jan-Mar. The length of the harvest period regardless of planting time (early, mid-season, or late) is about 2 months, with harvesting done every 5 days during that period. In Taiwan, processing tomato is entirely harvested by human labor, which facilitates quality control (such as color selection and discarding of split or otherwise unacceptable fruit). The harvested tomatoes are put in wooden or plastic boxes and transported to processing plants for inspection. There are two kinds of tomato production contracts: (1) The plant makes a contract directly with the farmer, in which case, the products are transported directly by the plant to the plant for weighing and processing. (2) The plant makes a contract indirectly with the farmers through the Farmers' Association. In this case, the products are transported to Farmers' Association inspection stations. After inspection and weighing, the processor then is responsible for transportation to the processing plant.

Tomatoes are graded according to the following standards:

(1) First class material:

(a) Fruit weight is over 20 g.
(b) Fruit is vine-ripe but not post-ripe, color is deep red (over 90%), and no fruit stem.
(c) Fruit is free from pest damage, splitting, sun scald, injury, mold, or rot.
(d) Fruit has good shape, quality, and hardness.

(2) Second class material

(a) Fruit weight is over 20 g.
(b) Fruit is vine-ripe but not post-ripe; color is deep red (over 75%), and no fruit stem.
(c) Fruit is free from pest damage, splitting, sun scald, injury, mold, or rot.
(d) Fruit shape and quality is inferior to that of first class fruit.

TOMATO PESTS AND NATURAL DAMAGE IN TAIWAN

Since there will be a special session on tomato pests in this tomato symposium, I only list the major pests of tomato in Taiwan:

(1) Aug-Sep: Bacterial wilt, damping-off, Fusarium wilt, virus, aphid, cutworm, and root knot nematodes; rain and typhoon.

(2) Oct-Dec: Virus, bacterial leaf spot, *Sclerotium* rot, leaf mold, blossom-end rot, early and late blights, aphid, root knot nematodes, cutworm, and tomato fruit worm.

(3) Jan-Apr: Virus, bacterial leaf spot, leaf mold, powdery mildew, early and late blights; root knot nematode, tomato fruit worm; frost and sun scald.

Many kinds of pests attack tomatoes as noted above, but the most serious of these are the early and late blights, and tomato fruit worms.

THE EFFECTS OF IN-SITU MULCH ON TOMATO PRODUCTION

G.F. Wilson[a]

INTRODUCTION

The benefits of mulching on tomato production are well known, and mulching has become a standard recommended practice for tomato production, but the practical value of mulching is determined by the cost of material, labor involved in application, savings made in weed control, and the overall effect in increasing yield and profit (3). Quinn (4), working in northern Nigeria, found that mulching with grass or black polyethylene increased yield, but mulching with black polyethylene was uneconomical.

Grass and other plant residues are usually cheap mulch where they are available but the labor and/or equipment required for gathering, transporting, and applying the large volume of material needed are deterrents to such mulching materials. In-situ utilization appears a feasible method of mulching with plant residue, but the development of technique depends on chemical land preparation, crop establishment, and no-tillage. Recent developments in herbicide technology have made no-tillage crop production and in-situ mulching practical realities. Grains, mainly maize and soybean, are presently the main crops grown with no-tillage and in-situ (stable) mulch, but tomato, pepper, and tobacco, have been successfully established under no-tillage conditions (2,5,6,7).

Experiments on no-tillage vegetable production in the tropics have been very limited but peasant farmers have often produced vegetables under what can be regarded as no-tillage conditions. Under such conditions, soil disturbance is kept to the minimum at planting after clearing by burning. The soil, which is left bare after burning and subsequent manual weeding, is prone to erosion. It was with the aim of identifying fallow species suitable for an in-situ mulching, no-tillage vegetable production system, and the development of appropriate management techniques that this investigation was undertaken.

MATERIALS AND METHOD

A cover crop of tropical kudzu (*Pueraria phaseoloides*) was established by drilling in rows 75 cm apart. Growth was vigorous and a complete cover was observed about 8 months after planting. At 18

[a]International Institute of Tropical Agriculture, Ibadan, Nigeria.

months after planting, when the dry matter accumulation averaged 10 t/ha, the tropical kudzu was killed by 2 applications of paraquat at 2.5 ℓ/ha with a 7 day interval between applications. The second paraquat application was required for plant parts missed in the first spraying. A uniform mulch of plant residue was left after the second spraying.

A no-mulch control was provided by removing the cover crop residue. Two tomato cultivars, TLeX 9-1-(9), an indeterminate type, and TLeX 33, a determinate type, were used. A preplant application of 400 kg N/ha at first fruit set and first ripe fruit, was compared with a no-fertilizer control. Experimental design was a split plot with mulch-treatment as main-plot, cultivar as sub-sub-plot. Each sub-sub-plot was surrounded by a guard row. There were four re-applications.

Preplant fertilizer was applied to holes dug through the mulch a week before transplanting. In both hole preparation and transplanting, mulch disturbance was kept to the minimum. The no-mulch section was also established without tillage. The indeterminate cultivars were supported by staking while the determinate were unsupported. We routinely sprayed with Dithane M 45 and Sevin for pests.

Much of the difference in results shown in Table 1 was attributed to the effects of nutrients released from the decomposing mulch residue. *P. phaseoloides* are leguminous plants and the tissues of such plants are known to be high in nitrogen which, when released on decomposition, becomes available to other crops (1). The extent and rate of nitrogen released from *Peuraria* tissues are not known but they are being investigated. If a substantial amount of the nitrogen released from the decomposing mulch becomes available to the crop, then there should be substantial additional economic gain from reduction in the quantity of nitrogen fertilizer necessary.

Table 1. Performance of two tomato lines in in-situ mulch from *Pueraria phaseoloides*.

Cultivar	Mulch		No-mulch	
	fertilized	unfertilized	fertilized	unfertilized
	-------------------t/ha-------------------			
TLeX 9 (staked)	39.8	30.5	38.9	20.0
TLeX 33 (unstaked)	46.5	30.8	34.4	17.6

The higher yield noted in the unsupported cultivar was, undoubtedly, associated with the mulch, which protected stems, leaves, and fruit from diseases predisposed of by soil contact.

P. phaseoloides is a slow starting but vigorous and competitive legume.

Weeding is not usually necessary after sowing and the mulch suppresses a wide range of tropical weeds. Under conditions at Ibadan, Nigeria, 18 months appear optimum for development of a good mulch cover from unweeded *Pueraria*, but the period could be shortened upon the availability of a cheap and effective weed control method. *Pueraria* also suppresses root-knot nematode, a serious pest of tomato and many other vegetables, making it an ideal pre-vegetable cover crop.

While many other cover crops are potentially useful in in-situ mulching of vegetables, their use depends on the development of herbicides that can suppress them without leaving residues harmful to the succeeding vegetables - paraquat does not suppress them effectively.

Insect control was less effective with in-situ mulch, as the mulch offered good hiding places. However, this problem was regarded as a minor disadvantage.

Leaving productive land fallow for periods of 18 months or more may be unwelcome in regions with scarce land. Where land is available, the fallow is envisaged as an integral part of the rotation. The elimination of the cost of gathering, transporting, and applying associated with conventional methods of mulching makes in-situ mulching a promising new technique for increasing the profitability of tomato production.

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DISCUSSION SESSION III (AFTERNOON)

Caldwell: Were the yields shown on the slides for total yield or for marketable yield only?

Hubbell: Marketable.

Caldwell: What percentage of the total yield was marketable, and what percentage unmarketable in the middle of the wet season versus the end of the wet season?

Hubbell: The data are shown in the following Tables. There was a larger percentage of unmarketable fruit in the May planting than in the August planting. There is no consistent pattern of fruit quality during the harvest period.

Ratios by cultivar and season of bad fruit to total fruit. Ratios of fruit weight in %.

Cultivar	Late-wet 1977	Mid-wet 1978
CL11d	8	24
WS	4	15

Ratios by season, for (A) good fruit per harvest to good fruit summed over all harvests, (B) bad fruit to all fruit for each harvest, and (C) total bad fruit to total fruit. Ratios of fruit weight in %.

Planting date	Season	Location	Harvest	% good/total good	%bad/harvest	% total bad/total
Aug 27, 1977	late-wet	sand	1	4	45	
			2	19	18	
			3	17	8	
			4	18	3	
			5	42	6	
						6
Aug 27, 1977	late-wet	loam	1	2	45	
			2	11	18	
			3	21	8	
			4	17	3	
			5	50	6	
						6
May 2, 1978	mid-wet	sand	1	8	21	
			2	43	9	
			3	16	33	
			4	19	14	
			5	15	50	
						19

Caldwell: What were the major quality problems reducing marketable yield?

Hubbell: Fruit rot.

Riley: Do you anticipate any increased tomato volume and lowering of price in the summer as a result of the lifting of the ban on export of vegetables in Taiwan during the summer?

Su: Since summer fresh market tomato is grown under an unfavorable environment, it needs more intensive management for high yield and quality. This means higher production costs in summer tomato than winter-spring crop. So, it is difficult to tell what the effect will be on price.

Riley: We are now seeing more extensive use of mechanization in rice cultivation in Taiwan. Do you think there will be a similar increase of mechanization for production of tomato and vegetables?

Su: With small farm size and distribution of seasonal labor on growing tomato, mechanization is still difficult at present in Taiwan.

Holle: Are fertilizer requirements calculated for the individual crop or are they adjusted for the sequential patterns?

Su: For sequential cropping, the fertilizers will be applied on the indivudual component crop base. A field, after one or two years as a specialized vegetable farm, will be put back to paddy rice for two or three years in order to control the salt accumulation on the soil surface.

Holle: What is done with the tomato residues in intercropping or sequential patterns?

Su: In intercropping tomato with sugarcane, the residual stems and leaves will return back to the field as manures. But in sequential cropping on a specialized vegetable farm, the tomato residues will be taken off for convenience of the farm operation.

Caldwell: When I visited the Yung Ching area, I was told that the soil there is unique and for that reason beds with vertical walls and very deep ditches, such as shown in your slides, are limited to that area. Could you comment on the soil physical properties required for that type of bed system and the extent to which it could be extended to other areas in Taiwan and elsewhere?

Su: Raised bed in central Taiwan is adopted for vegetable farms surrounded by paddy fields. The soil type is clay loam. The objective is to prevent excess moisture by improving drainage during the rainy season. In the southern part of the island, tomato is grown in the cool-dry seasons, there are no problems of excess moisture or rain. Soil types of the tomato production areas in the south are sandy loam or sandy soil, so it would be difficult to make a deep raised bed as in Yung Ching area.

Ruelo: What is the incidence of bacterial and fungal damage on tomatoes with the mulching method you used in your experiments?

Wilson: The crop is sprayed weekly with a fungicide (Dithane) and there was no significant fungal attack. Slight bacterial spot was observed late in the season.

VARIETAL IMPROVEMENT OF TOMATO

DEVELOPMENT OF HEAT-TOLERANT TOMATO VARIETIES IN THE TROPICS

R.L. Villareal and S.H. Lai[a]

INTRODUCTION

For optimum fruit-setting, tomato requires night temperatures of 15-20^{o}C (3, 6, 8, 10, 14-16). Unfortunately, the minimum temperatures in the lowlands of most tropical countries rarely drop to 20^{o}C even during the cooler months. To grow tomato in the lowlands in summer, heat-tolerant cultivars are needed. Such cultivars also often need to be moisture-tolerant, since the period of high temperatures coincides with the period of high rainfall in many locations. And, they should be resistant to the major yield-reducing diseases in the tropics.

In this paper we discuss AVRDC's program to develop heat-tolerant (i.e., ability to set fruit at high night temperatures) and bacterial wilt resistant tomato cultivars.

FIELD AND GREENHOUSE SCREENING TECHNIQUES

An effective screening technique is essential in the development of heat-tolerant tomato cultivars. At AVRDC, we have relied both on greenhouse and field tests to assess the ability of tomato cultivars and breeding lines to set fruit at high temperatures.

Field tests are conducted during the summer at AVRDC when minimum night temperatures are never below 21^{o}C, and usually fall between 23 23-25^{o}C. Heat-tolerance is scored 60-75 days after planting by appropriately trained researchers. Plants are scored 1-5 in the increasing order of fruit-setting intensity (12). We have repeatedly observed a high correlation (r = 0.72**) between the fruit-setting score and fruit-setting rate (%), suggesting that the former could be used as an indicator for the latter (Fig. 1). Fruit-setting rate is computed by the following foumula:

$$\text{Fruit setting rate (\%)} = \frac{\text{No. of fruits per cluster}}{\text{No. of flowers per cluster}} \times 100$$

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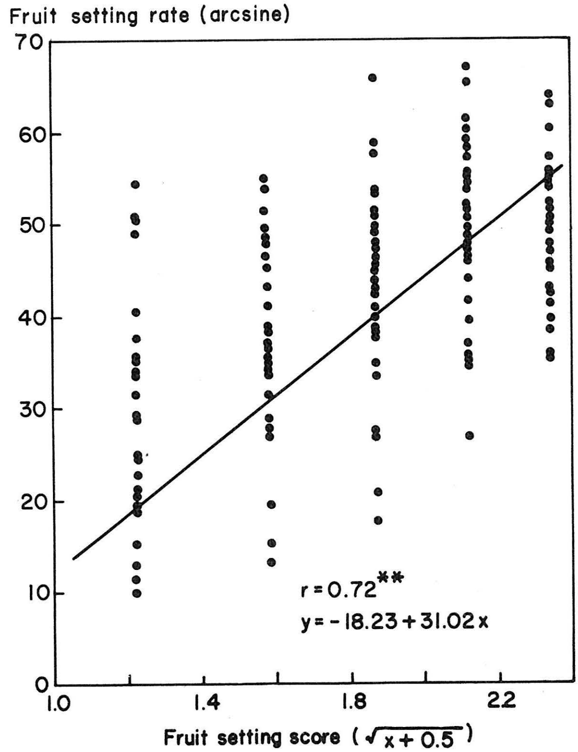

Fig. 1. Correlation between fruit-setting rate and fruit-setting score; AVRDC, 1978.

Growing tomatoes in the field and scoring them for heat-tolerance is difficult and laborious. The crop is susceptible to heavy rainfall and strong winds. In 1973, 1975, and 1977, for example, we lost thousands of materials and several hundred man days due to flooding. Too much water both in the soil and in the air can complicate the evaluation, since some cultivars can better tolerate moisture than others (7). Field screening during the summer when precipitation is excessive could mean screening both for heat and moisture tolerance.

As in the field tests, greenhouse tests are conducted in summer. We transplant 24-day-old tomato seedlings to 20 cm pots containing equal amounts of sand, soil, compost, and rice hulls. We pinch the terminal bud of every plant after the fifth cluster is attained. The fruit-setting score of each entry is recorded as in the field screening.

There are three major drawbacks to this technique. The technique cannot be used for massive screenings of segregating populations because of greenhouse space limitations. Second, temperatures in AVRDC greenhouses could go as high as 47°C. Balingasa and Villareal (2) observed high pollen and pollen tube bursting at temperatures beyond 25°C, especially in the heat-sensitive cultivars. At 40°C, P.G. Smith (personal communication) observed actual destruction of pollen grains under greenhouse conditions in California. And, third, solar radiation in our shaded greenhouse is about 40-50% of the prevailing solar radiation. Thus, fruit-setting ability could be affected by reduced light intensity. Research has shown variability in this trait among accessions and breeding lines grown under 50% shade (4,11). Therefore, when we screen under the greenhouse for heat-tolerance, we are also evaluating our materials for shade tolerance, and pollen and pollen tube heat-tolerance.

ALTERNATIVE SCREENING METHODS

It become imperative to find other methods for heat-tolerance screening. An ideal method should be repeatable, inexpensive and , if possible, usable during the seedling stage. Several promising methods were explored at AVRDC.

Growing in pots. Tomato seedlings were grown in 14 cm pots. The fruit-setting score of 5 consecutive clusters was recorded when the fruit turned red (13). In addition, the numbers of flowers and fruit per cluster were recorded, and the fruit-setting rate computed.

The fruit-setting rate ($r = 0.65^*$) and score ($r = 0.70^*$) of the potted plants grown in the open were significantly correlated with similar traits in the field-planted tomatoes (13). The observation indicates that the fruit-setting ability of tomatoes grown in pots in the open parallels that of field grown tomatoes. Thus, this technique can be used to screen for heat-tolerance in tomato cultivars and to select for this trait in segregating populations when field evaluation becomes prohibitive.

The technique has the following advantages: reduced risk due to inclement weather, convenient soil preparation and pest management, small space requirement, and reduced cost. It could be especially useful in places like Guam, Taiwan, the Philippines, and other typhoon belt countries; and in universities and experiment stations with budget and space limitations.

Ethrel treatment. AVRDC physiologists noted that yellowing induced by high temperature in the pedicels of tomato fruit were comparable to ethrel-induced yellowing. Also, ethrel application had been shown to promote adventitious root formation in many plants, including tomato. Following these leads, 3000 mg/ℓ ethrel was applied to 3-week old seedlings of 7 heat-tolerant and 8 heat-sensitive cultivars. Cultivar differences in the number of adventitious roots occurred due to ethrel application(1). The number of roots was inversely related to fruit-setting scores. This means that heat-tolerant cultivars produced fewer adventitious roots than heat-sensitive cultivars. We are currently evaluating this technique in a mass screening of our segregating populations. Eventually, we plan to grow to maturity genotypes with fewer adventitious roots (presumably heat-tolerant) side by side with the more adventitious rooted ones and observe them for actual high temperature fruit-setting ability.

HEAT-TOLERANT ASSOCIATIONS

AVRDC's tomato program initially emphasized the collection and identification of diverse germplasm to serve as the pool from which desirable genes can be used when needed. We now have 4752 accessions from 79 countries. Of these accessions, 4616 have been screened in the field for heat-tolerance during the summer of 1973, 1974, 1976, and 1978 (Table 1).

Table 1. Observed fruit set on 4616 *Lycopersicon* accessions screened for heat tolerance; 1973-78, AVRDC.

Species	Total	Observed fruit set			
		none	light	moderate	heavy
L. esculentum[a]	4129	3387	536	170	29
L. esculentum var. cerasiforme	49	15	25	7	2
L. pimpinellifolium	204	143	47	7	7
L. peruvianum	61	61			
L. cheesmanii	1		1		
L. hirusutum	16	16			
L. glandulosum	10	9			
L. esculentum x *L. pimpinellifolium*	153	78	53	21	1
L. esculentum x *L. hirsutum*	1	1			
Total No.	4616	3710	662	205	39
% Total	100	81	14	4	1

[a]Includes several type species from *pyriforme* and var. *cerasiforme*.

This year one new accession (PI 390522 from Ecuador) was identified as heat-tolerant. Thus, we now have 39 heat-tolerant cultivars which can be used for developing heat-tolerant varieties (Table 2). They originated from 15 countries, indicating possible diversity of heat-tolerant genes. Most of these accessions, however, belong to *L. esculentum* and *L. pimpinellifolium*, and are small or medium fruited.

ENVIRONMENTAL INFLUENCE ON HEAT-TOLERANCE

We conducted four experiments to clarify environmental influence on heat-tolerance expression, since we have received reports that some of our accessions and breeding lines were heat-tolerant in one location and heat-sensitive in another. This study was conducted in 5 tropical Asian countries during the early phase of the AVRDC program when heat-tolerant accessions did not yet have the bacterial wilt resistant genes. Unfortunately, almost all heat-tolerant accessions tested were susceptible to wilt and succumbed to the pathogen before any data could be gathered. Therefore, we decided to conduct all future experiments at AVRDC.

Two experiments were grown in the greenhouse and two in the field to simulate location and season. The greenhouse experiments represented high temperatures (22-47^{o}C), partial shade, and no rain conditions, whereas the field experiments represented moderate temperatures (22-35^{o}C), full sunlight, and rain.

Table 2. The 39 *Lycopersicon* accessions that showed high levels of heat-tolerance, 1973-78, AVRDC.[a]

AVRDC acc. no	Cultivar name	Origin	Fruit-setting score[b]
125	Divisoria 2	Philippines	5.0
2972	PI 289296	Hungary	5.0
3690	PI 365914	Ecuador	4.8
232	Nagcarlan	Philippines	4.8
3982	Tagalog	Philippines	4.5[c]
3692	PI 365916	Ecuador	4.5
283	Tamu Chico III	U.S.A.	4.2
3693	PI 365917	Ecuador	4.2
4361	PI 390511	Ecuador	4.2[d]
1076	PI 136452	Canada	4.1
226	NRG 7247	Canada	4.1
230	Sub Artic Midi	Canada	4.0
181	LA 1467	Colombia	4.0[c]
142	LA 1263	Ecuador	4.0[c]
3969	Gambia-2	France	4.0[c]
2907	PI 289231	Hungary	4.0
2984	PI 289308	Hungary	4.0
2985	PI 289309	Hungary	4.0
3040	PI 294443	Israel	4.0
3695	PI 365920	Peru	4.0[c]
3716	PI 365967	Peru	4.0
180	LA 1466	Peru	4.0[c]
18	VC 11-2-5	Philippines	4.0
1488	PI 203232	South Africa	4.0
2991	PI 290856	U.S.A.	4.0
3510	PI 341155	U.S.A.	4.0[c]
99	LA 1622	Zambia	4.0[c]
1394	PI 190256	New Calendonia	3.9
4	VC 9-1-2-9a	Philippines	3.9
492	PI 114968	India	3.8
493	PI 114969	India	3.8
3042	PI 294445	Israel	3.7
6	VC 8-1-2	Philippines	3.6
476	PI 110597	England	3.6
229	Sub Artic Plenty	Canada	3.5
1834	PI 357489	China	3.5
11	VC 11-3-4	Philippines	3.5
2	VC 9-2-1-2	Philippines	3.5
126	Nova	U.S.A.	3.5

[a]All accessions belong to *L. esculentum* except LA 1263, PI 365914, PI 365916. PI 365917, LA 1466, PI 365920, and PI 365967 which all belong to *L. pimpinellifolium*, and PI 190256 which is cross between *L. escutum* and *L. pimpinellifolium*. [b]From 1 to 5 in the increasing order of fruit-setting intensity. Data are averages of at least 3 screenings unless otherwise indicated. [c]Data are averages of two replications from 1976 screening. [d]Average of two replications from 1978 screening.

In most cases mean squares for fruit-setting rate, score, and stylar exertion were significant whether the materials were grown in the greenhouse or in the field (Tables 3 & 4). The significant interaction (S x E) in both greenhouse and field plantings suggest that some entries had higher fruit-setting ability and stylar exertion in one season, while other entries were superior in another. Similar response was also observed when data from Greenhouse I and Field I were combined (Table 5). Significant interaction (L x E) suggests that some entries would perform well in the greenhouse, while others could perform better in the field. These observations indicate, therefore, that there are accessions that could set fruit under high temperatures and partial shade, although better fruit-setting could be obtained when there is full sunlight with moderate temperatures, even under rainy conditions.

Table 3. Summary of mean squares for fruit-setting score and stylar exertion from a combined analysis of two greenhouse plantings.[a]

Source of variation	Degrees of freedom	Fruit-setting score[b]	Stylar exertion[c]
Season (S)	1	0.60**	37^{ns}
Reps within season	2	0.33**	74^{ns}
Entries (E)	22	0.24**	2817**
S x E	22	0.06^{ns}	124**
Error	44	0.04	54

[a]Combined analysis of greenhouse I (potted April 19) and Greenhouse II (potted Aug. 11) was carried out since Barlett's test showed variances were homogenous. [b]Data were transformed to $\sqrt{x + 0.5}$ prior to analysis of variance. [c]Data were transformed to arcsine prior to analysis of variance.

Table 4. Summary of mean squares for fruit-setting rate and score and stylar exertion from a combined analysis of two field plantings.[a]

Sources of variation	Degrees of freedom	Fruit-setting rate[b]	Fruit-setting score[c]	Stylar exertion[b]
Season (S)	1	1108**	1.67**	319**
Reps within season	2	12^{ns}	0.03^{ns}	16^{ns}
Entries (E)	20	260**	0.09**	1688**
S x E	20	62**	0.04**	238**
Error	40	16	0.01	74**

[a]Combined analysis of Field I (planted April 19) and Field II (planted Aug. 18) was carried out since Bartlett's test showed variances were homogenous. [b]Data were transformed to arcsine prior to analysis of variance. [c]Data were transformed to $\sqrt{x + 0.5}$ prior to analysis of variance.

Table 5. Summary of mean squares for fruit-setting rate and score and and stylar exertion from a combined analysis of one greenhouse and one field planting.[a]

Sources of variation	Degrees of freedom	Fruit-setting rate[b]	Fruit-setting score[c]	Stylar exertion[b]
Location (L)	1	125**	0.6**	5406**
Reps within location	2	49**	0.22**	10^{ns}
Entries (E)	22	570**	0.20**	173**
L x E	22	44**	0.60**	169**
Error	44	15	0.03	42

[a]Combined analysis of Greenhouse I (potted April 19) and Field I (planted April 19) was carried out since Bartlett's test showed variances were homogenous. [b]Data were transformed to arcsine prior to analysis of variance. [c]Data were transformed to $\sqrt{X + 0.5}$ prior to analysis of variance.

The findings from these experiments suggest that the heat-tolerant genes are easily influenced by environment and may involve shade tolerance, pollen heat-tolerance, stylar exertion, and parthenocarpy. Therefore, heat-tolerant selections should be tested in as many locations and seasons as possible before any recommendations are made. It is equally desirable to screen AVRDC breeding lines for heat-tolerance where the tomatoes will be finally grown commercially. This is extremely important when we consider the wide range of climatic factors and differential strains of pests and diseases present in the tropics.

HEAT-TOLERANCE AND MOISTURE TOLERANCE

Understanding moisture tolerance is another important aspect in developing tropical tomatoes. Heat-tolerant tomatoes must also be moisture tolerant to allow their cultivation in the many locations where the period of high temperature coincides with the period of high rainfall.

We conducted an experiment to clarify the relationship between heat-tolerance and moisture tolerance in relation to tomato fruit-setting. Nagcarlan and Divisoria 2 possess both heat and moisture tolerance, as evidenced by higher fruit-setting ability than either moisture-tolerant or traditional (neither moisture nor heat-tolerant) cultivars (Table 6).

Research (7) on the differential response to moisture of Nagcarlan (heat-tolerant), LA 1421 (moisture-tolerant), and White Skin (neither moisture nor heat-tolerant) showed that simulated rain by sprinkling reduced root and top dry matter, fruit-setting rate, and score in all cultivars (Table 7). The degree of reduction was magnified when drainage was poor (i.e., flooding). On the other hand, watering (irrigation, flood) the individual plants resulted in higher root and top weight and fruit-setting rate and score because, in this treatment, only the roots were moist, with water loss due to evaporation as well as transpiration,

Table 6. Summary of fruit-setting scores and rates of heat-tolerant (HT) moisture-tolerant (MT), and traditional (T) tomato cultivars tested under field and greenhouse conditions; AVRDC, 1976.

Type	AVRDC acc. no.	Varietal name	Field experiment[a] score[c]	Field experiment[a] rate[d]		Greenhouse experiment score[c]	Greenhouse experiment rate[d]	
				%	(A)		%	(A)
HT	125	Divisoria 2	4.1	47	43	-	-	-
HT	245	KL 2	2.5	54	48	2.8	27	31
HT	232	Nagcarlan	4.9	54	48	4.8	52	46
	Means		3.8	52	46	3.8	40	39
MT	146	LA 1291	3.0	56	48	-	-	-
MT	166	LA 1421	2.4	20	26	1.0	0	0
MT	133	LA 1231	1.6	29	32	1.3	6	14
	Means		2.3	35	35	1.2	3	7
T	203	Floradel	1.1	20	26	-	-	-
T	97	Healani	1.0	0	0	-	-	-
T	388	Green Fruit	1.0	10	11	1.1	4	12
	Means		1.0	10	16	1.1	4	12
	LSD 5%		1.9		30	0.4		11

[a]9 entries were planted in the field Jul 23, 1975. All values are means of 3 replications. [b]6 entries were planted in pots Jul 23, 1975 and placed in the greenhouse. All values are means of 10 plants. [c]Scoring of 1 to 5 in the increasing order of fruit-setting intensity. [d]Cumulative fruit-setting of first 10 clusters; (A) = arcsine transformation.

the growth and development of the tomato plants were normal. Nagcarlan and LA 1421 were not seriously affected by excess water or poor drainage and, thus, seem to possess one or more of the traits that are important to survive poor drainage conditions.

The findings from these experiments indicate that if the breeding objective is to develop varieties for hot, dry conditions, screening for heat-tolerance can be accomplished when night temperatures are high. If the varieties, however, are intended for the hot, wet tropical conditions, screening should be done for both moisture and heat-tolerance, and should be conducted under conditions of high night temperatures and excessive water both in the atmosphere and in the soil.

GENETICS OF HEAT-TOLERANCE

The genotype-environment interactions observed in these experiments and the influence of high temperature on tomato growth and development

Table 7. Effect of flooding and rain on horticultural traits of 3 tomato cultivars.

Traits	Irrigation[a]			Flood[b]			Rain[c]			rain + Flood[d]		
	Nag-carlan	LA 1421	White Skin	Nag-carlan	LA 1421	White Skin	Nag-carlan	LA 1421	White Skin	Nag-carlan	LA 1421	White Skin
Root dry matter (g/plant)	3	25	16	3	18	2	1	7	5	1	7	2
Top dry matter (g/plant)	104	118	158	153	119	212	71	52	73	20	24	34
Fruit-setting rate (%)	85	77	71	79	75	68	57	49	40	40	35	23
Fruit-setting score (5-1)	4.9	4.9	4.1	4.8	4.8	4.1	3.0	2.7	2.6	2.3	1.8	1.2

[a]Dispensing, good drainage. [b]Dispensing, poor drainage. [c]Sprinkling, good drainage. [d]Sprinkling, poor drainage.

(as discussed earlier in this symposium by Aung and Kuo) make it difficult to study the genetics of heat-tolerance without the use of growth chambers. Precise control of the environmental conditions (i.e., temperature, relative humidity, and solar radiation) is essential to understanding the genetics of this trait.

In spite of these limitations, we conducted 4 field experiments at AVRDC to determine the inheritance of heat-tolerance. The experiments failed 50% of the time. For those experiments completed, we noted a continuous distribution of fruit-setting score among the parentals and different progeny generations suggestive of fairly complex inheritance of heat-tolerance. While it was relatively easy to identify both extremes (i.e., no fruit to light fruit vs heavy fruit set), it was difficult to classify the intermediates. The heat-tolerant parents showed a preponderance of higher scores, whereas the non-heat-tolerant parents exhibited a preponderance of lower scores. Heritability values were generally low, ranging from 5-19%, which indicates that the greater proportion of variability observed was due to environmental causes. The low heritability of heat-tolerance is compatible with the observation that characters with the lowest heritabilities are those more closely connected with reproductive fitness, whereas, those characters with the highest heritabilities are those that are least important to reproduction (5).

By virtue of the complex inheritance of heat-tolerance and the influence of environmental factors in its expression, we are probably losing many genotypes with excellent fruit-setting ability due to the technique we use in combining bacterial wilt resistance and heat-tolerance. We have been mass inoculating segregating populations with bacterial wilt pathogen and planting only those genotypes that survive. About 10% or less survive. Thus, genotypes subjected to heat-tolerance screening are limited to bacterial wilt resistant progenies. We have to do this, or field thousands of materials. An alternative is to select first for heat-tolerance, and later inoculate these selections with bacterial wilt pathogen.

Another technique is to advance our materials through SSD without selection for either heat-tolerance or bacterial wilt resistance. This will be discussed later in this symposium by Dr. Tee from Malaysia.

STATUS OF DEVELOPING HEAT-TOLERANT VARIETIES

In the first paper of this symposium, the progress of AVRDC's tomato breeding program was reported. Also the general performance of AVRDC materials were evaluated in several tropical countries for bacterial wilt resistance, heat-tolerance, fruit quality, and other traits. It is difficult to ascertain, however, the yield advantage attributable to heat-tolerance alone; in most cases these lines have been evaluated in wilt-infested areas. Nevertheless, we can get some information where trials are conducted in areas where wilt resistant lines are included or, in exceptional cases, in wilt free areas. In the former case, Sunarjono et al.(9) reported the yield superiority of AVRDC materials over the wilt-resistant check. AVRDC lines gave 11-24 t/ha compared to 1 t/ha for the check, indicating that the yield difference could be mainly due to heat-tolerance in the AVRDC materials. In Chiangmai, Thailand, our cooperator reported that "Seda", a local tomato cultivar, barely had fruit, whereas a number of AVRDC materials were loaded. In a wilt free area at AVRDC, our breeding lines yielded 500-900% higher than "White Skin", a local check (Table 8). Thus, using a massive breeding program based on a world-wide germplasm base, significant increases in yields due to the incorporation of heat-tolerant genes and other traits are possible.

Table 8. Performance of heat-tolerant breeding lines compared to a local check, 1978 AVRDC.[a]

AVRDC Sel. or (acc. no.)	Pedigree or (cultivar name)	Yield	% of check
		-t/ha-	
9d-0-3-6	VC 11-1-2-1B/Saturn	18	900
143-0-10-3	VC 48-1/Tamu chico III	16	800
9-0-0-1	VC 11-1-2-1B/Saturn	16	800
8d-0-7-1	VC 11-1-2-1B/Venus	16	800
11d-0-2-2-0-3	VC 11-1-2-9/Venus	15	750
123-2-4	ah TM-2a/VC 8-1-2-1	13	650
143-0-6-9	VC 48-1/Tamu chico III	12	600
(1)	(VC 48-1)	10	500
(387)	(White Skin), Check	2	100
	LSD .05	5	

[a]Planted May 11, 1978 in a wilt free field; harvested 4 times beginning July 14 and ending July 28; means of 3 replications.

RESEARCH DIRECTIONS

These are some research areas that deserve our attention:

1. Identification of a simply inherited heat-tolerant gene. The observation made at Cornell University on a dominantly inherited resistance to powdery mildew in cucumber has given us hope along this line. Resistance to this disease has been known to be recessive for the last 20 years. Apparently, a mutation has occurred which resulted in a dominantly inherited trait. Obviously a simply inherited heat-tolerant gene would speed up the development of heat-tolerant cultivars. It could also be useful in the production of F_1 hybrid tomatoes with heat-tolerance potential.

2. Clarification of the exact role of high temperature to fruit setting. Would a brief cool period (15-20^{o}C) for one hour or less be sufficient to permit optimum fruit setting on tomato? An affirmative

answer would have a tremendous practical application comparable to what a brief dash of light could do to induce flowering in some ornamental plants.

3. Improvements in fruit-setting among heat-tolerant cultivars. Would keeping of about five clusters and removal of all other flowers improve fruit setting in heat-tolerant cultivars?

4. Exact nature of moisture tolerance must be understood. In addition, would it be possible to find a *Lycopersicon* genotype similar to a rice plant, which is adapted for growth in submerged soils because of the tiny tubes that extend from the leaves to the roots?

CONCLUSION

We wish to point out that in addition to our attempt at AVRDC to develop heat-tolerant cultivars, there has been a growing interest in this particular plant breeding problem among our collaborators in the tropical areas of Asia, Africa, and Latin America. In the past 5 years, we have been encouraged by their continuing cooperation and quest for new disease and heat-tolerant germplasm. We share the optimism of our collaborators. Together we can contribute to the development of a truly tropical tomato that will find its way to farmers' fields and the tables of consumers.

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BREEDING TOMATOES FOR PROCESSING

M. Allen Stevens[a]

INTRODUCTION

The past 15 years have seen tremendous changes in the production of processing tomatoes in the United States, especially in California. In 1960, about 4 million tons of tomatoes were produced in the U.S. (about 55% in California). In 1961, G.C.(Jack) Hanna released the first tomato cultivar developed specifically for mechanical harvest. That cultivar, VF 145, eventually became the most important processing tomato in California and was chiefly responsible for expanding production to 80% of the 7-3/4 million tons of processing tomatoes produced in the U.S. in 1977.

In the mid-1940s, when Hanna began his effort to develop a cultivar for mechanical harvest, most people considered it of little practical import. For many years he persisted, making crosses which would contribute to the concentration of set and the fruit firmness he perceived to be necessary in view of the severe handling that tomatoes would undergo during harvest. During the early years of that effort he had no concept of how the machine would function. As the breeding program progressed, he decided that it was necessary to develop a working relation with an agricultural engineer, so that the cultivar and the machine could be developed simultaneously. That led to a combined effort by Hanna and Coby Lorenzen of the Agricultural Engineering Department at Davis. In the late 1950s and early 1960s, they worked to develop a cultivar that would be suitable for mechanical harvest and a machine that would harvest the fruit with maximum efficiency and minimal damage. In the early 1960s , California politicians decided to eliminate the Bracero program, which had allowed laborers from Mexico to harvest crops. The Braceros had been essential for harvest of the processing-tomato crop.

Suddenly, everyone was interested in mechanical harvest of processing tomatoes, and, thanks to their farsighted 15 years of effort, the cultivar and the machine were ready. The transition from hand-harvested processing tomatoes to machine harvest was rapid, and within a few years virtually all processing tomatoes in California were harvested mechanically. The rapid transition was greatly abetted by the very favorable growing conditions in California. The long, dry summers, coupled

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with a well developed irrigation system throughout the Central Valley, are ideal for growing processing tomatoes for mechanical harvest. Other states have attempted to follow the example of California, but unfavorable weather has made the transition slow or nonexistent.

Additional changes have occured in the processing-tomato industry in California since the mid-1960s, although none so dramatic as the transition to mechanical harvest. In the hand-pick days, the fruit were transported in field lug boxes which held less than 23 kg. With mechanical harvest, there was a change to bins which hold about 680 kg. Since 1974 there has been a transition to large bulk tanks which contain about 11 t of fruit. These changes to bulk handling procedures have necessitated changes in fruit characteristics, primarily fruit firmness.

In many ways, the processing-tomato breeding programs in California are atypical. Generally, California has fewer disease problems than other tomato production areas, as a result of near-ideal weather conditions. Breeding emphasis is therefore quite different from that in areas with a wider range of disease problems and weather conditions that hamper harvest. This paper discusses certain characteristics receiving attention in the processing-tomato breeding program at UCD.

YIELD

The most important characteristic of a successful processing-tomato cultivar is a high yield potential. Unless a new cultivar has a potential equal to or exceeding that of current cultivars, it will achieve little or no success even if it has excellent machining characteristics and quality.

A machine-harvest cultivar must have a concentrated fruit set. This has been achieved using the self-pruning (<u>sp</u>) character with a compact vine. The consequences of the drive for heavy, concentrated fruit set have included an increase in the harvest index (a decrease in the ratio of vine to fruit). There have been accompanying changes in the quality characteristics of the fruit. To maximize use of existing physiological potential, a major goal of the UCD breeding program has been to maximize use of the total fruit production of the plant. Fruit lost because they are overripe and soft or grass-green do not represent effective yield. In recent years, firm-fruited cultivars have been developed that can remain on the vine in good condition for several weeks after they reach full color.

FIRM-FRUITED CULTIVARS

In the late 1960s, Hanna crossed an elongated firm-fruited cultivar (VF 65) with firm-fruited lines from Florida. From those crosses came a number of strains with fruit firmness and vine-storage characteristics superior to those of other mechanical-harvest cultivars. These firm-fruited cultivars have become increasingly important in the California industry and represent the first really important change since the release of VF 145.

One of the most striking characteristics of these firm-fruited cultivars is that they remain in good physical condition for several weeks after they have reached full red color. In trying to understand the physiological basis of that vine-storage characteristic, we found that these cultivars have high levels of the alcohol-insoluble components of the fruit, a thicker outer pericarp, and a smaller locular area. The rate of breakdown of the cell-wall material does not appear to differ between these cultivars and those which are too soft to harvest soon after full color development. Rather, the firmness is greater at all stages of fruit ripening and senescence. As a result, several more weeks of softening are required before they reach the stage where they are easily broken during handling.

REMOVAL FROM THE VINE

Another important characteristic to achieve full utilization of the fruit is ease of removal from the vine. If tomatoes remove too easily, they shatter during harvest, with many remaining on the ground. Those too difficult to remove remain attached to the vine after it has gone through the shakers. One problem with firm-fruited cultivars is that they were more difficult to detach, leaving a higher percentage on the vine after harvest. The precise reason for this stickiness is still not understood. Initially it was believed that there was lower activity of the pectolytic enzymes, resulting in slower formation of the abscision layer, but studies did not support that view. In general, the firm-fruited cultivars are more difficult to remove from the vine than softer-fruited cultivars, and plant breeders must pay careful attention to the size of the stem scar to assure that fruit removal does not become a serious problem.

Pedicel retention on the fruit is undesirable in processing tomatoes since pedicels damage other fruit in the load and affect the flavor of the processed product. Processors prefer cultivars with low ($<20\%$) stem retention. We have worked considerably with the jointless ($\underline{j_2}$) character to reduce stem retention. All jointless lines developed so far have a slight yield disadvantage. The $\underline{j_2}$ also increases stem adhesion to the fruit.

HIGH-TEMPERATURE FRUIT SET

One of the greatest deterrents to a concentrated fruit load on tomato plants is loss of blossoms due to stress conditions during the peak fruit-setting period. Temperatures in California during flowering are frequently hot enough to cause blossom drop, resulting in a split fruit-set. This problem could be solved by developing cultivars that can continue to set fruit despite high-temperature stress. An added benefit of genotypes with high-temperature fruit-set capability would be increased adaptability, since it has been shown that genotypes which set fruit well at high temperatures also set fruit better under low-temperature conditions (3). A large number of tomato genotypes with reported high-temperature fruit set capability have been screened in higher-temperature growing areas in California and in greenhouses in summer. Certain genotypes have a clear capability to continue setting fruit during the highest temperature conditions normally encountered in California. The high-temperature performance of these divergent lines varied in their physiological basis (Fig. 1), so we are using several in the breeding program to incorporate their strengths into a single genotype.

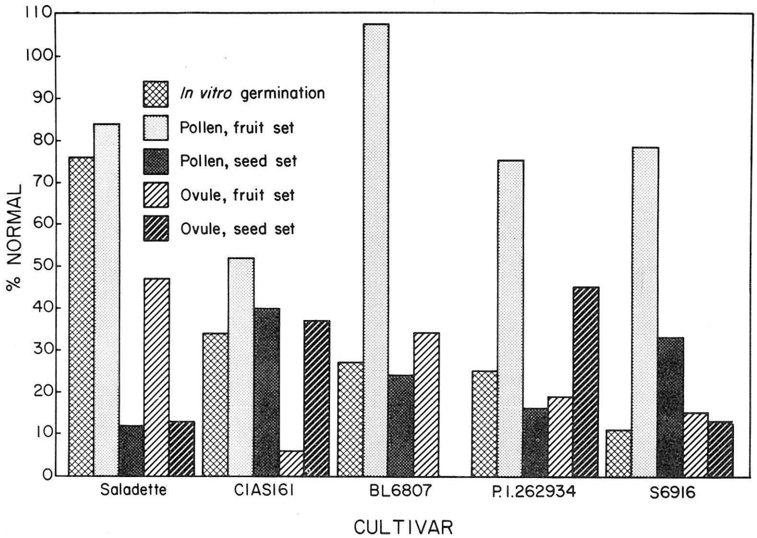

Fig. 1. Reproductive responses of several high temperature cultivars to high temperatures (37.8°/26.7° day/night) as a percent of their performance in normal temperatures (27°/20°C) (4)

The best overall high-temperature performance of the lines studied was by the cultivar "Saladette", developed by Paul Leeper in Texas. It lacks stigma exsertion and has a relatively high pollen production under high-temperature conditions. In vitro germination of high-temperature pollen was higher than in the other genotypes studied. Saladette also had a higher percentage of fruit set than the other high-temperature genotypes when the ovules were exposed to high temperatures.

BL 6807, a cold-set selection bred at Beaver Lodge, Alberta, Canada, appears to have an unusual capability of partitioning more of the available photosynthate to the reproductive organs during high-temperature stress conditions. It also had the highest fruit set of all cultivars tested when the pollen was exposed to high temperatures. Fruit set was high when both pollen and ovules were exposed to high temperatures, but the fruit was pathenocarpic.

PI 262934, the cultivar "Malintka 101" from the USSR, had the highest fruit set of the genotypes studied when both the ovules and pollen were exposed to high-temperature conditions. It had better ovule viability, as indicated by the number of seeds produced. Number of seeds in the fruit is a better indication of gamete viability than is percent fruit set.

"Narcarlan," developed in the Philippines, had the best capability of producing seeds when the pollen was exposed to high-temperature, indicating that the male gametes are resistant to high temperatures.

A diallel analysis showed that these high-temperature genotypes differ genetically in the characteristics which contribute to the high-temperature fruit set (5). Percent fruit set is under the control of a largely additive genetic system, and heritability is moderate at high temperatures. The dominance components for seed set are greater than the additive components at high temperature. Heritability of seed set was low at high temperatures. Stigma exsertion is controlled by partially dominant genes. The additive genetic component and heritability for stigma exsertion were high. At present we are using a modified system of recurrent selection for specific combining ability to combine the strengths of these high-temperature genotypes into a single cultivar. Screening is done in summer in the greenhouse, where there is some environmental control.

DISEASE AND INSECT RESISTANCE

Diseases of prime concern are generally limited on tomato in California. The dry, favorable growing climate reduces problems with bacterial and foliar fungus diseases. For a number of years all successful California cultivars have had resistance to *Fusarium oxysporum* f. sp. *lycopersici*, race 1, and *Verticillium dahliae*, strain 1. In recent years a second race of *F. oxysporum* and a second strain *V. dahliae* have been found in the state.

FUSARIUM WILT

Resistance to the second race of *Fusarium* wilt has been bred into cultivars in Florida and subsequently into cultivars from Israel which are similar to VF 145. Most California tomato breeders now have programs to breed resistance to race 2 of *Fusarium* wilt into a wide range of tomato genotypes. Race 2 of *Fusarium* wilt, currently a serious problem in the tomato-growing areas in northern California, appears to be spreading to other areas of the state.

VERTICILLIUM WILT

No resistance has been found to strain 2 of *Verticillium* wilt. Grogan, Kimble, and Loannou (6) found none in a large survey of tomato genotypes. It is still not clear how serious this disease may become in California. Although reported in various locations, no serious yield losses are yet evidenced. Grogan and Kimble are seeking techniques to screen for tolerance to this disease, since the seedling-screening technique used at present eliminates all plants lacking a high degree of resistance to the disease.

NEMATODES

Nematodes are widespread throughout the tomato-growing areas in

California, but DBCP (1,2-dibromo-3-chloropropane) has been an inexpensive and effective control, discouraging efforts to breed resistant cultivars. Recently, however, DBCP has been banned by the Food and Drug Administration as causing sterility in men.

Interest in nematode-resistant cultivars has now increased. In 1974, Rick and Fobes (10) showed an association between an isozyme of acid phosphatase and resistance to nematodes. This association, which appears to be a linkage, can serve as a useful tool in efforts to develop nematode-resistant cultivars. The gel-electrophoretic technique makes it possible to tell whether a breeding line is lacking, heterozygous, or homozygous for the Mi gene. This technique is being used by a number of tomato breeders interested in developing nematode-resistant cultivars. We are now surveying a wide range of nematode-resistant genotypes which apparently have a single *L. Peruvianum* parent as the source of nematode resistance (12). There are some undesirable linkages in much of the nematode material, and we are determining which nematode-resistant material has a minimum of undesirable characters.

INSECT RESISTANCE

Although a wide range of insect pest resistance has been demonstrated in the tomato (18), there has been little specific effort to develop insect-resistant cultivars. Since it is possible to control most insects effectively with pesticides and since plant breeders have a large number of other pressing problems, insect-resistant cultivars have received little specific attention. In cooperation with entomologists, we have had a program to evaluate the potential of developing cultivars with resistance to certain insects that are major problems in California, particularly the tomato fruit worm (*Heliothus zea)* and the beet army worm (*Spodoptera exigua*). An array of species and cultivars were screened under field conditions for susceptibility to insect pests. Large differences were observed in the attractiveness of the genotypes to the prevalent pests. Evaluation of the glycoalkaloid content of these lines showed attractiveness to the fruit worm and the army worm to be related to tomatine concentration. Feeding studies with *H. zea* showed that tomatine has a definite antibiotic effect on the larvae of the pest. Mortality rate and life-cycle time increased, and larval, pupal, and adult size decreased as tomatine concentration in the diet increased (Fig. 2). Tomatine has attraction as a natural antibotic agent since the alkaloid disappears as the fruit ripens (7). Studies are under way to determine in greater detail the changes in concentration of tomatine as tomatoes develop, mature, and ripen. Studies are also being conducted on the genetics of variation in tomatine concentration.

PROCESSING QUALITY

One of the major goals of the UCD processing-tomato breeding program has been an improvement in the quality of processing cultivars. As indicated earlier, the development of cultivars suitable for mechanical harvest has degraded certain processing characteristics and made it difficult to maintain and improve quality. The most striking relationship is the negative one between soluble-solids content and yield.

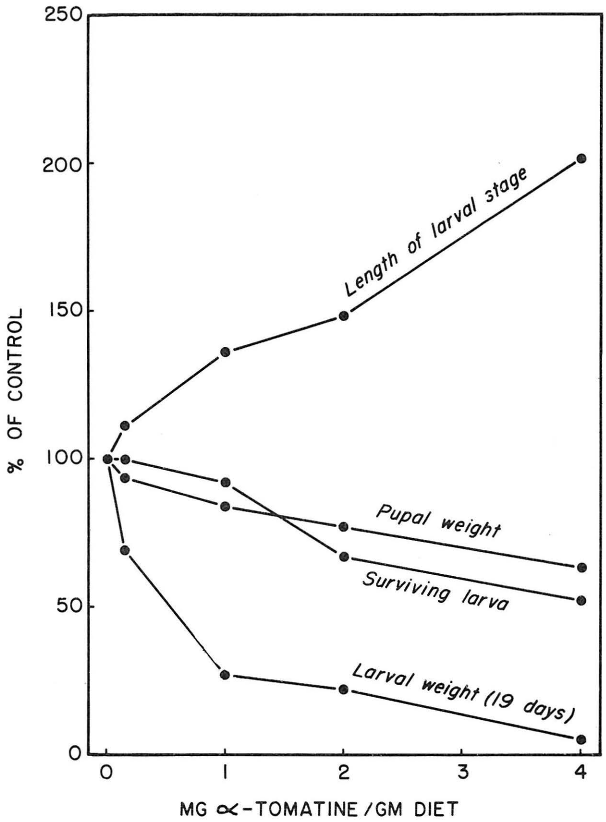

Fig. 2 Effect of α-tomatine concentration on growth characteristics of larva of *Heliothus* zea.

Numerous studies have shown that as yields are increased through the development of new higher-yielding cultivars or through changes in cultural practices, the solids content of the fruit generally decreases. Experience has also shown that changing the genetic potential for one major component of the fruit affects other major fruit components.

SUGARS

The most prevalent organic components of tomatoes are the reducing sugars fructose and glucose. Generally they constitute at least 50% of the total solids of most cultivars. Processors are interested in soluble-solids content primarily because it relates to case yields of products, which are sold on a solids basis. Paste, the most important product in California, has as a part of its identity standard a certain soluble-solids content. It has also been shown that the sugars make an important contribution to the flavor of tomatoes.

A major emphasis of our program has been to increase soluble-solids content in high-yielding cultivars.

Much of our program has centered on the high-solids breeding lines developed by C.Rick from an interspecific cross with *Lycopersicon chmielewskii* (9). It is extremely difficult to transfer the high-solids potential of the Rick high-sugar lines to a genotype which is satisfactory for mechanical harvest. We recently undertook a single seed descent program with the Rick material. Experience had indicated that yield potential is reduced as high solids are selected, and solids are reduced as yield potential is selected. It is hoped that the single seed descent program will result in a combination for solids and yield potential not obtained previously. More than 1600 F_6 families were evaluated in 1978.

One of the likely reasons for the adverse relation between solids and yield is that high-yielding cultivars, having a heavy concentrated fruit set on a compact vine, do not have enough photosynthate available to give high solids in the fruit. An additional approach we have taken is to evaluate diverse tomato genotypes for differences in photosynthetic efficiency. Augustine showed a large variation for carboxylation efficiency among genotypes which have varying chlorophyll content in the foliage (2). Several lines with high chlorophyll content in the leaves had high carboxylation efficiency and in segregating populations there is an association between carboxylation efficiency and chlorophyll content (Fig. 3). The chlorophyll content is conditioned by a major gene (1), so we are developing isogenic lines to test the precise effects of these chlorophyll mutants. If genes for high carboxylation efficiency could be coupled with others for high translocation efficiency to the fruit and a reduced respiration rate by the fruit, then higher yield potential and/or higher solids content might be expected. Of the cultivars currently used in California, VF 145-7879 has the highest fruit solids. Several recent experiments have shown that fruit of this cultivar have a lower respiration rate than other cultivars, which may contribute to their higher solids content.

At present, the solids content can be improved much more through controlled cultural practices than through plant breeding. Several studies have shown that judicious use of irrigation water can improve fruit solids content with minimal effects on yield (11).

ACIDS

The tomato's organic acids are an important processing characteristic, since they are a major factor in determining pH. Since tomatoes are processed as an acid fruit, a pH of less than 4.5 is desirable for safe processing; a higher pH can result in problems with thermophilic organisms such as *Bacillus coagulans*. It is well established that acid content and pH are important factors in tomato flavor.

The firm-fruited cultivars sometimes have reduced acid levels. Since these cultivars have a smaller locular area, they also tend to have a higher pH because acid content is higher in the locular than in pericarp tissue. To help alleviate this problem, we made crosses with high-acid genotypes to incorporate genetic potential for higher acid concentration. Primarily, we used PI 263713 from Puerto Rico, characterized by an unusually high citric acid content under simple genetic control (15). Crosses between PI 263713 and the smaller-locular-area firm-

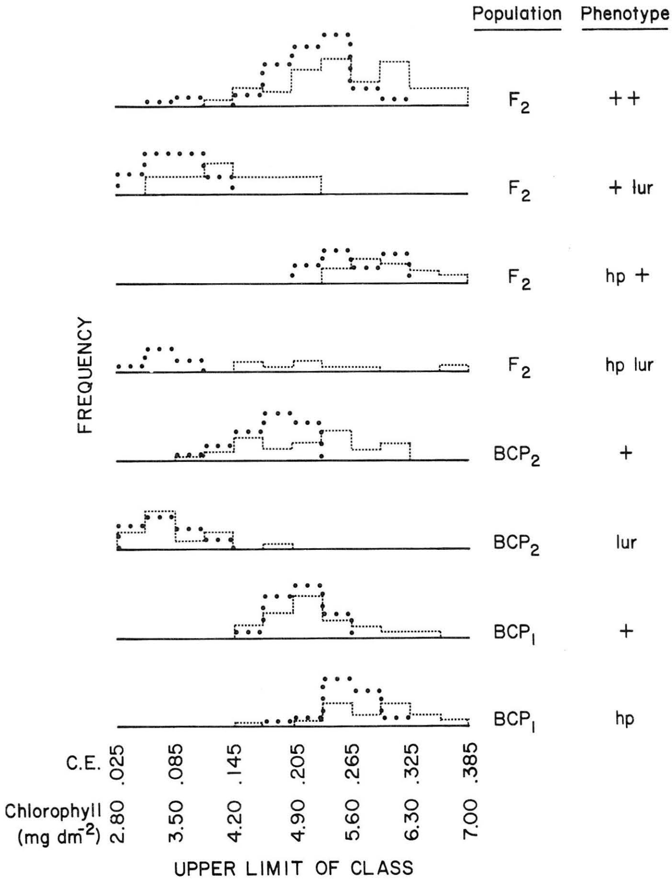

Fig. 3. Frequency distribution for carboxylation efficiency (CE) (....) and chlorophyll content (....) in F_2, BCP_2 and BCP_1 populations from a cross between Ottawa 67 (high pigment) and LA959 (lurida) (1).

fruited genotypes have resulted in breeding lines with higher acid concentration and lower pH. The low-acid problem appears much easier to solve than the low-solids problem.

ALCOHOL-INSOLUBLE SOLIDS (AIS)

As indicated earlier, the firm-fruited cultivars have higher levels of AIS. The consistency of the products made from tomatoes is closely related to the concentration of these components, which are generally considered to be cellulosic and pectic compounds (Fig. 4). High AIS results in thicker catsup and sauce products, a desirable trait. The development of the firm-fruited cultivars has resulted in the possibility of making sauce and catsup products thicker than previously possible. Buyers prefer paste made from these firm-fruited cultivars because it reconstitutes into thicker products.

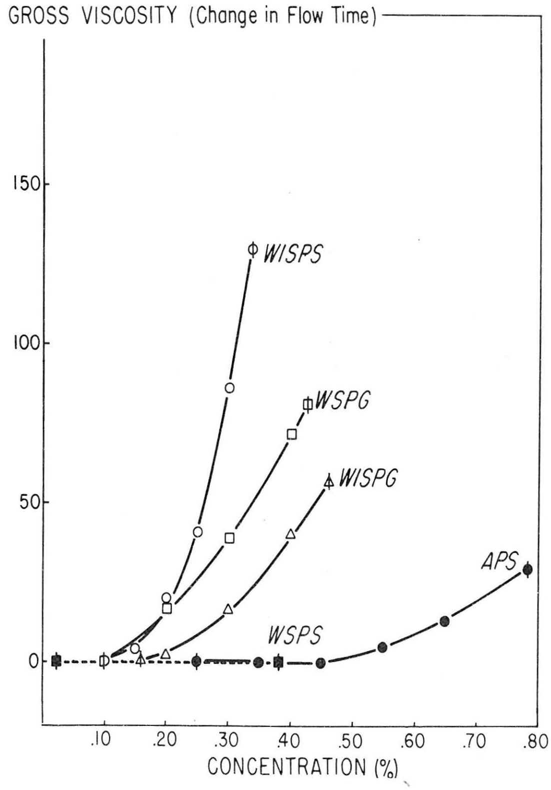

Fig. 4. Effect of change in concentrations of water insoluble polysaccharides (WISPS), water soluble polygalacuronides (WSPG), water soluble polysaccharides (WSPS) and acid hydrolyzed polysaccharides (APS) on gross viscosity of tomato puree (16).

Not all high-viscosity cultivars have firm fruits, but, within our germplasm, it has been relatively easy to select for high viscosity simply by selecting for firm-fruited genotypes. The increase in AIS has resulted in a further decrease in the soluble solids content of the fruit. Since available dry matter is limited, partitioning more of it into the AIS decreases other major components. Our efforts have indicated that it is much easier to get high soluble solids in a soft-fruited than a firm-fruited cultivar, probably because there is less demand for photosynthate for the AIS. It is possible to develop low-yielding cultivars which have high AIS, high soluble solids, and high acidity, but it is extremely difficult to get this combination together in a high yielding cultivar.

COLOR

Much of our direct effort on color has involved the crimson (og) and high-pigment (hp) characters. We have generally avoided the og alone, because of its adverse effect on the vitamin-A content of the fruits. Our interest in the og, hp combination resulted from informal information that that combination overcame some of the adverse effects of the hp alone.

We started the program by obtaining "Ottawa 67," which has both of these genes. A backcross program has been used with selection for the hp in the seedling stage (8) and selection for og during flowering by putting the plants under cool-temperature conditions. That is a nice combination, since it is possible to assure that progeny to be screened for horticultural conditions contain both genes before they are planted in the field. The og, hp combination results in fruit with a beautiful color, and it appears that progress has been made in getting this combination into desired horticultural types. The principal problems have been a lack of seedling vigor and an open vine that allows sun damage. The fruit must have good foliar coverage because their darker-green immature color makes them more susceptible to sun damage. The high lycopene conditioned by these genes appears related to changes in fruit flavor. There is a relationship between the volatile-compound composition of tomato fruit and their carotenoid content (13). The high-lycopene content results in higher levels of certain volatiles which may contribute to an off-flavor defect. The importance of this change to the flavor of processed products remains to be tested.

NUTRITIONAL QUALITY

The major nutrients of tomatoes are vitamins A and C. The hp results in about a 25-50% increase in vitamin-A content, whereas the og results in about a 25% reduction. The og, hp combination has about 25% greater vitamin-A than standard cultivars. Although we do not routinely evaluate the vitamin-A content of breeding lines, it is evaluated in lines where the color-difference meter indicates a substantial change in color.

The vitamin-C content is related to fruit size and shape as well as to locular content, and depends on the amount of light hitting the fruit and the amount of fruit surface exposed to the light. As a consequence, smaller-fruited cultivars tend to have higher vitamin-C content. The vitamin-C is highest near the skin and in the locular tissue, which means that the firm-fruited cultivars tend to have lower vitamin-C levels. Certain of the elongated cultures have lower vitamin-C, and that is believed attributable largely to their denser foliage, reducing exposure to the sun.

In an attempt to increase the vitamin-C potential of processing tomatoes, we have made crosses with the cultivar "Doublerich", which has a vitamin-C level double the normal. Several years of experience with the progeny of a backcross program with selection for high vitamin-C level indicates that it will be difficult to develop a high-yielding cultivar with a substantially higher vitamin-C level.

PEELING CHARACTERISTICS

Whole-peel tomatoes are a very important economic product for the processor. Losses in processing of the whole-peel pack are tremendous, since peeling losses tend to be high and only a small percentage of the fruit peeled are acceptable as a whole-peel product. In California, about five tomatoes are peeled for every one that actually ends up in a whole-peel product. Peeling losses average 18-20% on each fruit peeled. The requirements for a good whole-peel cultivar include an intact fruit with a peel that is easy to remove, coupled with uniform color and lack of discolorations. Unfortunately, tomatoes which are easy to peel tend to be very soft; the firm-fruited cultivars are difficult to peel. This relationship, coupled with a tendency for the white area in the vascular tissue mentioned earlier, makes the firm-fruited cultivars less than ideal for a peeled product.

We have been attempting to use the easy-peel gene in improving the peeling characteristics of firm-fruited cultivars. Crosses have been made between easy-peel material and the firmest-fruited lines, with subsequent selection for a combination of fruit firmness and peelability. At this stage it is difficult to assess how successful the effort will be. It is difficult to obtain the combination, although there are some indications that it will be possible. Heavily stressed in our program for peelability are the uniform-ripening characteristic and lack of internal discoloration.

FLAVOR

It is difficult to assess the importance of flavor to consumers of processing tomatoes. In heavily seasoned products, of course, the flavor of the tomato makes little contribution, but in other products, such as whole-peel tomatoes, tomato soup, and tomato juice, the flavor of the raw product is very important. Improved flavor has not been a major goal of our breeding program. Our studies with fresh-market tomatoes clearly indicate that if cultivars can be developed which have higher soluble-solids content and high acid levels, the net result will be improved flavor (17). There are also certain volatiles which have been shown to contribute to good tomato flavor. Particularly striking is the result with 2-isobutyl thiazole, which has been shown to make an important contribution in certain cultivars with a reputation for good flavor (14). The problems of breeding for higher concentrations of a specific volatile compound have been dealt with only in certain specialized situations and would be difficult to manage in most breeding programs.

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TOMATO GERMPLASM RESOURCES[a]

Charles M. Rick[b]

An unusually large array of germplasm is available for breeding improved cultivars of the tomato. The sources comprise modern cultivars, older outmoded cultivars, primitive cultivars (land races), wild forms of the cultivated species *Lycopersicon esculentum* Mill., and related, exclusively wild species. Available in increasing numbers for the past 50 years, these materials have already been used by tomato breeders to solve many serious production and quality problems. Although many battles have been won, other adversaries and numerous areas for additional improvement remain to challenge current and future programs.

The area of greatest achievement is possibly that of disease resistance. Utilizing these varied sources of germplasm, workers have sought and found resistance to more than a dozen serious pathogens. Further, the list of acceptable improved cultivars with such resistances is impressive. As examples, certain new, important F_1 hybrid cultivars have been bred with resistance to from five to eight different diseases each, based on intelligent manipulation of an even larger number of responsible genes. The role of the wild taxa as a source of such genes is particularly important - a point that I hope to develop later in this presentation.

The primary purpose of this article is to enumerate the sources of germplasm and to attempt to evaluate their potential for future improvement of the tomato. For such evaluations and comparisons, a suitable unbiased measure of variability is needed. Modern developments in the separation and identification of isozymes have provided a tool of unsurpassed precision for measuring genetic variation (6). The usefulness of this method for comparison of the tomato species is amplified by the additional feature that genetic analysis of progenies from controlled hybridization permits identification of the genetic loci and their component alleles, the immediate products of which are allozymes. The capacity of allozymes to index variation reliably in tomatoes has been established by the fact that the results are concordant with observations of variation in morphological and physiological characters in all species thus far tested: *L. cheesmanii* (19), *L. chmielewskii* and *L. parviflorum* (23), *L. hirsutum* (22), and *L. pimpinellifolium* (21). Studies on the other species

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are not yet complete but enough data have been obtained to give an approximate idea of their variability patterns. Frequent reference will be made to allozyme analysis.

SOURCES OF TOMATO GERMPLASM

In comparison with crop plants in general, the status of tomato germplasm collections is relatively satisfactory. This situation can be attributed partly to the very high level of autogamy in *L. esculentum* and certain related species, which protects the purity of accessions, and to the relatively extensive recent activity in collecting new material. AVRDC maintains the largest collection of tomato germplasm, consisting of 4752 accessions in all categories in addition to numerous breeding lines adapted to tropical conditions. The second largest collection - to a large extent duplicating that of AVRDC - is the 4,163 items of the U.S. Department of Agriculture at its North Central Regional Plant Introduction Station at Ames, Iowa. A collection of some 1,600 items, specialized in tomato species, genetic, and cytological lines is maintained by the Tomato Genetics Stock Center, Department of Vegetable Crops, University of California at Davis. Smaller collections, mostly of a specialized nature, are kept at other locations.

THE CULTIVATED FORMS OF *L. ESCULENTUM*

The major source of variation used until now for tomato improvement has been assorted cultivated forms of *L. esculentum*, including breeding lines as well as the aformentioned categories of cultivars. The results have been spectacular, yet the inadequacies of this source are evident in the frequent excursions made into germplasm reserves of the wild taxa. The limitations of the cultivated sources are particularly evident in attempts to gain pest resistance and to improve color, flavor, and other quality components.

It is noteworthy that some of the most spectacular gains have been made by exploiting spontaneous monogenic mutations. The mutant of possibly greatest economic impact is determinate or self-pruning (sp) plant habit. Determinate plants are compact with precisely restricted growth and concentrated flowering. The agronomic consequences of sp are a plant form more amenable to cultivation and to hand and machine harvest and a greater concentration of fruit set than that permitted by indeterminate habit (17). Other genes that have been or are being utilized are j, j-2, and $j\text{-}2^{in}$ - the "jointless" series preventing easy abscission of fruit and retention of the undesirable pedicel stubs; hp, the fruit color intensifier; og^c, the crimson gene that partly suppresses synthesis of β-carotene, thereby improving color for certain products; nor and rin, the ripening inhibitors; and a long list of genes that condition disease resistance (references for these genes in review by Rick, 15). Genes that promote the development of parthenocarpic fruit (pat and pat-2) are receiving increasing attention by several investigators (7,8,9). One intriguing possible application of hereditary parthenocarpy is to improve yields of the hitherto highly unfruitful autotetraploids (1). Genetic changes in *L. esculentum* can be readily effected by induced mutation. An impressive array of X-ray induced mutants has been assembled by Stubbe (27, a paper that also enumerates the mutants described in previous papers in this series). Numerous mutants have also been successfully induced by neutron radiation (28) and the chemical mutagens EI (4) and EMS (5).

As already mentioned, the array of genotypic variation in cultivated *L. esculentum* is limited. Compared with variation in the wild taxa, it is minimal. A similar situation prevails in many cultigens - for instance, muskmelons (3). The extent of these limitations is delineated by the following comparisons of allozyme variation.

The overwhelming majority of *esculentum* cultivars are monomorphic at some 25 loci coding for isozymes. The exceptions consist of seven alleles, four of which are limited to the native range of the genus in the central Andes. Essentially the same situation prevails for var. *cerasiforme* (20). In contrast, 14 variant alleles have been detected at 8 of 14 tested loci in the closely related *L. cheesmanii* (19), 41 variant alleles at all of the 11 tested loci, scarcely any 2 individuals having the same genotype in certain populations *L. pimpinellifolium*, and the extent of allozyme variation is known to be even larger in the obligately outcrossed self-incompatible species. By this measure, cultivated *L. esculentum*, particularly the extra-Andean material is depauperate in variability in comparisons with the wild species.

It is not difficult to account for this remarkable uniformity of the extra-Andean cultivated forms of *L. esculentum*. As suggested by Rick and Fobes (20), "Migration of *L. esculentum* var. *cerasiforme* from its native Andean region through the great distance to Mexico was undoubtedly accompanied by frequent restriction in population size. Similar restrictions were undoubtedly experienced during domestication and transport of the tomato to Europe. Passage through such bottle necks, undoubtedly under selection pressure (Founder Principle), would have tended to reduce genetic variability. The autogamy enforced by lack of appropiate pollinators in the non-native regions would have led to rapid fixation of genes, further depletion of genetic variability, and consequent extreme uniformity."

THE WILD TAXA

In view of the restricted genetic variability of *esculentum* cultivars, it is important to assess the potential of the wild taxa, including var. *cerasiforme* of *L. esculentum* and the related exclusively wild species.

The significance of this group is epitomized by the list of genes that they have contributed for resistance to serious tomato diseases. The following thirteen examples are listed according to the source species:

L. esculentum var. *cerasiforme*: Anthracnose (*Colletotrichum* spp.), collar rot (*Alternaria solani*), verticillium wilt (*Verticillium albo-atrum*).

L. chilense: Curly top virus.

L. hirsutum: Botrytis mold (*Botrytis cinerea*), septoria leaf spot (*Septoria* sp.).

L. peruvianum: Corky root (*Pyrenochaete terrestris*), root-knot nematode (*Meloidogyne incognita*), tobacco mosaic virus.

L. pimpinellifolium: Fusarium wilt (*Fusarium oxysporum* f. *lycopersici*), gray leaf spot (*Stemphyllium solani*), leaf mold (*Cladosporium fulvum*), spotted wilt virus.

Observations on the autecology of the wild species can facilitate the search for potentially useful traits (13). The value of species collections would be greatly amplified if such information were available for each accession. A few notes by the collectors regarding the physical and biological nature of each site could yield clues as to the virtues of the respective accessions. It is particularly in the area of stress resistance that clues can often be found regarding the presence of valuable genes. Examples of such relationships are given under the respective tomato species.

L. ESCULENTUM VAR. *CERASIFORME* (DUN.) A. GRAY.

Embracing the small, cherry-fruited wild and cultivated forms, this botanical variety is now widespread throughout the tropical and subtropical regions of the world. As a matter of fact, var. *cerasiforme* is such an aggressive weed that it is difficult to ascertain its truly native region. If the native area is arbitrarily considered as the Ecuador-Peru region, which is the center of distribution of the genus *Lycopersicon*, the same interesting differences in genetic variability are ascertained. Thus, within Peru, var. *cerasiforme* is rather variable, differing from one region to another in zymotype and sometimes variable within populations. At least part of this variation seems to be attributable to introgression of genes from *L. pimpinellifolium* (25). In contrast, var. *cerasiforme* from all other regions is almost monomorphic, the same zymotype as that of the cultivated tomato prevailing (20). A possible reason for this situation was discussed in the preceding section in relation to cultivated *L. esculentum*. It is therefore reasonable that in the search for desired characters, particularly disease resistance, the Ecuador-Peru forms have contributed more than all the remaining accessions considered together.

In keeping with the aforementioned indices of genetic variability, the Ecuadorian-Peruvian forms vary to the greatest extent in their ecological adaptations. On the Peruvian coast they survive relatively xeric conditions. In the Ecuadorian-Peruvian highlands they are found in relatively mesic conditions. Eastward, they thrive in the wet tropics. Under the last mentioned conditions, var. *cerasiforme* is the only taxon of *Lycopersicon* that survives, growing to maturity and producing fruit abundantly despite the early death of *esculentum* cultivars grown under the same conditions. It is therefore logical that accessions from these regions have provided genes for resistance to such foliar fungal diseases as *Cladosporium fulvum*.

L. PIMPINELLIFOLIUM (JUSL.) MILL.

This is the most closely related of the tomato species to *L. esculentum* in respect to morphology and crossability; in fact, the interspecific cross can be made as readily as hybridizations within either species, and the F_1 hybrid and subsequent generations are fully viable and fertile.

Previously considered a relatively uniform taxon, *L. pimpinellifolium* has proved to be quite heterogeneous in the following respects. According to an extensive allozyme survey (21), it is very uniform and highly self-pollinated at the N and S margins of distribution, but becomes vastly more variable and is cross-pollinated up to 40% in north central Peru. In view of these regional differences, testing and evaluation must be done according to the extent of variability if the germplasm in this species is to be properly exploited. Relatively few individuals per accession should suffice for the marginal regions, whereas testing of the north central region requires that large numbers of individuals should be tested per accession. This species has already contributed significantly to the repertoire of disease resistances as well as improved color and other fruit quality attributes. Possession of wilt resistance might have been predicted for the following rationale. This species is found mostly as a weed in cultivated fields of the Peruvian coastal valleys. These fields are irrigated by water that is diverted by ditches from the rivers into the fields and the excess is drained back into the streams. This practice dates back to pre-Columbian civilizations, possibly some 5,000 years ago. Even prior to the establishment of agriculture, level areas bordering the streams were probably subject to flooding. This continual flushing provides ideal conditions for the spread of the soil-borne wilt diseases. Natural selection for resistance would have been intense for any wild species that evolved under these conditions.

L. CHEESMANII RILEY

This species, endemic to the Galapagos Islands, is unique for its yellow-to-orange fruit color and other morphological characters. Although *L cheesmanii* crosses easily with *L. esculentum*, the segregating generations are subject to low viability and reduced fruitfulness. Analysis of morphological characters (10) and allozymes (19) reveals that it is highly autogamous, many wild populations veritably approximating pure lines. Despite such uniformity <u>within</u> populations, genetic differences are frequently found <u>between</u> populations and races of the species.

Among the various traits that have been bred from *L. cheesmanii*, retention of fruit by the action of <u>j-2</u> and <u>$j\text{-}2^{in}$</u> genes are being exploited, particularly for cultivars bred for mechanical harvest, and thick pericarp offers opportunities for improving fruit durability (12). Our discovery of a coastal ecotype that thrives despite the high salinity of its habitat led to tests by Rush and Epstein (26) of possible salt tolerance. Their experiments demonstrated that such accessions can withstand concentrations up to 100% seawater and that this ability reflects sodium tolerance of the cells, not restrictions on uptake or translocation of sodium. The lack of disease and insect resistance often observed in field plantings is predictable because, in its isolated situation, *L. cheesmanii* evolved in the absence of such pests.

L. CHMIELEWSKII (23)

This species is characterized by slender stems, relatively simple form of leaves and inflorescences, and fruit that ripen to a greenish-white color. It is native to a restricted zone in the intercordilleran region of Depts. Apurimac and Ayacucho, Peru, and prefers mesic conditions at mid-altitudes. According to our studies of its allozyme variation, *L. chemielewskii* is moderately variable and, though self-compatible, is subject to natural cross-pollination.

L. PARVIFLORUM (23).

Similar in most morphological characteristics and autecology except for its much smaller flower size and tendency to inhabit lower, moister situations, this entity is a sibling species of *L. chmielewskii*. It occupies the same territory but extends much farther northward, approaching the Ecuadorean frontier. Like *L. cheesmanii*, it is highly autogamous and is genetically uniform; indeed, in the first survey of allozymes, no exceptions were found to a monomorphic condition throughout the species. Rick et al. (23) offer the opinion that *L. parviflorum* originated sympatrically from *L. chmielewskii*, isolation having been achieved by acquisition of autogamy. Of the two species, *L. chmielewskii* is the more amenable because it does not have the defoliator (Df) gene, which leads to much weakness and lethality in *esculentum-parviflorum* progenies (2). Accordingly, *L. chmielewskii* was chosen as the source of high soluble solids in the project to transmit this character to *L. esculentum* (14).

SOLANUM PENNELLII CORR.

S. pennellii is another green-fruited species that hybridizes readily but unilaterally with *L. esculentum*. Despite its taxonomic classification as a species of *Solanum*, *pennellii* responds to all biosystematic tests like a species of *Lycopersicon* (18). Its distribution is limited to mid-elevations in the western drainages of central Peru. Although sympatrict with *L. peruvianum* in many sites, *S. Pennellii* occupies the higher dryer elevations in situations that are the most xeric of any tomato species. The ability to cope with such dry conditions seems to be vested in the capacity of *pennellii* leaves to resist water loss (29), a characteristic currently being investigated. Preliminary allozyme analyses reveal a very high level of genetic variability - a condition that is concordant with the self-incompatibility found in all accessions except a single collection made at the southernmost extension of its range.

L. HIRSUTUM HUMB. & BONPL.

Large robust plant size, dense hairiness, green fruits, and a rank odor characterize *L. hirsutum* and distinguish it from all other tomato species. It is native to the western watersheds of Peru and Ecaudor but also extends its range east of the continental divide in Ecuador and northern Peru. It can be hybridized with *L. esculentum*, but only if the latter is used as the female parent. Frequenting moist situations, often on streambanks, *L. hirsutum* ascends to higher elevations than any other tomato species. Although not able to withstand frosts and freezing temperatures, the biotypes from the highest elevations (3,200 m) are more resistant to damage from chilling temperatures than those from lower elevations according to unpublished research of E. Vallejos and J.M. Lyons of the University of California at Davis. The freedom from insect attack that is often observed in the wild and in cultivation augurs well for the use of this species as a source of insect resistance. The pattern of genetic variability in *L. hirsutum* is remarkably similar to that of *L. pimpinellifolium* in respect to extreme uniformity at the northern and southern extremities, with increasing variability toward a maximum north central Peru. The least variable accessions are self-fertile and the most variable in the center of the distribution are self-incompatible (22).

L. PERUVIANUM (L.) MILL.

This species and *L. chilense* form a subgeneric complex that is separated from the rest of the genus by a severe incongruity barrier. The cross with *L. esculentum* can be made normally only with great effort and application of sterile culture. The species is distributed rather widely in Peru along the coast and western drainages, extending southward into northern Chile and northeastward irregularly into the canyon of Rio Marañon. *L. peruvianum* is undoubtedly the most variable of the tomato species. The outcrossing enforced by the strict self-incompatibility prevailing throughout this species undoubtedly provides high generic variability. At least 35 races can be distinguished; furthermore, within most races marked variation in morphology and zymotype can be detected between populations and between individuals in populations. The ecological preferences are fairly constant, *L. peruvianum* generally being found in mesic to dry situations throughout its range. Because it is immensely variable and because hybridizations are difficult, only the tiniest portion of the available germplasm of this species has been exploited by breeders.

L. CHILENSE DUN.

Although most closely resembling *L. peruvianum*, it can be distinguished by several morphological characters. The ranges of the two species overlap in southern Peru and northernmost Chile, but the range of *L. chilense* extends farther south in the latter country, at least to the latitude of Taltal. Like *L. peruvianum*, it is entirely self-incompatible and relatively variable, although the paucity of accessions does not allow a good assessment. The ecological preferences are similar but *L. chilense* tends to prefer dryer situations. Since hybridizations with *L. esculentum* are somewhat easier to make with *L. chilense* than *L. peruvianum*, the former is a more accessible source of desired germplasm. Like *L. peruvianum*, its germplasm potential has scarcely been realized.

UNIFORMITY VS. DIVERSITY

Collections of tomato germplasm are hardly worth acquiring if they are not effectively utilized and properly maintained. From the foregoing considerations of mating systems and the nature of genetic variability in the tomato species, it is clear that utilization and maintenance must be tailored to fit the requirements of each species, and, in certain cases, to regional types within the species. For highly autogamous accessions, which are usually monomorphic, a few plants suffice for testing and propagation. For the highly outcrossed, highly polymorphic accessions, these activities must be conducted on a much larger scale to be effective.

No system can preserve indefinitely and exactly the original variation in accessions of the obligately outcrossed species, but every effort should be made to approximate it as closely as possible. Induction of flowering in day-length sensitive biotypes and obtaining sufficient reproductive isolation pose additional problems in this group. This topic is treated in greater detail elsewhere (16).

CLOSE VS. DISTANT SOURCES

Most specialists maintain that, in seeking specifically desired characters, the easiest sources of germplasm should be exploited first, the most distantly related forms being utilized only as a last resort. While this policy is reasonable from the standpoint of achieving immediate goals with the least expenditure of time and effort, it leads to neglect of the tremendous reserves of germplasm in the wild species. Breeding from the latter is often a long, tedious, and sometimes unsuccessful enterprise. In such projects, the breeder attempts to transfer one or a few desired characters, but avoids including the great bulk of the wild genes, nearly all of which code for unacceptable phenotypes.

These considerations reveal the need for a type of genetic activity which has become known as "developmental breeding." Instead of continuing the breeding program from the initial crosses between the cultivated and wild parents to the ultimate conclusion of finished cultivars, it strives only to transfer the genes from the wild parent into a genetic background of the cultivated species and to evaluate their expression there. By thus incorporating the new genes in a relatively advanced form, the investigator provides material that is far more useful to the plant breeder than the wild accession in which the desired genes were first discovered.

Developmental breeding also serves other important purposes. The effects of countless other genes of the wild parent may be observed as they are introgressed into the cultivated milieu. Also in the course of such manipulations "novel variations" are first observed. These frequently encountered deviating characters, which are not normally detected in the parents and are therefore unpredictable, have been discussed elsewhere (24, 11). Additional interesting aspects of such projects are the inheritance of wild characters in the new background, the manifestations of incongruity, hybrid sterility, and other causes of unfruitfulness, all of which bear importantly on evolutionary theory. Despite these highly useful aspects of developmental breeding, it is an activity that is badly neglected currently in respect to support and interest.

The opportunities for research and service to other workers in the area of developmental breeding are boundless as the following considerations reveal. The tomato species are not homogeneous entities. Whereas certain characters (for example, the taxonomic key characters) are constant within a given species, a vastly larger number are variable. The behavior of a given wild allele in the *esculentum* background will not be known until it is transferred there. It therefore follows that an unlimited field of experimental breeding exists until answers are known to all questions that might be asked about the outcome of introgression, even from a single wild species. *L. peruvianum* might be considered as an example. As indicated above, the extent of genetic variation in this species is enormous at the levels of race, population, and individual. Now, the dimensions of a project aimed at assessing the breeding potential of all variations existing in *L. peruvianum* when transferred into *L. esculentum* strains the imagination and is, of course, physically impossible on any conceivable basis of research resources. Yet, it must be remembered that this source of germplasm is available for exploitation and may serve as a rich resource in the future. It is doubtful, furthermore, whether any significant amount of wild germplasm will be utilized until developmental breeding is vigorously promoted.

It can be concluded that the opportunities for further improvement of the tomato are bright. It is futile to debate the relative potential value of the major sources of variation. In the long run they may all play important roles; to neglect any of them would be shortsighted.

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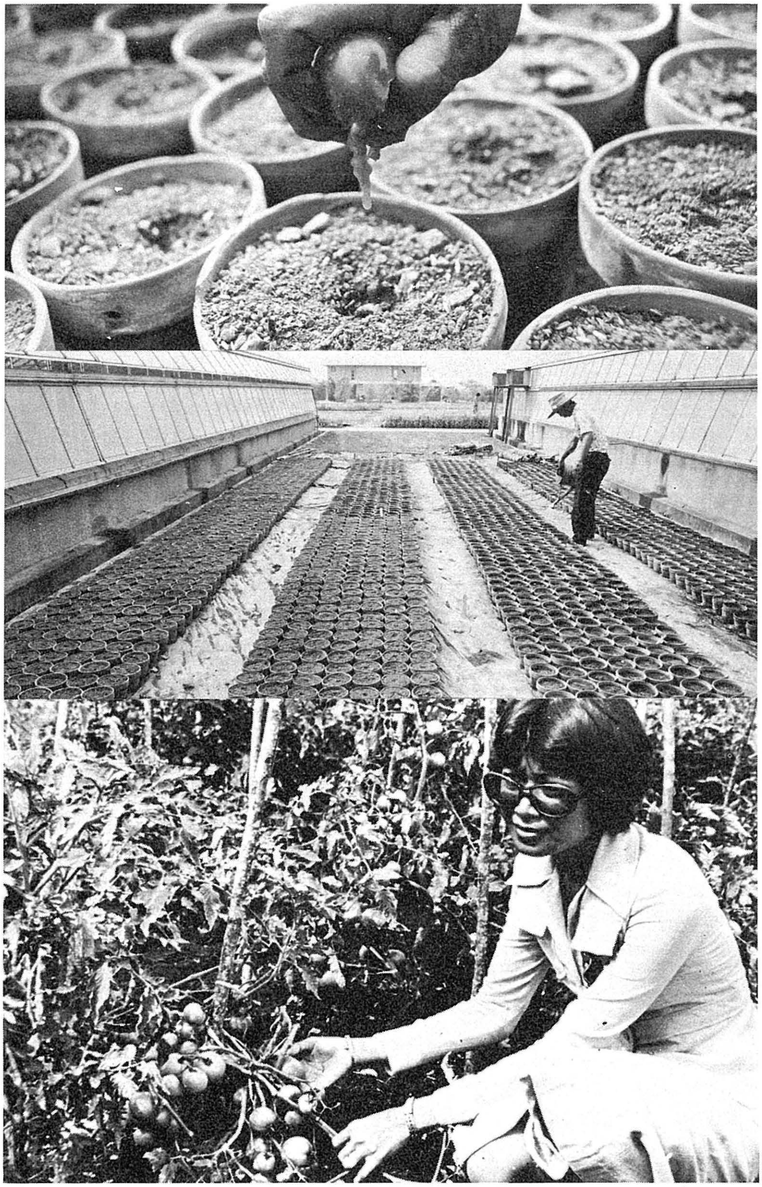

Top to bottom: Hybrid populations are advanced by using a single seed to perpetuate succeeding generations until the desired degree of homozygosity is achieved. AVRDC uses the single seed descent method in its search for heat-tolerant tomatoes resistant to bacterial wilt. Ms. Melor Rejab examines tomatoes at MARDI station in Malaysia.

SINGLE SEED DESCENT - A NEW APPROACH TO THE IMPROVEMENT OF TOMATO IN THE TROPICS

T.S. Tee[a], R.L. Villareal[b] and M. Rejab[a]

The tomato (*Lycopersicon esculentum*) is one of the most popular vegetables in the world and is becoming an important vegetable in the tropics. Recent statistics place the tomato as the most important vegetable in Asia and Southeast Asia (3). Taiwan, Philippines, Thailand, and Sri Lanka regard it as their most important vegetable. It ranks second in Japan, Indonesia, and Bangladesh, and third aftercabbage and chillies in Malaysia. However, tomato production in the hot humid tropics is confronted with a number of problems. Diseases are the major limiting factor. In the lowlands, bacterial wilt (*Pseudomonas solanacearum*) is the principal disease, whereas, in the highlands, late blight (*Phytopthora infestan*) is common. Another problem is temperature, which causes poor fruit set and, thus, affects yield. Although chemical sprays are available for crop protection, the most practical means to overcome problems of tomato cultivation in the tropics is through systematic breeding of disease resistant lines with tolerance to the high tropical temperatures.

This paper describes the effectiveness of single seed descent (SSD) as a new approach to the improvement of tomatoes in the tropics, and emphasizes the importance of international cooperation to bring about rapid development of locally adapted technology for the farming community.

HANDLING OF SEGREGATING POPULATIONS

Hybridization followed by evaluation of the segregating progenies constitutes the basis of breeding procedures for many self-pollinated crops. Pedigree and bulk-population breeding are two classical methods used in handling hybrid-derived populations of self-pollinated crops.

The pedigree method requires selecting superior progenies at each segregating generation and maintaining records of all parent-progeny relationships. This method is laborious and expensive, thus population size is generally kept small. The restricted population size minimizes genetic recombination and reduces genetic variability. Hence, the breeding potential of the parents that enter into the hybrid may not be fully exploited.

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The bulk-population breeding method involves harvesting the plants in bulk and taking a random sample to generate the next cycle. Large populations can be handled inexpensively. However, the efficiency of the bulk-population method is restricted owing to the possibility of loss of good genotypes through natural selection as the hybrid population approaches homozygosity (1, 13).

The SSD, first developed by Goulden (10) and later modified by Brim (5), appears to have the potential of overcoming the problems of competition in bulk handling hybrid populations. This scheme involves advancing hybrid populations by taking a single seed from each plant and compositing the seed to perpetuate the succeeding generation until the desired level of genetic homozygosity is obtained. Essentially, the system ensures equal reproductive capability for every individual plant at each generation. It is expected that the SSD method will maintain wider genetic variability than will classical pedigree or bulk methods. Empig & Fehr (9), compared 4 methods of developing soybean lines and concluded that SSD minimized the effect of natural selection and allowed the use of greenhouse and winter nursery environments. In addition, SSD was most economical in terms of money spent for labor. In the computer simulation studies by Casali & Tigchelaar (6), the SSD was found most effective where several traits of differing heritabilities are under simultaneous selection.

The SSD method of rapid generation advance in tomato was initiated at AVRDC in 1974 using populations from crosses involving 3 parents with resistance to bacterial wilt (2). According to Villareal (14), emphasis was given to the wilt pathogen because it exists in a number of pathotypes throughout Asia. The pathogen could not be imported to Taiwan primarily because of the danger of introducing a virulent pathotype into the country. Besides, it was felt that the development of bacterial wilt-resistance lines should be undertaken in the country where the tomatoes would be eventually grown so that the role of genotype, pathogen, and environment in the expression to wilt reaction could be fully considered. In addition, under the pedigree and bulk-population breeding, a selection made in a specific location may not be necessarily the best genotype in other locations. For example, a heat-tolerant and wilt-resistant genotype identified at AVRDC in a particular climate will not necessarily be well-suited to other areas of the tropics. It is also possible that the genotypes discarded at AVRDC would do well elsewhere. This will not be a problem when SSD is used because the original variability in the F_2 is advanced through to the F_5. And the F_5 lines are the ones sent to cooperators.

PROCEDURES USED FOR SSD (2)

1. Ten F_1 plants are grown to obtain as many F_2 seeds as possible.

2. 2,000 F_2 plants are grown and 10 F_3 seeds of each genotype are retained.

3. Two F_3 seedlings are grown per genotype but only one plant is allowed to produce fruit.

4. Ten F_4 seeds are collected from each genotype. Again, two seedlings are grown, but only one is allowed to produce fruit.

5. All the F_5 seeds are collected from each genotype and are available to send to cooperators for screening at various locations.

6. Selections are made by cooperators for F_5 plants with plant traits desired at that locality.

7. Seeds from the selected genotypes are then increased in the F_7 generation.

8. At each location, the cooperators can introduce the selected cultivars into appropriate seed production and certification programs.

Where selection in the early generation could be practiced, a modified SSD is suggested by Villareal (14). Casali and Tigchelaa (7) found in tomato that a pedigree selection in the F_2 and F_3 generations, followed by SSD, would maximize breeding progress. Pierce (11) showed also that SSD following one cycle of pedigree selection would result in progress equal to that obtained through the pedigree system alone.

AVRDC TOMATO COOPERATIVE PROGRAM

AVRDC operates cooperative research programs with various tropical countries, particularly in Asia, aimed at developing technologies to improve tropical vegetable production. In 1977, AVRDC supplied 1,329 seed packets of elite breeding lines to scientists in more than 40 countries (4).

We started to receive AVRDC materials in Malaysia in 1974, and evaluated them for 4 consecutive seasons in the same field. Our latest tests indicate that SSD lines with heat-tolerance and bacterial wilt resistance have performed exceptionally well in the peat soil (Tables 1 and 2). Considering the complete destruction of check varieties, "Roma" and "Banting" (a local cultivar), the SSD lines were impressive. Survival rate exceeded 50% and, in certain lines, 90%. The results clearly indicate the high degree of tolerance to the bacterial wilt pathogen. In addition, a number of breeding lines had fair to excellent fruit-setting, as evidenced by their good yields (Tables 1 and 2). We consider selection for resistant genotypes a breakthrough in Malaysia. Formerly, we could not grow tomatoes at MARDI without grafting them to wilt-resistant eggplant.

In another separate experiment in Malaysia, SSD lines together with other AVRDC selections were compared. The tomatoes were grown on new peat areas where bacterial wilt symptoms have not been observed. The entries gave comparable yields (Table 3). We graded the tomato fruit into: >5 cm and <5 cm. Using these grades, 4 AVRDC breeding lines were bigger than Roma in the >5 cm category but comparable in <5 cm category.

Thus far, the results of evaluating CL 555 with pedigree VC 8-1-2-1/Venus//Kewalo, both at AVRDC and in Malaysia and Papua New Guinea, clearly show that selections from a given cross differ from country to country primarily because of varied environmental conditions (i.e. different

Table 1. The best yielding VC 6-1-1p/Saturn//Kewalo in a preliminary trial; 1977, Malaysia.[a]

SSD no.	Marketable yield per plant	Marketable yield ha	Fruit size	Days to flower	Survival[b] rate
	-g-	-t/ha-	-g-	-days-	-%-
16	598	30	42	34	85
43	530	26	24	23	90
14	525	26	42	27	65
25	438	22	26	25	60
47	420	21	56	28	80
23	409	20	52	23	65
44	362	18	33	26	70
12	350	17	48	28	70

[a]Planted Nov 16, 1976 and harvested Jan, 1977; data are means of 20 plants. [b]Under natural epiphytotic of *P. solanacearum*; check cultivar was completely wiped out by the disease.

Table 2. The best yielding VC 9-1-2-9B Venus//Kewalo in a preliminary trial; 1977, Malaysia.[a]

SSD no.	Marketable yield per plant	Marketable yield ha	Fruit size	Days to flower	Survival[b] rate
	-g-	-t/ha-	-g-	-days-	-%-
20	775	38	38	27	80
30	445	22	41	28	80
18	389	19	54	32	80
34	336	17	50	30	55
45	303	15	58	30	70
35	288	14	49	30	70
26	285	14	34	32	70

[a]Planted Nov 16, 1976 and harvested Jan, 1977; data are means of 20 plants. [b]Under natural epiphytotic of *P. solanacearum*; check cultivar was completely wiped out by the disease.

strains of bacterial wilt, temperature fluctuations, etc.). However, it is also possible to select a genotype with wider adaptability, as in the case of SSD number 12, which gave the highest yield both in the AVRDC and Malaysia trials (Table 4).

Table 3. Yield and other traits of AVRDC breeding lines compared to a check cultivar; 1977, Malaysia.[a]

AVRDC selection (or acc. no.)	Pedigree (or cultivar name)	Marketable yield	Fruit set >5 cm	Fruit set <5 cm
		-t/ha-	-----g-----	
555 F_5-16	VC 8-1-2-1/Saturn//Kewalo	31	54	24
555 F_5-18	VC 8-1-2-1/Saturn//Kewalo	31	80	40
555 F_5-49	VC 8-1-2-1/Saturn//Kewalo	29	46	24
7d-1-0-1-0-0	VC 11-1-2-1B/Florida MH-1	33	74	38
9d-0-9-1-0-0	VC 11-1-2-1B/Saturn	34	64	38
32d-0-1-1-0-0	VC 9-1-2-3/Venus	35	82	40
(115)	Roma[b]	27	56	36
	LSD .05	ns	4	5
	.01	-	5	6
	C.V. (%)	16	12	13

[a]Data supplied by Mr. Leong Ah Chye and Dr. Thean Soo Tee, Malaysia Agricultural Research and Development Institute, Malaysia; Planted May 5, 1977, and harvested 4 times starting Jul 16 and ending Aug 8; data are means of 4 replications. [b]Check cultivar.

Table 4. Marketable yields of the best SSD lines from VC 8-1-2-1/Venus//Kewalo in preliminary trials, AVRDC, Malaysia and Papua New Guinea.

AVRDC[a]		Malaysia[b]		Papua New Guinea[c]	
SSD no.	Yield	SSD no.	Yield	SSD no.	Yield
	-t/ha-		-t/ha-		-t/ha-
12	20	12	36	22	48
27	20	47	24	15	42
15	20	16	24	18	38
14	19	18	24	24	34
Green Fruit (check)	1	Red Cloud (check)	0	2	30

[a]Planted Aug 26, 1977; means of 2 replications. [b]Planted Jul 12, 1976; means of 2 replications. Both AVRDC and Malaysia trials were under natural epiphytotic of *P. solanacearum*. [c]Data supplied by Mr. K.J. Blackburn, PIHRS, Laloki, PNG; means of 2 replications.

We noted that some lines developed through the pedigree method could outperform some SSD derived lines. For example, in the Indonesia trials SSD line Cl 503 F_5-25 was not as good as the pedigree lines (Table 5). Low yields in this trial were due to inappropriate management practices. The plants were trained to a single stem thus limiting their production potential. These materials, except "Venus" and "Bonset", are all determinate , and do not require training to a single stem.

Table 5. Yield of the best entries in Cipanas observational trial; 1977, HRI, Indonesia.[a]

AVRDC selection (or acc. no.)	Pedigree (or cultivar name)	Marketable yield		Survival[b] rate
		-kg/plot-	-t/ha-	-%-
32d-0-25-0	VC 9-1-2-3/Venus	3.92	11	100
32d-0-1-13-0	VC 9-1-2-3/Venus	2.98	8	100
32d-0-1-1-0	VC 9-1-2-3/Venus	2.38	7	83
(L 95)	Venus	1.90	5	78
CL 503-F_5-25	VC 9-1-2-9B/Saturn//Kewalo	1.64	5	71
-	Bonset (check)	1.05	3	64
	LSD .05	0.56		-
	.01	0.75		-

[a]Data supplied by Dr. H. Sunarjono and Mr. S. Sahat, Horticulture Research Institute (HRI), Pasar Minggu, Indonesia; planted Oct, 1976 and harvested Jan, 1977. [b]Under natural epiphytotics of *P. solanacearum*.

IMPACT OF SSD

One objection to SSD is genetic drift or a great loss of desirable alleles (12). This objection, however, could be partially overcome if large populations could be maintained to advance generations. With large populations, gene frequencies could be stabilized since each plant is represented in each succeeding generation. Thus every individual plant would have equal opportunity of being represented at each generation until the final selection to isolate potential lines. AVRDC has demonstrated handling as many as 2,000 F_2 lines as initial materials using the SSD. Another disadvantage is that much of the materials advanced through SSD will be worthless. Our experiences with tomatoes suggest that the advantages of using SSD outweigh its disadvantages.

The advantages of SSD are: generation time can be shortened and competitive effects among heterozygous individuals can be averted as testing is delayed until the F_5 generation when plants are more or less homozygous (8). Another advantage of SSD, particularly in developing countries, is that less supervision by a trained plant breeder is required to carry out simple yield trials. In these countries, there is a lack of trained plant breeders assigned to vegetable breeding.

However, the more important aspect of SSD at AVRDC is the cooperative evaluation of advanced generation lines at various cooperating national programs. At F_5, the segregating population is approaching homozygosity and if any of the line should perform well in a specific country, the line can be developed into a variety and seed produced quickly for the farming community. Selections are made by the cooperator himself at a specific climatic condition and for the consumer demands of a particular region. Therefore, plant breeders of national programs become active cooperators with an international agricultural research center. When the time comes to introduce the selected cultivar into their seed production and certification programs, they will do so as active participants in the creation of such cultivars. Thus, AVRDC's SSD technique for tomatoes, and the cooperative projects between AVRDC and various local and national programs in the tropics, can help accelerate the development and adoption of new tomato varieties.

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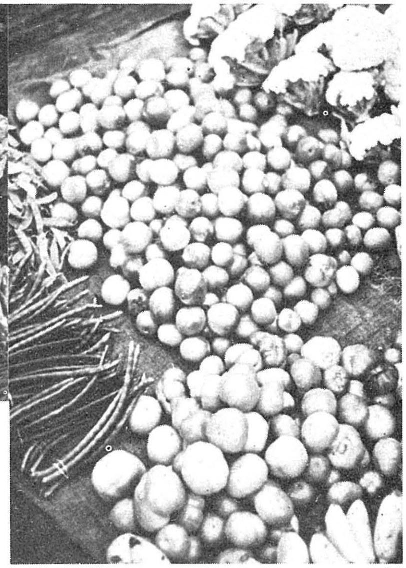
Wholesale vegetable market in Bangkok, Thailand.



The breeding program at Khon Kaen University aims to increase production of high quality tomatoes for markets like this one in Surin

A market in Surin, Thailand offer locally grown tomatoes.

Thaworn Kowithayakorn, tomato plant breeder.

TOMATO IMPROVEMENT PROGRAM AT KHON KAEN UNIVERSITY

Thaworn Kowithayakorn[a]

INTRODUCTION

Ninety percent of the work of the tomato improvement program at Khon Kaen University is processing tomatoes because of the high potential crop yield per unit area. In addition to the high crop yield, farmers can grow processing tomatoes on a large scale and seem to have fewer marketing problems than with table tomatoes. In Thailand, at the moment, factories concerned with tomato products are confronted with the problem of insufficient raw materials for the machines, and the fruit quality does not meet standard requirements.

Low crop yield per unit area is responsible for the poor quantity and quality of processing tomatoes. Factors involved with low crop yield are: hot climate, too high a temperature at fruit setting (Table 1), and frequent attack by pathogens, such as virus, nematodes, and bacterial wilt. Consequently, the incidence of *Cercospora* leaf spot, *Sclerotium* stem rot, early blight, late blight, and leaf mold are very common. Poor quality is likely due to poor fruit color, low solid content, high pH, low total acidity, low sugar content, cracked fruit susceptible to attack by microorganisms, hollow fruit, and low vitamin C content.

The key to sufficient production of good quality tomatoes is to breed for high yield and good quality when grown under a hot and humid climate. Attempts to achieve this goal have been made by introducing 35 processing tomato varieties and 325 table tomato varieties to Khon Kaen University between 1970-1977. It is unfortunate that few varieties have shown both high yield and good quality even when the plants were grown under a mild climate (Table 2). However, such high yields were drastically reduced under wet conditions (Table 3).

BREEDING PROGRAM FOR HIGH CROP YIELD

Observations suggest that low tomato crop yield in Thailand is associated with high temperature, virus diseases, nematodes, and bacterial wilt.

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Table 1. Mean yield of some tomato varieties as influenced by hot and mild weather during fruit setting period.

Varieties	Mild weather 10 Oct - 15 Mar 1972/1973	Hot Weather 28 Dec - 20 Apr 1973
	---------t/ha	-------------
Hawaii 476	79.7	59.1
Hawaii N_{55}	46.1	36.5
Rehovot 2	64.3	46.6
Rehovot 219	78.0	33.0
Rehovot 0827	77.8	-
Chosen Elon	72.2	42.5
NO 217	65.2	49.2
Royal Ace	44.4	36.5
Nes-Ziona 4	70.3	33.4
Tropic	44.3	25.9
Tropigro	70.2	42.3
Determinant Marmond	63.0	38.4
Summer Marmond	76.6	33.9
LSD .05		14.5

<u>To obtain high temperature resistant varieties</u>.

1. Select healthy plants with dark green, thick leaves, big stems, heavy fruit set, and many seeds per fruit when grown under high temperature conditions.

2. Select plants with a high percentage of pollen viable under high temperature conditions. Only a few pollen tubes can penetrate the style and reach the egg under high temperature conditions (9). Therefore, it is necessary to determine the number of pollen tubes which can penetrate the style and fertilize the eggs. This can be done by using the Kho and Bair method (6). Plants that have more fertilized eggs under high temperature conditions should be selected. The selected plants will be crossed with plants that are good for other characteristics.

3. Attempt to get tomatoes flowering in hot weather and select the plants or lines which produce a short stigma under the anther cap. The best time to check stigma position is around 10 a.m.

<u>To obtain virus resistant varieties</u>. The most important virulent virus for tomatoes grown in Thailand is tomato yellow leaf curl (7). This kind of virus cannot be transmitted by a mechanical transmission like TMV, CMV, and tomato bushy stunt. However, virus transmission can occur

Table 2. Quality and quantity of crop production for some processing tomato varieties grown under a mild weather (28 Oct - 20 Mar).

Varieties	Soluble solid brix	pH	Titratable acidity in % citric acid	Total solid	ascorbic acid	Sugar acid ratio	Lycopene content	Yield
			-%-	-%-	-mg/100g		-mg/100g	-t/ha-
KKU-I1 (Gamad/Parker)	3.2	4.68	0.308	4.72	17.57	10.39	6.37	34.6
KKU-I2 (Gamad/Parker)	3.0	4.52	0.280	4.46	20.0	10.71	8.58	34.0
VF 145 B 7879	3.5	4.55	0.399	4.89	26.06	8.77	6.26	29.3
Chico Grandee	4.0	4.85	0.266	5.15	20.0	15.04	7.83	25.2
Chio - III	3.0	4.72	0.287	4.43	14.54	10.45	7.24	34.5
VF 315	3.0	4.88	0.245	4.06	15.76	12.24	4.61	28.0
VF 145 - F_5	3.0	4.61	0.366	4.47	19.39	8.93	4.31	22.3
Napoli	4.0	4.82	0.266	5.5	19.39	15.04	5.83	35.5
VF 317	4.0	4.67	0.301	5.72	19.39	13.29	5.88	25.3
Mecheast 22	4.0	4.85	0.329	5.39	14.54	12.16	6.81	24.9
VF 198	3.0	4.78	0.266	4.81	15.15	11.28	4.47	17.5
Saladette	4.0	4.75	0.336	5.68	21.21	11.90	4.67	27.0
LSD .05								7.3
LSD .01								7.7

Table 3. Effects of mild climate and wet weather on the mean yield per plant of some tomato varieties.

Varieties	Oct 1975 - Feb 1976	Jun - Sep 1976
	------------g/plant------------	
Mecheast 22	2,900	270
F_1 19-1 x 96	3,850	-
NO 1955F	4,300	380
KVFN	2,000	950
Improved Harbot	3,500	198
Up 1169	2,600	460
No 2321	4,000	0.090
Ohkan	3,400	0.080
F_1 - Shi Kwang No 2	3,600	-
VF 317	2,500	250
Fukugo Taiyo	2,920	-
Tropic	4,100	390
Makheakleab	3,300	480
Master No 2	3,160	-
Lieu Guan	2,750	310
Red Globe	3,620	0.060
VF 317	3,300	180
VF L-13	2,000	260
Romulus VFN F_1	3,100	47
Chico - Grandee	3,300	0.030
Topset RR F_1Hyb. R.S.	3,100	220
VF 198	2,800	460
A.V.R.D.C. L-22	2,800	430
A.V.R.D.C. L-15	2,900	520
All Season	2,600	120
VC 9-1	2,600	330
L. Pimpinellifolium	1,200	610
Hawaii N 55	2,900	280
Fara Dale	4,000	260
Marglobe Selection	3,700	430
73-556-1-4-5-6	3,000	360
VC 48-1	2,800	340

Table 3. (cont.)

Varieties	Oct 1975 - Feb 1976	Jun - Sep 1976
Elon-Hawaii 476	2,920	380
AIYR - 0	2,800	-
VF 145 F_5	3,100	370
Spring Giant F_1	2,500	240
Mecano VF	2,000	220
Supermarket	2,750	150
Ailsa Graig	3,820	310
Ohtori	2,860	340
Marglobe Selection	2,940	430
Saturn	3,860	380
Venus	4,000	460
Houryoku	3,900	310
No 2201	3,950	260
Fuerteventura	2,780	-
Tropic Gro	3,640	380
VC 14-1	2,680	330
Seda	2,830	390
Romulus VFN F_1 (H)	2,800	370
Nesziona - 4	3,250	280
Maui	2,620	230
Summer Giant F_1	2,600	190
Napoli VF	3,300	420
Rihovet 2	3,370	210
Wase Daruma	3,800	290
Asahikari	3,000	200
Fukuju No 2	2,800	170
Hownishi	3,600	360
Chico III	3,200	360
VC 11-1	3,000	490
Homare	4,500	130
Gamad	3,200	340

when grafting the plants. Nevertheless, the grafting method used for virus transmission in the screening process to obtain resistant plants is disadvantageous because it is labor intensive and time consuming.

White fly (*Bemisia tabaci*) is an insect vector able to transmit the tomato yellow leaf curl (2), whereas *Myzus persicae*, *Niphotettix virescens*, and *Nilaparvata lugens* are unable to do so. Using *Bemisia tabaci* to induce this symptom may be easier than grafting.

Generally, the inoculation method for tomato yellow leaf curl is not as simple as the one for TMV or CMV. An effective method or special techniques for screening resistant genes for this virus should be developed. Irrespective of high potential for resistant genes of tomato plants, tomato yellow leaf curl virus should be inoculated with plants in subgenus *Eriopersicon*.

Recently, the inoculation method developed at Khon Kaen University seems to give promising results. It is undertaken by inserting a small piece of stem tissue from a tomato yellow leaf curl plant into another plant stem.

<u>To obtain nematode resistant varieties</u>. There appear to be two well known species of nematodes which are considered dangerous to tomato production in Thailand: *Meloidogyne incognita* and *M. javanica*. In practice, there are two steps involved in getting nematode resistant varieties:

1. Growing tomato varieties that are known for nematode resistance, such as *Lycopersicon peruvianum* D.I. 128657 (3), HES 4521 (4), Kewalo and Anahu (1), VFN8 and VFN36 (5), in soil inoculated with *M. javanica* and *M. incognita*. At high soil temperature (35°C), these nematodes produce more viable eggs than in the lower temperature ranges (10). The varieties or lines that show a high resistance to the nematodes will be chosen. The chosen plants are then crossed with a desirable variety which is good for other characteristics.

2. Grow hybrid plants or backcrossed plants in the presence of a high population of nematodes for 40-50 days. This is followed by checking the occurrence of nematode galls. Plants with nematode galls are discarded, whereas those withut nematode galls will be planted. The screening process is continued until the fifth generation where the uniformity of resistant lines is assured.

<u>to obtain bacterial wilt resistant varieties</u>. The study of bacterial wilt (*Pseudomonas solanacearum*) strains is important to Thailand because the virulent strain has not been reported yet. Simultaneously, there is also a need to learn which varieties of tomato possess resistant genes.

To meet the above objective, screening for the resistant varieties is the first step. Normally, resistant lines can be obtained by growing tomato plants in soil inoculated with the virulent strain of bacterial wilt at a controlled soil temperature of around 32°C, and selecting the plants that are not susceptible. The resistant lines are then crossed with the desirable variety which lacks resistant genes. AVRDC (1) reported that bacterial wilt in tomato is controlled by multiple recessive genes. Hence, better chances can be expected when two or three-way crosses are employed.

BREEDING PROGRAM FOR HIGH QUALITY FRUIT

The most important qualities of fruit required for processing tomatoes are a dark red color, high solids content, low pH, and low fruit crack. The fruit analysis of tomatoes is fundamental in this program. Data obtained from this analysis will give information about chemical quality (Table 4). This will suggest whether they are desirable characteristics or not. Varieties with good characteristics will be used as breeding material in the crop improvement program.

To obtain desirable fruit color. During the growing season plants should be supplied with sufficient K, but not an excess of N fertilizer. Select plants with all fruit well covered with leaves. Mature fruit are light green, or a pale red color without green shoulder on plants which have a high lycopene content when the temperature is above 25°C.

All plants in the subgenus *Eulycopersicon* should be used for crossing in order to increase the chance of red-colored fruit. Using varieties that possess a crimson gene (og^c) or high pigment gene (hp) are advantageous, while plants with ring gene, apricot gene, high fiber content, or green seed jelly should be avoided.

In situations where crossing with subgenus *Eriopersicon* is necessary, backcrossing to subgenus *Eulycopersicon* for a few generations is required.

To obtain varieties with high solid content. A high solids content is an important economic factor for making paste. Using high solids content tomatoes will reduce the cost of a product. This is mainly due to the large volume of material obtained and the short processing time.

Normally plants with thick and many leaves are associated with high solids content. Therefore, such plants should be selected and analyzed.

While sampling, fruit should be taken from plants that have received the same amount of water in order to get correct results.

Plants with a high solids content will be crossed with other desirable varieties. Only progeny with high solids content are then selected.

To obtain varieties with fruit having a low pH. Factors like water supply and fruit age can mislead the analysis of fruit pH. Therefore, all plots should be supplied with the same quantity of water. It is also important that fruit of the same age be used when sampling for pH analysis. The number of days after pollination and fruit color are good indicators for maturity.

Generally, firm fruit are related to low pH. Thus, selecting plants with firm fruit is the selection criteria. In crossing for improvement of low pH, tomato lines with low pH are often used as the mother plant. In making the selection, plants with more jelly in the fruit cavity than seed or placenta are preferable. Plants with hollow fruit are discarded.

To obtain crack-resistant varieties. Desired characteristics for this purpose are plants or lines with thick and big leaves, shallow fruit shoulder, small fruit stems, and small numbers of fruit cavities.

Table 4. Analysis of fruit chemical quality of some tomato varieties in KKU collection.

Varieties	Soluble solid brix	pH	Acidity % citric acid	% Total solid content	Fruit color[a] skin	Fruit color[a] flesh
			-%-	-%-		
Fire ball	3.0	4.62	1.75	5.1	O(g) 28A	R(g) 45A
Floradil	4.1	4.22	2.9	5.61	O(g) 28A	R(g) 47A
Roma VF	2.6	4.23	2.35	5.1	O(g) 28A	R(g) 47A
Homestead 24	2.0	4.35	3.9	4.671	OR(g) 31A	R(g) 48A
Mecheast 22	3.8	4.45	2.2	5.87	OR(g) 28A	R(g) 45B
All season	3.4	4.47	2.4	5.81	O(g) 25A	R(g) 47A
Rijk Zwaan No 862	4.0	4.33	2.05	6.38	O(g) 25A	R(g) 47A
Rijk Zwaan No 830	4.0	4.25	1.65	6.3	O(g) 28A	R(g) 39A
Rijk Zwaan No 1955	4.5	4.15	3.25	7.69	OR(g) 32B	OR(g) 34A
Topset FR	4.0	4.27	2.6	6.33	O(g) 28A	OR(g) 34A
UP 1169	3.5	4.04	3.5	5.3	O(g) 25A	R(g) 44C
VC 11-1	4.0	4.31	3.35	6.209	O(g) 25A	R(g) 47B
VC 9-1	3.0	4.32	2.3	4.5	OR(g) 31A	OR(g) 34A
Spring Giant	3.0	3.59	2.3	4.675	O(g) 28B	OR(g) 34A
Nagecolang	3.0	3.52	2.3	6.285	O(g) 28C	R(g) 42C
Futurobrid	3.8	4.25	2.2	6.18	R(g) 51A	R(g) 47B
Multicross A-12	5.0	4.25	3.1	6.56	O(g) 28B	OR(g) 34A
Eilon x Hawaii 476	3.0	4.31	2.4	5.62	OR(g) 32B	OR(g) 34A
323/72	4.0	4.44	2.9	7.203	O(g) 28A	R(g) 45A
Chico Grande FR	3.8	4.55	1.95	4.84	R(g) 44A	R(g) 43B
Mecano VF	3.1	4.42	1.5	-	O(g) 28A	R(g) 42A
Romulus VFN	2.0	4.17	1.7	4.1	R(g) 42A	OR(g) 34C
ASAHIKARI	4.8	4.13	3.15	6.573	R(g) 44A	R(g) 47B
Lyc. pimpinallifolium 56241	4.0	4.41	4.15	5.493	OR(g) 34B	R(g) 40A
Vagabond	4.0	3.41	2.9	5.978	OR(g) 31A	R(g) 47B
Ailsa Craig	4.0	3.78	-	5.864	OR(g) 31A	OR(g) 34A
Fuertaventura	4.0	4.47	2.5	5.24	O(g) 28B	R(g) 47A
Romano NR	2.2	4.25	2.35	4.9	OR(g) 34A	R(g) 45B
ACE improved	VF	4.67	1.7	8.21	OR(g) 34B	R(g) 47A
C 28 FR	4.0	4.45	18.85	6 03	OR(g) 34B	R(g) 47B

Table 4. (cont.)

Varieties	Soluble solid brix	pH	Acidity % citric acid	% Total solid content	Fruit color[a] skin	Fruit color[a] flesh
			-%-	-%-		
Roforto VFN	2.4	4.38	1.6	4.94	O(g) 28A	R(g) 42A
NapoLi VFN	4.0	3.37	2.0	5.26	OR(g) 33A	R(g) 46B
ES 58 FR	2.8	4.8	2.2	5.37		
Money cross	4.0	4.27	2.45	6.68	O(g) 28A	R(g) 45C
Stacos	3.9	4.51	2.2	5.48	OR(g) 34B	OR(g) 34A
Money dor	4.0	3.42	2.4	5.978	O(g) 28A	R(g) 42A
Itapak	3.0	-	1.9	5.192	O(g) 28A	R(g) 47B
Primset	3.0	3.58	2.3	5.0	O(g) 24A	R(g) 42A
Red Cloud	3.0	4.32	2.3	4.89	O(g) 28A	R(g) 39A
Tiny Tim	2.9	4.4	2.6	4.43	R(g) 44B	R(g) 45B
Lony yun	3.9	4.51	2.2	5.48	O(g) 25A	R(g) 42A
Trohigro	5.0	3.38	3.4	5.567	O(g) 24A	OR(g) 34A
VF L-13	3.0	4.35	2.15	5.062	YO(g) 17A	R(g) 42A
Gamad	3.4	4.28	2.4	5.87	O(g) 28A	R(g) 47A
Rehovot 2	3.0	3.38	2.85	5.754	OR(g) 33B	R(g) 47B
VF 145 B 7879	3.0	3.54	2.2	5.225	O(g) 28A	R(g) 44A
Nes-zona 4	4.2	4.25	2.15	6.57	OR(g) 31A	OR(g) 34A

[a]Color is classified according to the Royal Horticultural Society color chart, London, England: O= orange, R=red, Y=yellow; (g)=group.

In screening for crack-resistant lines, the technique is to grow tomato plants and let them bear fruit during the rainy season or under a sprinkler irrigation system. These conditions will reveal whether the lines or plants carry crack-resistant genes or not.

Allowing tomato fruit from various plants to absorb water and then checking for cracked fruit was suggested by Meszoly (8). He also stated that the ability of a fruit to absorb 0.6-0.4 g of water without any effect on fruit cracking indicates that the fruit has a crack-resistant gene.

Generally, plants or lines with good characteristics are susceptible to cracks. It is preferable to cross with "Roma" type or "San Manzano", which are crack-resistant varieties.

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SELECTING FRESH-MARKET TOMATOES IN FLORIDA FOR RESISTANCE TO BACTERIAL LEAFSPOT, AND INHERITANCE STUDIES IN IMPROVED ROOT DEVELOPMENT

R.B. Volin[a]

BACTERIAL LEAFSPOT

Tomato leafspot caused by *Xanthomonas vesicatoria* (Doidge) Dows. (XV) is often a severe foliage and fruit disease of tomatoes (*Lycopersicon exculentum* Mill.) in both temperate and tropical regions of the world. This disease is among the most difficult to control and is the most common foliage problem in tomato production in Florida. The disease also attacks various species of pepper (*Capsicum* spp.).

Foliar symptoms include the appearance of circular, water-soaked spots which become necrotic and measure from 1-5 mm in diameter. Infected leaves soon turn chlorotic and drop. Necrotic spots often occur on fruit as well. Although infection is not systemic in nature, a downward curling of the diseased foliage is a characteristic response to infection. In Florida, where over 16,000 ha of fresh market tomatoes were produced during the 1977-78 season (1), XV outbreaks can occur anytime during the crop season, however they are most prevalent from mid-Aug through Sep, early in the season when temperatures are high and rainfall is abundant. Predisposing climatic conditions often occur again in May, at the end of the crop season.

Tomato plants are established in the field in south Florida by direct seeding, thereby exposing very young plants to field infection. Control measures are only partially effective but include the combined spray application of manganese ethylene bisdithiocarbamate and cupric hydroxide. Alternate applications of Streptomycin sprays have only short-term effectiveness because strep-resistant strains soon predominate (2, 10).

Resistance to XV has been reported in a number of cultivars and introductions of *Capsicum* spp. (6, 8). Resistance was characterized by hypersensitive necrosis and limited *in vivo* bacterial multiplication following foliar injection of concentrated inoculum (9). This response is simply inherited (3).

The search for resistance in tomatoes has not been very successful.

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The severity of the disease and the importance of tomatoes in Florida has encouraged researchers to continue the search for heritable levels of resistance which could be utilized in a breeding program (5). The purpose of this report is to identify some tomato introductions having disease tolerance and to discuss our procedure.

MATERIALS AND METHODS

A group of tomato Plant Introduction (PI) accessions obtained from Dr. W.H. Scardla, USDA Plant Introduction Center, Ames, Iowa, were evaluated for field tolerance to bacterial leafspot. *Lycopersicon esculentum* candidates selected by R.T. McMillan, Jr. (personal communication) for continued testing included: PI270243, PI272664, PI140403, PI129061, PI270266, PI272711, and PI134208. These were used as parents in crosses with commercially acceptable fresh market tomato cultivars (11). Progeny from these crosses were screened for resistance and evaluated for horticultural acceptability for five generations.

Inoculum for all tests was isolated from field-grown tomato foliage and cultured on nutrient broth media. The media was incubated under continuous agitation for 36 hrs, diluted to approximately 10^6 cells/mℓ with sterile water, and sprayed on the foliage in a fine mist.

Seedling plants were grown in metal flats and inoculated at the one true leaf stage. After inoculation, the flats were exposed to an intermittent water mist for 48 hrs. The mist was timed to spray for 15 sec out of every 1 min cycle. The F_2 seedlings and parental selections were given a qualitative rating of moderately resistant (MR) or susceptible (S). Seedlings of later generations were assigned a disease index (DI) value derived from the average number of infection sites on terminal leaflets of the progeny selections divided by the average number of infection sites on terminal leaflets of the susceptible entry FLA 720635-1. The quotient was multiplied by one hundred to give the DI.

Maturing plants in the field were rated according to a numerical scale from 0 to 9:0 = escape or immune, no visible symptoms; 1 = spots very small ($<$0.5 mm dia), necrosis very localized on older leaves; 2 = spots small ($\leq$0.5 mm), necrosis localized; 3 = spots small ($\leq$1.0 mm), necrosis very limited; 4 = spots moderate in size ($\leq$1.5 mm), necrosis limited; 5 = spots moderate in size ($\leq$1.5 mm), necrosis more evident; 6 = spots occasionally coalescing $\leq$2.0 mm with necrosis; 7 = spots coalescing $\leq$2.0 mm with necrosis; 8 = spots coalescing $\leq$2.0 mm with considerable necrosis; and 9 = spots and necrosis coalescing and covering much of the leaf. Ratings 1-3 were tentatively considered resistant, 4-6 moderately resistant, and 7-9 susceptible.

Seedling plants were evaluated initially after the susceptible control entries began exhibiting symptoms, usually after about 8 days of incubation, and were rated at least once again after 5 days. Although cotyledon leaves often showed symptoms, only the first true leaf of each seedling plant was rated. The field plants were rated approximately 2 weeks after transplanting and again at the mature-green fruit stage. It was unnecessary to re-inoculate the field transplants as secondary disease-spread had occurred since the initial infection. Bacterial lesions on the fruit were not rated quantitatively because of the unreliability of infection.

Susceptible plants were discarded in the F_2 population at the time of seedling evaluation. The tolerant seedlings (i.e., those with low disease ratings) were transferred to the field for selection of single plants which demonstrated sustained tolerance and possessed desirable horticultural traits. Seed of these single plant selections were kept separate throughout later generations; however, the quantitative data shown in Table 1 was derived from combining all the selections within a family.

Table 1. Bacterial leaf spot comparative disease index and ratings of tomato hybrids, *L. esculentum* accessions, and cultivars evaluated as seedlings and maturing field plants.

Accession, improved selection, or cultivar	Filial generation[a]							
	Disease index and rating[b]							
	F_2		F_4			F_5		
	Sg[c]	Mt[d]	Sg	Sd[e]	Mt	Sg	Sd	Mt
PI 270266	MR	5.0				89		4.0
PI 272711	MS	4.0				45		4.0
PI 134208	MS	2.0	17		4.0	105		3.0
PI 140403	MS	2.0	22		5.0	55		3.0
D7151 FLA 2148/PI 140403	MR-S		21	1.00	4.5	117	1.48	4.8
D7153 FLA 2317/PI 140403	MR-S		25	2.12	4.5	142	3.00	6.0
PI 129061	MR	4.0	11		3.0	95		3.0
D7154 FLA 2354/PI 129061	MR-S		19	0.71	5.5	149	2.00	7.0
D7155 PAKMOR/PI 129061	MR-S		21	0.58	5.3	120	1.41	7.0
PI 270243	MS	2.0	39		6.0	73		3.0
D7288 PI 270243/FLA 2432	MR-S		61	1.20	8.0	68	1.10	7.0
PI 272664	MS	3.0	44		6.0	29		3.0
D7289 PI 272664/FLA 2432	MR-S		44	0.50	6.0	77	1.30	5.0
FLA 720635-1 (check)	S	8.0	100		8.0	100		7.0
FLA 2432	S	7.0	97		8.0	127		8.0
WALTER	S	7.0	94		8.0	117		8.0
FLORA-DADE	MS	6.0	91		7.0	167		8.0

[a] F_3 plants were not evaluated for bacterial leafspot resistance.
[b] Disease Index = average number of infection lesions on terminal leaflets of candidate seedlings divided by the average number of infection lesions on terminal leaflets of susceptible check FLA 720635-1. Rating value assigned as 1-3 (resistant), 4-6 (moderately resistant) and 7-9 (susceptible).
[c] Sg = evaluation as seedlings in greenhouse flats. [d] Mt = evaluation as maturing plants in the field. [e] Sd = standard deviation of the means.

RESULTS

All the PI accessions and F_1 hybrids developed XV symptoms as seedlings and in the field as maturing plants. Overall disease ratings however were lower for the accessions than for FLA 720635-1, FLA 2432, and Walter. FLA 720635-1 was the most susceptible, with large, coalescing spots and considerable leaf curling early in the progression of the disease.

The plant families in which PI 270266, PI 272711, and PI 134208 were used as parents had very few F_2 progeny which expressed any measure of resistance. Those families were not considered further. From 8-33% of the F_2 plants from each of the other families were retained for future evaluation. The F_3 generation plants were not screened in flats as seedlings because of inadequate space but, instead, were transplanted to the field and inoculated at 4 wks of age. However, weather conditions failed to provide optimum conditions for field infection and prevented uniform disease development. Between 20-30% of the plants from each family line were selected on the basis of horticultural traits and evaluated the following season.

All seedling disease ratings in the F_4 were less than FLA 720635-1 (Table 1). The lines D7151, D7154, and D7155 demonstrated the least symptoms. In the field, disease ratings were lowest for the same three families. The standard deviation (SD) of 2.12 was especially high in family D7153. This suggested that the family line was still segregating for disease response. The disease symptoms among both the seedlings and the maturing plants were greater during the following season in the F_5 than in the F_4 families. Most of the PI accessions also had a higher seedling disease severity than during previous seasons and were rated nearly as high as the susceptible check line FLA 720635-1. All the plant families except D7288 and D7289 had seedling disease symptoms greater than the susceptible check. Only the field ratings among the family selections and PI accessions were somewhat lower than FLA 720635-1.

DISCUSSION

The presence of restricted disease development among the PI accessions in this study initially suggested that disease pressure should promote selection of plant segregates with a level of functional field tolerance or possibly with the type of hypersensitivity noted by others in pepper (4). This could be a practical type of plant resistance since it would restrict plant damage and greatly reduce disease spread in the field. Several explanations could be proposed as to why this moderate resistance was not evident in selected progeny: 1) Resistance to this disease in tomato may be conditioned by multiple genetic factors. The transfer of all factors needed for moderate resistance would require the evaluation of larger numbers of progeny. In our study the F_2 population for each family numbered from 200-260 plants. To screen and evaluate more than this number would require a great increase in space and time. 2) Bacterial isolates were obtained from several tomato cultivars in the field which very likely were a mixture of differentially pathogenic strains. The proportion of pathotypes possibly varied from one isolation to the next, producing varied host-pathogen responses depending upon the virulence of the inoculum. Selection for resistance using several strains should produce a genotype which more closely resembles horizontal resistance. The occurrence of different tomato strains in XV, however, remains to be verified. The fact that pepper XV isolates differ in pathotype was documented by Cook & Stall (4). 3) It is difficult to quantitatively rate disease symptoms among plant populations and from one season to the next. This often involves subjective judgment which is vulnerable to inconsistencies. Growing conditions affect response differences to XV in pepper (3). The fact that progenies segregate in the field for determinant/indeterminant growth habit precludes the effective use of the Horsfall-Barratt disease rating system.

It is likely that usable resistance to XV is non-existent among *L. esculentum* plant types. Other tomato species may carry factors conditioning resistance (7). We have noted that an accession of *L. hirsutum*, appears to possess a hypersensitive response to XV in the field. This has not yet been verified by seedling tests. We emphasized the selection of desirable horticultural characters with a minimal number of backcrosses. In other studies, no XV strain was found to which tomato was hypersensitive, although isolates from tomato were found which were differently pathogenic on specific pepper selections (4). These results substantiate the likelihood that pursuit of usable field resistance to XV, especially among *L. esculentum* selections, will be unproductive and that any type of hypersensitive resistance could be overcome in the field by new XV strains.

INHERITANCE STUDIES ON IMPROVED ROOT DEVELOPMENT

Brown root rot (BRR) disease of tomato, caused by *Pyrenochaeta lycopersici* Schneider and Gerlach, is not considered a common disease in tropical or subtropical areas. However, this fungus has been isolated from tomato roots grown in south Florida (R.T. McMillan, Jr., personal communication). It is visibly pathogenic in fields where tomatoes have been continuously grown for several seasons. Brown lesions form on the roots of susceptible tomato cultivars, thereby reducing root growth and fruit productivity.

For several seasons tomato plant introduction accessions have been screened for resistance at the University of Florida AREC, Homestead, both in the field and in an environmentally controlled greenhouse. We have reported the genetics of resistance and heritability in specific hybrid progenies (13).

The selection for BRR resistance has favored plant genotypes with improved root mass or volume. However, at least some of the heritable components of increased root volume appear independent of factors conditioning resistance to BRR. Although somewhat preliminary, we feel that the research progress merits summarization and discussion.

MATERIALS AND METHODS

Tomato accessions evaluated in the field were selected on the basis of resistance to *P. lycopersici*. Hybrid progenies, composed of crosses between resistant accessions and the commercially susceptible cultivar "Flora-Dade" were also evaluated in the field for resistance. Resistant selections were backcrossed three times to "Flora-Dade" and screened for disease response after each backcross (Bc) generation. During field evaluation of the third generation Bc progeny, the extracted roots of each parental line and the Bc selections were freed of soil particles and weighed.

Five roots of each parent contributed to parental means. The Bc progeny mean for each family line was obtained by weighing individual roots from each single plant selection. A different number of selections were chosen for each Bc line. The PI 270278 family line had 23 selections, the PI 142880 line had 6 selections, and the PI 91458 had 7 selections.

The results reported herein are from only three selected Bc family lines which illustrate advances in improved root development. Many others have been evaluated. Advanced commercial tomato selections, other than "Flora-Dade", have been used as recurrent parents.

RESULTS AND DISCUSSION

The fact that "Flora-Dade" is susceptible to BRR contributes to a greater decline in root development than would be present in soils free of the disease organism. "Flora-Dade" is resistant to *Verticillium* wilt and *Fusarium* wilt races 1 and 2 (12). Comparisons of root size of "Flora-Dade" and the Bc selections in two families indicated that an increase in root weight approaching 53% was achieved (Fig. 1). This improvement was

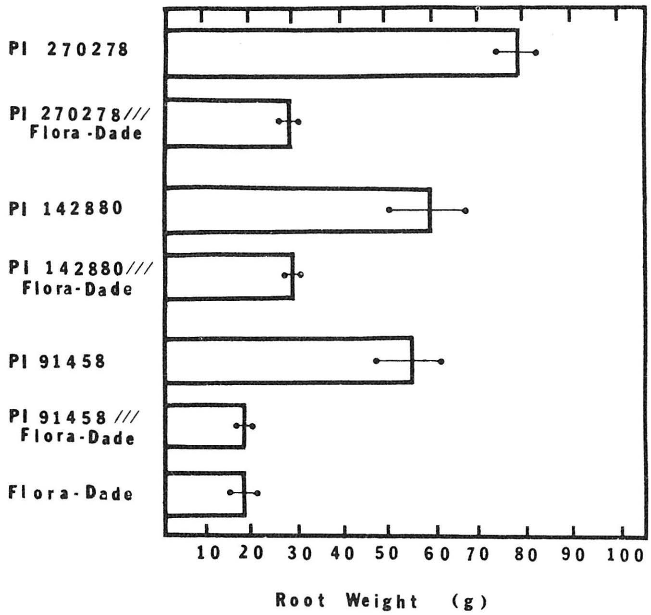
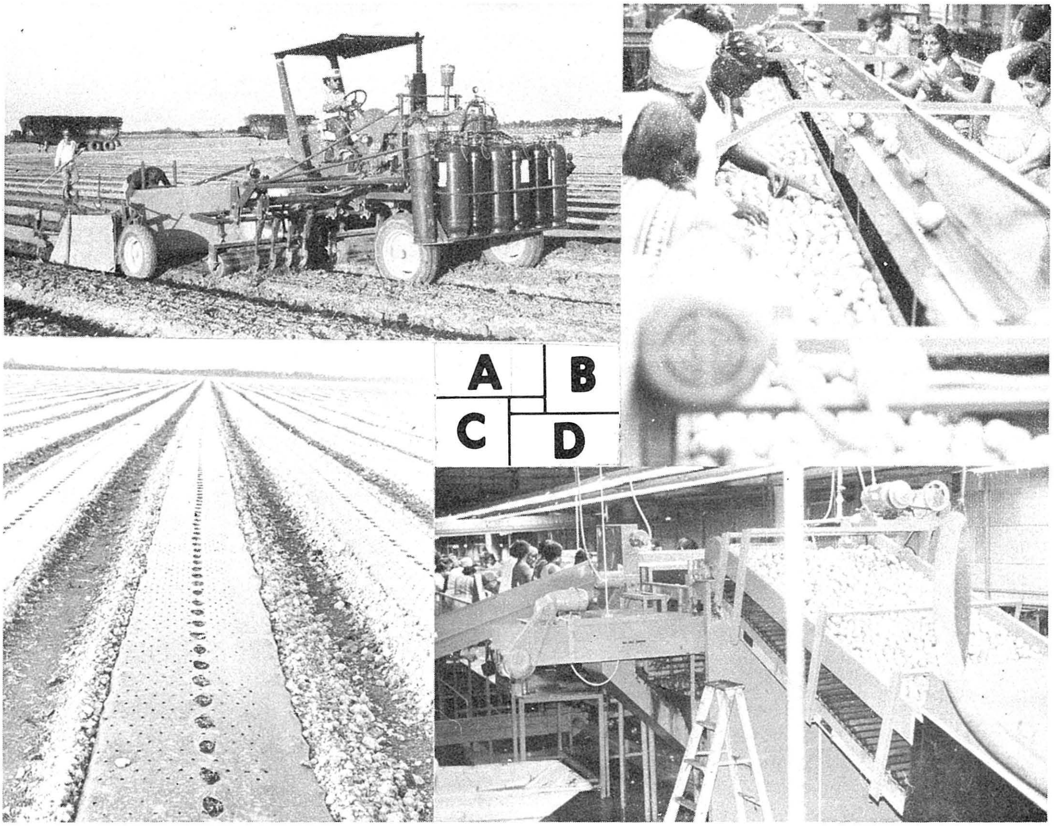


Fig. 1. Comparative dry root weight and standard deviation of the means of tomato backcross, *L. esculentum* accessions, and the fresh market cultivar "Flora-Dade" grown under field culture.

less than the larger differences noted between "Flora-Dade" and the PI parents; however, a decline is expected as selection progresses toward smaller plant size. Only in the recurrent selections of the PI 91458 line was no progress in root development achieved.

It is likely that through recurrent selection, additive factors conditioning large root size have been diluted. Zobel (14) demonstrated that genetic differences exist which contribute to differences in root development among tomato cultivars. He also demonstrated a genetic-environmental interaction among the same cultivars.

Not all gains in root volume are due to selection of resistant genotypes because some of the large root selections were moderately susceptible to BRR. An increase in both lateral and fibrous root components contributed to improved root volume. Such improvements are believed to be critical components of improved fruit productivity and quality, especially in the porous, low nutritional limestone soils of south Florida. A program for selection toward improved root development must be coupled with disease resistance evaluation to achieve the maximum benefit.



A Land preparation for planting fresh-market tomatoes at Homestead, Florida, USA. Raised beds containing fertilizer are injected with fumigant (tanks in front of tractor) through chisels in front of the roller. Plastic mulch covers the beds immediately after injection. Each machine can treat and cover about 7 ha/day.

B Fresh-market tomatoes are being sorted and packaged for shipping. Packaging is automatic.

C After fumigating, the plastic-covered beds are perforated (small holes) to allow water penetration from irrigation. Plants become established in the larger holes (30 cm apart) by direct seeding.

D After being dumped in a chlorinated water bath, tomatoes are graded by hand and sorted by size automatically by passing over moving belts containing specifically-sized holes.

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DISCUSSION SESSION IV

Tong: In your screening program, do you use any growth regulator to facilitate harvesting? If not, could you describe your harvesting method?

Villareal: No. However, we are experimenting with ethrel to stimulate concentrated ripening. Normally we harvest ripe fruit weekly over a period of 7 to 11 weeks.

Chang: Why do you use a minimum night temperature of 22^{o}C when the range for minimum temperature in the summer is about 23^{o}-25^{o}C in Taiwan? Usually the screening temperature should be set 2-3^{o} above the mean monthly temperature.

Villareal: We are not using a minimum night temperature of 22^{o}C. AVRDC does not have facilities to control temperature. Thus, we conduct our field screening during the summer when minimum night temperatures are never below 21^{o}C and usually are between 23 and 25^{o}C.

Villareal: Mr. Kowithayakorn, please comment as to why most of the cultivars you presented in your slide have very low soluble solids. I think the highest you have is about 4.

Kowithayakorn: First of all, in the table, I showed soluble solids (Brix^{o}) and percentage of total solid content. Soluble solids is different from solid content. Sugar is one material in the group of soluble solids content, which affect the Brix. Many factors increase the soluble solids and sugar content including limiting light, high N-fertilizer application, high soil moisture content, and genetic background.

Riley: Did I understand you to say that resistance to nematodes decreased infection of the bacterial wilt pathogen?

Kowithayakorn: No, if we want real bacterial wilt resistance, we should have both nematode and bacterial wilt together in the screening block. The nematodes will make a wound which the bacterial wilt can easily enter.

Villareal: What proportion of the 16,000 ha of fresh market tomato in Florida is direct seeded? What is the rate of seeding per/ha?

Volin: Two methods are used for direct seeding. Only 1200 ha are direct seeded without the use of plastic mulch. About 5200 ha are direct seeded through plastic mulch, using the "plug-mix" method where seed is mixed with vermiculite and peat moss and hill-planted with 12-20 seeds per hill. Without mulch the seeding rate is about 1 kg/ha. Using plug-mix the rate is about ¼ kg/ha.

Riley: What is the relationship between disease index, DI, and ratings 1-3 (R); 4-6 (MR); and 7-9 (S)?

Volin: Generally, disease index ratings on seedlings (based on a susceptibly check) and maturing plant rating 1-9 correlated fairly closely. However, in some cases a tolerant seedling selection was rated susceptible in the field. The seedling ratings were quantitative, whereas the maturing plant ratings were qualitative.

Riley: What environmental conditions favor bacterial leaf spot (BLS)?

Volin: The temperature optimum for BLS has been reported to be 28-30^{o}C. Rainy conditions with water-soaked foliage and high temperatures predispose the plant to infection.

Riley: Does the plastic mulch promote or lessen BLS?

Volin: Plastic mulch tends to promote BLS because the splashing action of the rain is accentuated.

Valdez: Please elaborate further on the screening for bacterial leafspot resistance, both in seedlings and field plants.

Volin: Seedlings which have a low DI are planted in the field. Ratings are then conducted among the field selections and only those having a low rating are advanced.

Tong : Do Florida farmers use ethrel for uniform maturing before the harvest of table tomato?

Volin: To concentrate maturity effectively and without damage to yield, the application rate of ethrel must be controlled very carefully and application timing coordinated with the proper growth stage of the plant. Ethrel has been used only experimentally in Florida as a pre-harvest application. There are regulations against its post-harvest use.

Tong: If ethrel is not used, how many times is a tomato crop picked?

Volin: Generally, tomatoes produced on ground-culture are picked twice, whereas those produced on short stakes are picked from 3 to 4 times, depending upon the market price.

Tong: What is the average yield of table tomato for (a) determinate type, (b) indeterminate type.

Volin: The average marketable yield for fresh tomatoes of the determinate type ranges around 10 t/ha. Few determinate types are grown in Florida, but the yield would probably approach 12-13 t/ha.
(12-13 t/ha).

Tong: What is the cost of plastic mulching per ha. Can you use it for the 2nd planting?

Volin: The current cost of plastic mulch is approximately US$380/ha just for materials. The cost of application would be extra.

At present it is removed by burning and not used for a second crop. It would be feasible to use it for a second planting of a short maturing crop, i.e. summer squash. With the advent of machine harvesting of tomatoes the culture of a second crop on the same soil beds is quite feasible.

Villareal: With good vine storage, how long can ripe tomatoes stay in the field?

Stevens: This is highly dependent on the environment. High temperatures or excessive moisture shorten the time. In California, it is not uncommon to vine-store the firm-fruited varieties for several weeks. In general, limited vine storage improves the quality of firm-fruited varieties. The exception is acidity, which decreases. Problems with high pH increase with longer vine storage.

Villareal: Please define harvest index for processing tomatoes.

Stevens:

$$\frac{\text{Economic dry matter production}}{\text{Total dry matter production}} = \frac{\text{Dry weight of fruits}}{\text{Dry weight of fruit and dry vines}}$$

Everett: What environmental conditions promote white tissue formation in the firm-fruited varieties?

Steven: There are many. Virtually every environmental factor, light, temperature, disease, nutrition, etc., have been shown to cause internal discoloration in tomato fruits. Extremely hot days or unusually cool nights increase the discoloration problem. In areas where there are extreme diurnal fluctuations in temperature the problem is more severe. The severity of the problem is clearly related to genotype.

Hubbell: What happens to α-tomatine as fruits mature?

Stevens: In the genotypes we have studied it disappears as the fruits mature. We have been unable to find α-tomatine in breaker stage fruits. α-tomatine has some mammalian toxicity, it is degradated by a specific enzyme into a sterodal compound which is apparently non-toxic.

Yang: What is the distribution of α-tomatine in various plant parts of the tomato? What is the last stage to assess α-tomatine?

Steven: It is greatest in young leaves and gradually decreases in foliage as it matures and senesces. The fruits contain less α-tomatine than foliage and lose the compound as they mature. I don't know about concentration in the roots. For comparative studies a seedling stage would be good.

Yang: Dr. Rick, you mentioned that there are about 36 races of *L. peruvianum*. Have these races been characterized by the isozyme techniques? If not, do you think that this (to characterize the races by way of the zymographic typing) should be done?

Rick: The answer to your first question is no. We have only sampled *L. peruvianum* in a preliminary fashion - enough to reveal a formidable extent of isozyme variation. The pattern of variability for certain enzymes - for instance, peroxidases - is so complex that pedigree tests will be necessary to differentiate loci from alleles before the survey would be meaningful. The answer to your second question is yes. We have started the pedigree studies and hope to survey the species for this type of variation.


TOMATO
PRODUCTION

PRODUCTION AND MARKETING OF F_1 HYBRID TOMATO SEED IN TAIWAN

Known-You Nursery & Seed Production Co. Ltd.[a]

INTRODUCTION

The tomato is an important vegetable and large quantities of seeds are required around the world. Since F_1 hybrid tomatoes have the advantages of hybrid vigor - (i.e. vigorous growth, good uniformity, and high yield), the demand for hybrid seeds has increased rapidly in recent years.

Although tomatoes have been grown in Taiwan for over 60 yrs, the commercial production and marketing of F_1 hybrid tomato seed only started in 1960. The first commercial hybrid variety in Taiwan was "Farmer No.1," which was developed and released by Farmers' Seed Shop in 1960. (This Shop was reorganized and combined with Taiwan Horticultural Research Farm in 1967 to become Known-You Nursery & Seed Production Co., Ltd.) In 1961, Farmers' Seed Shop accepted a contract to produce F_1 hybrid tomato seeds from parent lines supplied by a Japanese seed firm, and 50 kg of hybrid seed were exported to Japan in 1962.

TECHNICAL IMPROVEMENT OF F_1 HYBRID TOMATO SEED PRODUCTION

There were several experimental production tests of F_1 hybrid tomato seed in Taiwan's Agricultural Experiment Stations before commercial production began. But the production procedures were too complicated and uneconomical. In making crosses, the flower was emasculated before pollen dehiscence. A paper bag was put on the emasculated flower to exclude foreign pollen. Next day, preferably in the morning, the emasculated flower was pollinated and reclosed with a paper bag. Then an identification tag was fastened on the pedicle. The efficiency in hybrid seed production by the above procedures is low and unstable.

In order to improve efficiency, emasculation procedures, pollen collection methods, pollination methods, and environmental factors have been studied by the Farmers' Seed Shop. The following techniques are now used for commercial production:

1. Planting season. Tomatoes can be planted in southern Taiwan from Sep-Feb. But for hybrid seed production, it is best to plant in Sep and harvest hybrid seed in Feb of the next year.

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2. Ratio of female and male parents. Normally one male parent can provide sufficient pollen for six female parents.

3. Sowing and raising seedlings. Parent lines for F_1 hybrid seed production are usually not direct seeded. We normally sow male parents 1-2 weeks earlier than female parents to obtain sufficient pollen when female parents are ready for crossing. Seeds are sowed rather heavily in a sand box, and then transplanted to seedling pots at the two cotyledon stage. Seedlings can be transplanted to the field when they have 4-5 true leaves.

4. Transplanting. Male and female parents are planted separately in the field. Female parents, spaced 45 cm apart in rows 80 cm apart, are pruned and staked. Male parents, spaced 60 cm apart in rows 120 cm apart, will grow unstaked.

5. Staking and pruning. Female parents are staked in order to make both the job of hand pollination easier and to reduce fruit rot. If female parents are indeterminate, they need to be pruned to one or two main stems. Determinate types can be pruned to 3-4 stems.

6. Emasculation and pollination. Emasculation normally starts with the 2nd cluster of flowers in the female parent. Two days before flowering, the anther cone is removed by forceps. Emasculation is usually done in the afternoon. When the emasculated flowers are flowering, which can be identified by the color of the corolla, the pollen collected from the male is put on the stigma of an emasculated flower with the little finger. Then 3 sepals on the pollinated flower are cut to identify it when the fruit is mature.

Pollen collection from the male is improved by shaking the flower either by hand or by vibrator. Pollen can be stored and used for several days if kept in cool, dry storage.

The "escaped-emasculation" flowers or selfing-fruit on the female parent should be removed as soon as possible in order to avoid contamination. Setting 4-5 fruit on each cluster will be enough for a medium-sized variety.

7. Harvesting, washing, and drying. Fully matured fruit are harvested and stored in a cool place for 3-5 days as "after-maturing." The fruit are then crushed and put in a wooden or plastic container for 1-2 days fermentation. Then they are washed in running water until the clean seeds sink. The water is drained off and the seeds are dried.

8. Yield. The yield of hybrid tomato seeds varies according to the parent lines used for production, climatic conditions, and growing state, etc. The average yield is about 200 kg/ha.

FACTORS FOR DEVELOPING F_1 HYBRID TOMATO SEED INDUSTRY IN TAIWAN

Hybrid tomato seed production has become a big business in Taiwan and is playing an important role in providing seed to foreign countries.

The conditions for such development are:

1. The climate in southern Taiwan is most suitable for growing tomato during the dry season. The adequate temperature and sunshine, and scarce rainfall provide good conditions for fruit setting and seed development.

2. Tomato can be planted in the interval between two crops of rice. This crop rotation system not only can increase land use but also can eliminate tomato diseases.

3. The production of F_1 hybrid tomato seed requires advanced technology, highly intensive cultivation, and skillful manual labor which cannot be replaced by machinery. The developed countries cannot produce hand-pollinated hybrid seeds economically due to high labor costs. Furthermore, not all countries with cheap labor can produce F_1 tomato seeds because of the strict conditions required. The most important of these conditions are the farmers' industry and expertise with intensive cultivation methods. In this connection, Taiwan is in a superior position to develop hybrid seeds.

MARKETING OF F_1 HYBRID TOMATO SEED IN TAIWAN

F_1 hybrid tomato seeds produced in Taiwan are either for local market consumption or for export. For local market, most hybrid varieties are developed and released by Known-You Nursery and Seed Production Company. The annual requirement is only about 300 kg. The majority of F_1 hybrid tomato seeds are produced by using parent lines supplied by foreign companies and the hybrid seeds are exported. The local seed companies accept orders from foreign seed companies and then usually recontract with local farmers to produce hybrid seeds. According to our estimates, 50 kg of F_1 hybrid tomato seed were exported in 1962. This increased to about 15,000 kg in 1977. Most of these seeds are exported to USA, Japan, and Europe.

PROBLEMS OF F_1 HYBRID TOMATO SEED PRODUCTION IN TAIWAN

Since the industry is expanding rapidly in Taiwan, F_1 hybrid tomato seed producers are finding it increasingly difficult to hire farm labor to do hand-pollination. The cost of labor is increasing. We forecast that after 5 yrs, Taiwan will no longer be able to produce F_1 hybrid tomato seeds because of high labor costs.

TOMATO PROCESSING BY THE PRESIDENT ENTERPRISE COMPANY

P.Y. Hsu

Agriculture is a vital component of Taiwan's economy. Although Taiwan is becoming more industrialized, its agricultural population still accounts for a large proportion of its total population. Agriculture is still the cornerstone of the Republic of China's economy.

The President Enterprise Company is deeply involved in the production of goods derived from agriculture. These products include: feed, flour, instant noodles, salad oil, canned goods, soy sauce, dairy products, bakery products, and others. Our goal is to provide an outlet for agricultural products and thereby increase the welfare of farmers. With this in mind, we established our tomato processing plant.

The tomato processing plant was constructed in 1973, and began operation in 1974. The plant is located beside the main highway near the village of Hsin-hsih. Also used to produce fruit juice and assorted canned foods, its main product is processed tomatoes. We installed the Italian-made Rossil-Catalli machine, and established an excellent system of tomato contracts with farmers. Thus, we are able to produce good quality tomato paste by having good equipment and good raw materials. In the last 4 years, we have faced many difficulties, but by providing excellent, consistent quality and making continuous efforts to open new markets, we have been able to enter foreign markets.

Right after we established the tomato processing plant, we were faced with the world oil crisis. The resulting world-wide economic recession dealt a heavy blow to exporting industries, and the tomato processing industry was no exception. Serious reduction in markets and low prices caused our company heavy losses so we adopted the following measures to tackle the situation:

1. <u>Exploitation of the U.S. market</u>. Japan has been the main market for Taiwan's tomato paste. Because the U.S. market demands a very high quality product, and because of the high shipping costs to the U.S., Taiwan tomato companies sold only to the Japanese market. In preparation for entering the U.S. market, our company sent a technician to the U.S. to participate in the National Canning Association's quality control training program. After that, we were able to improve the quality of our canned tomato products. In the last 4 years, we have sold more than one-third of our tomato paste to the U.S. and Puerto Rico. We have been able to satisfy our buyers in the U.S., and, in so doing, break the marketing bottleneck and open a broad outlet for the products of the Taiwan tomato canning industry.

2. Increasing concentration. Until now, Taiwan has produced only low concentration tomato paste of less than Brix 28°. We consider that a more concentrated paste can reduce shipping costs, so we have increased the concentration of our paste as much as possible. We are now producing large quantities of Brix 33° products for foreign buyers who welcome the more concentrated product. We are still making efforts to increase the concentration of our paste further.

3. Introduction of 4.5 kg can size. Taiwan used to produce tomato paste only in 3.16 kg and 4 kg can sizes. In order to reduce costs and increase market competitiveness, we were the first to introduce a 4.5 kg can. Later, other producers also adopted this can size. We are continuing to develop even larger containers in order to reduce further production and shipping costs.

4. Dispersion of markets. Besides Japan and the U.S., we have also exploited the Middle East, and the Philippines markets. In addition, we are now in the process of establishing a foothold in the Korean, Thai, and Malaysian markets. Our Taiwanese tomato canning companies normally sell more than 85% of their production to Japan. When they are unable to market in Japan, they run a serious risk of suffering heavy losses. Our policy of dispersing markets, on the other hand, can provide a stable outlet.

5. Implementation of production and sales plans. Unplanned production and marketing have been the main weakness of Taiwan producers. As a result, they have suffered much. In the beginning, due to a lack of buyers, it was very difficult for us to make a successful production and marketing plan. Gradually, however, we have been able to obtain regular buyers. On this basis we are now able to determine each year in advance how much planting acreage will be needed and contract with farmers accordingly.

6. Improvement of varieties and quality. Quality is closely correlated with variety. Our company tests new varieties each year in different areas with different soil types. AVRDC makes a big contribution in this area.

In general, through our efforts, buyers have gained confidence in our products, and we have been able to establish a broad and stable sales network. We believe that on this established foundation our tomato canning has a promising future and can make a valuable contribution to our nation's agricultural processing industry.

TOMATO HYBRID SEED PRODUCTION: A PHILIPPINE EXPERIENCE

Victor E. Paner, Jr. and Dalmacio M. Tecson[a]

INTRODUCTION

The tomato is one of the leading vegetable crops in the Philippines (Table 1). Most farmers save seeds from the local varieties they have been growing for decades, so there is limited commercial demand for seeds locally. It is only when an agricultural college of experiment station releases new varieties that there is a demand for seeds. Even then, the volume required is not large enough to stimulate local seed production. Also, the delay before the farmers adopt a new variety makes seed production a speculative project.

In mid-1977, one of the seed companies (dealers) in the Philippines made a contract with a seed company in California, USA, to test the production of 100 kg of hybrid tomato seeds in Isabela, about 400 km north of Manila. This is the first attempt to produce hybrid tomato seeds on a commercial scale in the Philippines.

Table 1. Vegetable production statistics; Philippines, 1977.[a]

Crop	Area	Volume	Yield	Value
	1000 ha	1000 t	t/ha	million US$
1. Sweet potato	221.7	887.7	4.0	56.70
2. Watermelon	12.9	177.7	13.7	39.54
3. Tomatoes	18.6	145.9	7.9	26.53
4. Garlic	4.9	16.0	3.3	14.67
5. Cabbage	8.7	67.9	7.8	13.93
Total of all vegetables	439.4	1,990.6	82.6	264.62
Average			5.9	

[a]Bureau of Agricultural Economics, Philippines.

[a]Vegetable Extension Specialist, University of the Philippines at Los Baños, and Agricultural Consultant, Hacienda Rizalina, (BM Domingo), Aurora, Isabela, Philippines.

SOIL AND CLIMATE

According to the soil tests, all 7 fields had heavy soil textures, pH ranging from 6.0-6.5, 2.5-3.0% organic matter, and sufficient P and K. Only nitrogen was needed, and 40 kg 21-0-0/ha was recommended at transplanting and again at flowering.

The data on the average number of rainy days, relative humidity, and temperature are shown in Figure 1. Isabela belongs to Type I climate, wet from May to Nov, and dry during the rest of the year. Temperature readings are relatively lower from Dec-Feb.

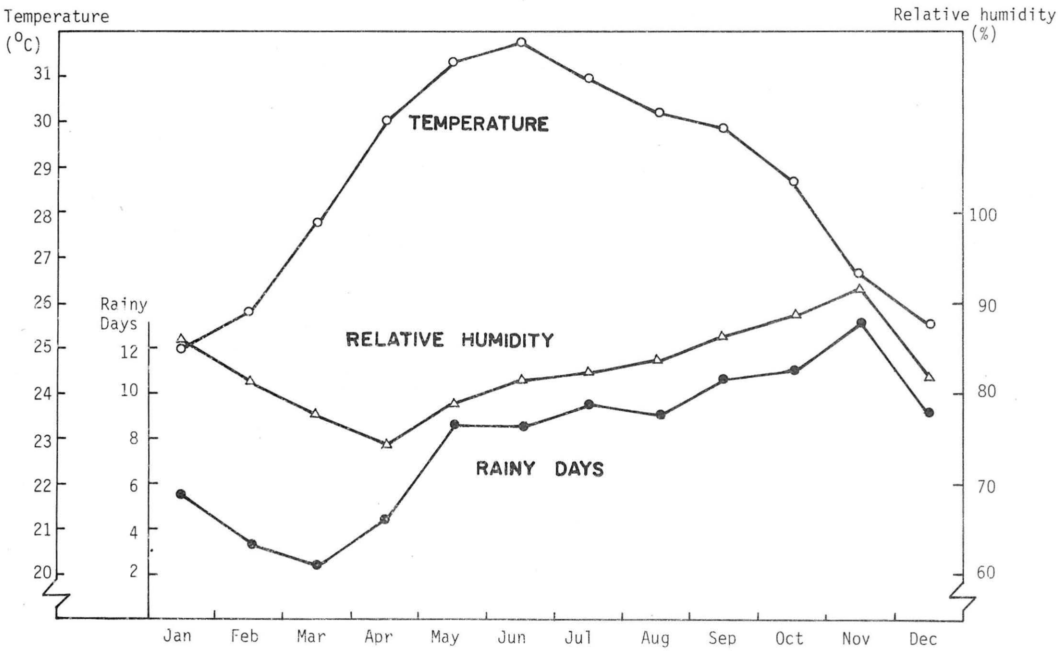

Fig. 1. Monthly average temperatures, rainy days, and relative humidity in Isabela, Philippines. (Averages are computed from weather data collected between 1966-75).

FIELD OPERATIONS AND OBSERVATION

The seeds were sown on Dec 14, 1977. One hectare of land was plowed and harrowed alternately 3 times before plots of 2 x 50 m raised 20 cm high were prepared. Transplanting was done from Jan 7-10, 1978. Basal application of Furadan 3G insecticide was done on Jan 11 before mulching with rice straw. Fertilizers (14-14-14) were applied Jan 12 and Feb 3 and 29.

The fields were irrigated Jan 7-10, 20-21, and Feb 8, and 20-21, 1978. Heavy rains were recorded Feb 3 and 28, and Mar 1, 1978.

Flowering started Jan 20th. The peak period was from Jan 9-15, and continued to decrease daily after Mar 1, 1978. Pollination was successfully done by 50 ladies averaging 50 fruits/plant. The technique used in Taiwan was adopted.

Unfortunately, the area was heavily infected with bacterial wilt. Heavy infestation was noticed starting Jan 13, when about 70% of the plants showed symptoms. By Mar 12 all the plants were affected and pollination was discontinued.

FUTURE PLANS

Because of the large demand for hybrid tomato seeds and the presence of experienced pollinators, both companies agreed to continue with the project and expand the area to 4-5 ha. Next time, the tomatoes will be planted after the lowland rice which will have been submerged for at least 6 mo because, it was noted, the 2 plots planted under this condition in a nearby field were not affected by the wilt.

There is a need to identify other areas which are free from bacterial wilt infestation. Maybe it will be better to consider higher elevations with lower temperatures to improve the success of pollination.

THE PROBLEMS OF THE TOMATO PROCESSING INDUSTRY IN TAIWAN

Yung Hui Lee[a]

INTRODUCTION

The tomato is a newly developed processing crop in Taiwan, and its products for export rank third following canned mushrooms and asparagus (Table 1).

Table 1. Exports of canned tomato products from Taiwan.[a]

	Total	Peeled whole tomatoes	Tomato paste	Tomato puree	Tomato sauce	Tomato juice
	1000 standard cases					
1976	1,556.3	662.0	824.3	11.0	31.4	27.5
1975	1,324.0	547.4	346.7	102.9	314.6	12.4
1974	832.7	479.8	339.9	-	7.0	5.9

[a]Ref. 3.

Among the products, canned peeled whole tomatoes have a big market in the western countries. However, production is limited due to the fact that only firm, well-colored tomatoes can be used. Although labor costs are comparatively low in Taiwan, sorting, peeling, and packing are still done by hand. Accordingly, it is very important to develop both a mechanical peeling method and a suitable tomato cultivar to promote production for export.

Concentrated tomato products are also important for export. Tomato paste, used mostly by the food industry for reprocessing into other products (eg. catsup, sauce, etc.), used to be packed in special No. 1 cans. Although the unit price of raw tomatoes is low in Taiwan (Table 2), the higher cost of containers and transportation makes competition with other tomato producing countries difficult. Accordingly, a larger container is preferred from the point of view of handling (opening), and may result in lower packaging and transportation costs.

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Table 2. Price of raw tomatoes.[a]

	Japan	Italy	U.S.A.	Taiwan
	----------- Japanese ¥/kg -----------			
1972	13.88	10.06	9.00	6.39
1973	14.20	11.93	8.62	7.00

[a]Ref. 2. US$1.00 = ¥285.00 (June, 1974)

PROBLEMS OF TOMATO PROCESSING IN TAIWAN

The tomato canning industry is confronted by problems such as the availability of suitable tomato cultivars, peeling methods for whole tomato, packaging costs, and spoilage due to a heat-resistant spore-forming bacteria, *Bacillus thermoacidurans (B. coagulans)*.

RAW MATERIAL

Tomatoes for canning should ripen uniformly, withstand post-harvest handling, and retain a firm texture in processing. Those having irregular shapes and wrinkled skins are difficult to peel and the loss in preparation is excessive (11). The qualities required for a tomato in canning may be summarized as follows (7):

(a) It should have a high soluble solids content (4.5-6.0^{o} Bx).

(b) It should possess an intense red color, for both the skin and the body.

(c) The flavor must be good and characteristic.

(d) In order to meet certain quality standards, the acidity should be fairly low (pH 4.2-4.5).

(e) It should resist diseases, pest infestation, and mold growth.

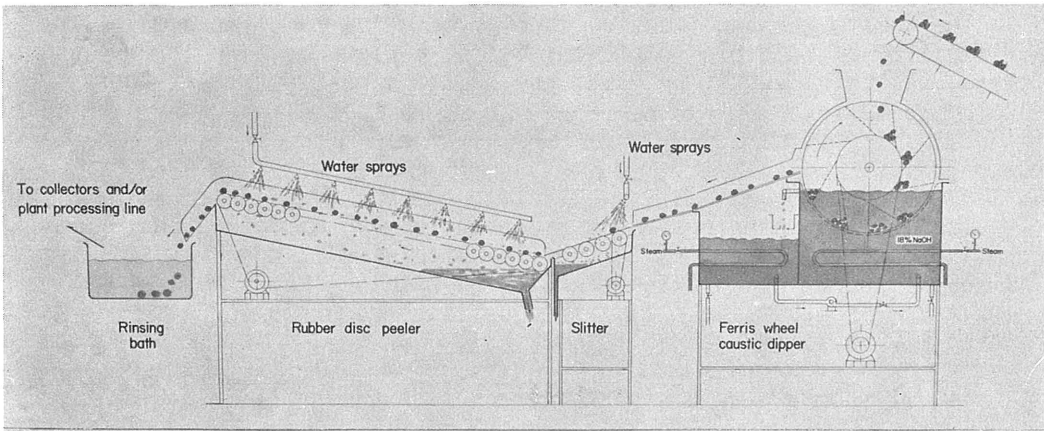
(f) It should resist skin cracking, so that damage during harvest and transportation are minimized.

(g) It should produce a reasonably consistent but not excessively fibrous body.

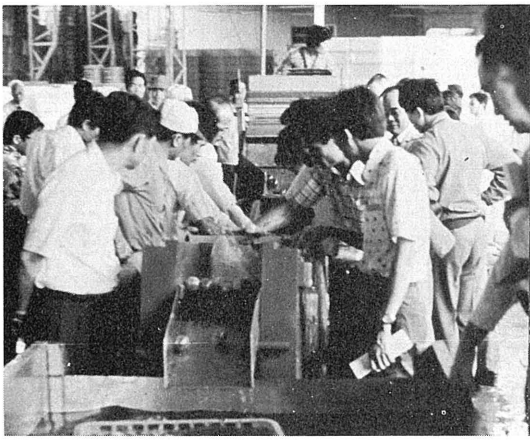
Two varieties of tomato are used in Taiwan, "T.K. No. 70" (Morioka) and "Roma". The former is usually juicier with a high brix, while the latter is deeper in color and firmer in body. Those varieties possessing large seed cavities and cores soften badly after canning and are unattractive.

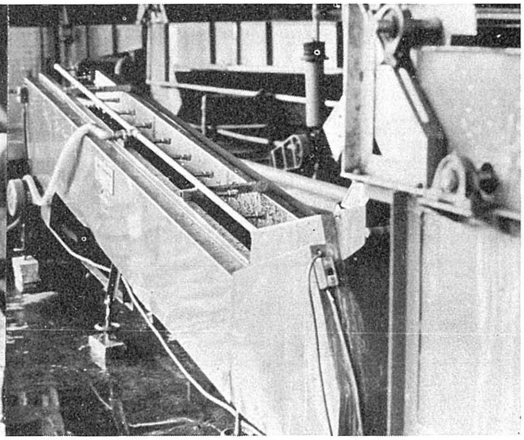
PEELING METHOD FOR WHOLE TOMATOES

Several peeling methods have been reported for canning peeled whole tomatoes: hand-peeling after being steamed or boiled for a short time, lye-peeling, calcium-chloride peeling, and freeze-peeling. The third method is common in Taiwan. The peel needs to be rubbed off by hand after immersion in a boiling $CaCl_2$ + NaCl bath followed by cooking in running water. Moreover, tomatoes need preliminary coring, otherwise the skin cannot be rubbed off easily. Coring is a very labor-consuming process. Lye peeling with the use of a surface active agent was reported to produce good quality and better yield (9). However, it still needs coring and hand-rubbing. In the United States, lye peeling is the generally accepted method for tomato peeling, and rubbing off the lye-treated peel is carried out by revolving rubber discs (8). Considerable water can be saved and the waste disposal is reduced appreciably with this method (5). The disadvantages of the conventional ($CaCl_2$ + NaCl) peeling method used in Taiwan are : high peeling losses, damage, and the use of large amounts of water.



PILOT-SCALE PEELING LINE : utilzes a rubber disc peeler to wipe lye-treated tomato skins from the tomato, thus reducing water consumption.





THE COST OF CONTAINERS

Container costs in Taiwan are higher than in other countries, and an effective way to reduce the cost of packing tomato paste is to increase the container size. However, due to the slower rate of heat penetration for tomato paste in large containers, a product of good quality cannot be obtained except when aseptic packing is applied. As more water is evaporated, the consistency of the concentrated tomato product increases and the rate of heat transfer decreases. Although the hot pack method is applicable from the sterility safety point of view, the cooling rate is too slow to get an acceptable product quality when packed in metal cans larger than Taiwan No. 1 cans. Over-cooking and darkening of the color results if the products are exposed to high temperatures for too long. The cooling rate may be accelerated by turning the cans around or end over end to agitate the contents. However, a satisfactory mechanical agitation may not be easily achieved with large cans (i.e. 18.9 ℓ cans). The aseptic canning technique many be the proper way to solve the problem. In this process the sterilized and cooled products are poured and sealed in a container aseptically and no further cooling is necessary after sealing. We have installed a Dole Aseptic Canning System in our institute under the project sponsored by the Chinese National Science Council. Some experience was gained in packing various viscous puree of fruits and vegetables with this system. The Dole Company also supplies aseptic canning systems for cans up to 18.9 ℓ capacity, as well as a system for plastic film pouches (1,4,6). Since cans for tomato paste should be internally lacquered, the use of a plastic pouch would be an economic alternative to lacquering cans. Naturally, the pouch has to be sterilized before packing the paste and vacuum sealing is necessary in addition to the aseptic filling.

SPOILAGE

An investigation of the microbial contamination level of raw tomato stock (Table 3), the efficiency of tomato washing operations (Table 4), and the microbial contamination level of unprocessed whole peeled tomato (Table 5) indicated that some tomato canning industries in Taiwan do not have a well-organized sanitation program. Although the contamination in raw tomato stock was lower than that in the U.S., the tomato washing operations in most of the tomato canneries in Taiwan should be improved.

Table 3. The level of contamination on 23 samples of raw tomato stock in Taiwan.[a]

Total bacteria		Total mesospores	
Range	Median	Range	Median
No/mℓ sample			
60×10^4 - 48×10^6	26×10^5	220 - 2,800	1,400

[a]Ref. 10.

The thermal resistance of spores of butyric acid anaerobes which might cause gaseous spoilage in canned tomato products is related to the pH of the product. Heat processes that raise center temperature within the range of 84-89^{o}C are satisfactory for tomato products with a pH value below 4.2.

Table 4. Tomato cleaning efficiency at canning plants in Taiwan.[a]

Cannery	No. runs	Avg. removal	
		Total bacteria	Total mesospores
		%	
A	4	75	96
B	6	42	37
C	6	50	45
D	7	94	60
Average		65	60

[a]Ref. 10.

Table 5. Contamination level of unprocessed canned whole peeled tomatoes in Taiwan canneries.[a]

Cannery	Total bacteria		Total mesospores		Flat sourspores	
	Range	Median	Range	Median	Range	Median
	No/mℓ sample					
A (N=13)	19-765	270	11-150	40	4-40	19
B (N=11)	190-1,600	762	17-1,140	162	4-45	21
C (N=8)	800-8,500	3,480	150-4,500	2,330	5-700	147

[a]Ref. 10.

Strict adherence to recommended processing schedules, plus good factory sanitary practices are recommended to reduce the hazard of butyric acid fermentation in the canned product. From our studies, we suggest the following points for controlling microbial spoilage in canned tomato products:

1. Only sound tomatoes of high quality should be allowed to enter the plant.

2. The tomato washing operations should be improved to attain a cleaning efficiency of at least 95% removal of total residues.

3. When considering the adequate thermal processing for canned tomato products, a pH value below 4.4 is recommended to minimize spoilage.

4. For thermal treatment of canned whole tomato, a rotary or agitating cooker is recommended to replace a stationary retort.

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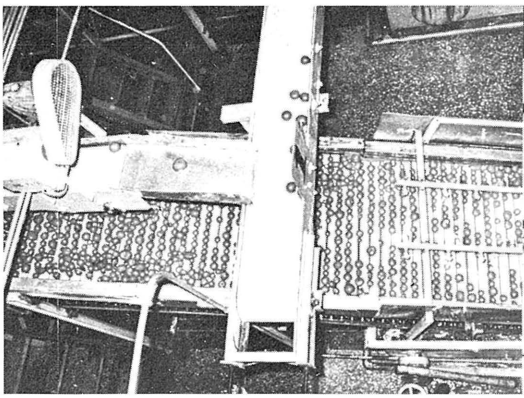
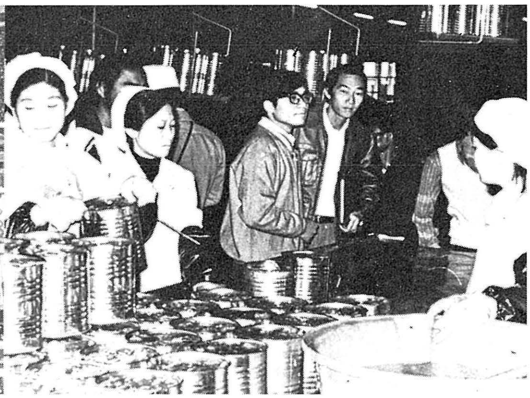


The expansion of tomato as a processing crop is partly due to processing techniques.



An effective way to reduce the cost of containers in Taiwan is to increase their size.

THE ECONOMIC CONTRIBUTION OF THE TOMATO PROCESSING INDUSTRY IN TAIWAN

Yu-kang Mao[a]

INTRODUCTION

Taiwan's tomato processing industry dates back to 1918. Its early products were mostly used with canned sardines. However, in 1931 tomato production in Japan began to decrease, thereby giving Taiwan a boost in the Japanese market. Because of good quality, Taiwan's tomatoes were favorable received by the Japanese.

Just before World War II, production of processed tomatoes reached an all-time high of 223,034 standard cases, produced on approximately 1,500 ha. The industry, at its height when war broke out, suffered the ravages of the times. Since the war, however, new processing industries with products such as pineapple, bamboo shoots, mushroom, and asparagus have been developed. The export of processed tomato products was discontinued.

In 1967, there was only one tomato processing company, the Kagome Food Company, a joint venture between Chinese and Japanese businessmen. Its primary objective was to produce canned tomatoes, with approximately 60% exported to Japan. The industry developed very rapidly. There were 50 food processing factories producing canned tomatoes in 1976.

The tomato processing industry in Taiwan recovered in recent years because of favorable conditions for tomato production, such as a dependable supply and relatively low labor costs, and the recent reduction of tomato production in major producing countries which caused a price hike in the world market.

THE IMPORTANCE OF TOMATO TO THE FOOD PROCESSING INDUSTRY

There were 194 food canning factories in 1976, 50 producing canned tomatoes. Additionally, these factories produced different products in different seasons to fully use facilities throughout the year. The average tomato production was 31,000 standard cases per factory. The largest, President Company, produced 302,405 standard cases per year and the smallest, Wuchung Company, produced 500 (Table 1).

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Table 1. The scale of Taiwan's tomato processing industry in 1976.[a]

Business scale	Factories	Market share
-standard cases-	-no.-	-%-
300,001 and over	1	19.43
200,001 - 300,000	2	31.58
100,001 - 200,000	1	8.57
50,001 - 100,000	2	7.43
25,001 - 50,000	8	18.24
10,001 - 25,000	8	8.67
5,001 - 10,000	7	3.35
2,501 - 5,000	9	2.32
1,001 - 2,500	2	0.19
501 - 1,000	1	0.04
500 and below	9	0.18
Total	50	100.00

[a]Ref. 2.

In order to fully use the existing facilities and labor, factories diversified production. Mushrooms, corn, water chestnuts and Mandarin oranges compete with tomatoes for the use of facilities. Asparagus, bamboo shoots and fruit other than Mandarin oranges complement tomato production.

Those 50 canning factories producing canned tomatoes in 1976 expanded production to 2-10 products (Table 2). Factories producing 3-6 products were the most common, accounting for 58% of the total. The importance of canned tomato products to total canned food in these 50 factories is shown in Table 3.

Table 2. Varieties of products canned in food processing factories in Taiwan, 1976.[a]

No. of products	1-2	3-4	5-6	7-8	9-10	Total
No. of factories	9	18	11	7	5	50
%	18	36	22	14	10	100

[a]Ref. 2.

Table 3 reveals that for 26 factories with a ratio of canned tomatoes to total products of less than 10% , the average production was only 8,000 standard cases per year. Diversification was the main reason these factories produced tomato products. On the other hand, for 6 factories with 56% of the total tomato exports in 1976, 3 were established in recent years. This indicates that the great potential for canned tomato products in foreign markets had encouraged entrepreneurs to invest in this venture.

Table 3. Canned tomato products' share of total canned food in 50 factories in 1976.[a]

The share of canned tomato to total output (%)	0-10	11-20	21-50	51-80	81-100	Total
No. of factories	26	10	8	4	2	50
Exported canned tomato (1000 standard cases)	205.9	250.9	234.1	314.9	550.4	1,556.3
Average export per factory (1000 standard cases)	7.9	25.1	29.3	78.7	275.2	31.1

[a]Ref. 2.

THE IMPORTANCE OF CANNED TOMATO PRODUCTS TO TOTAL CANNED FOOD EXPORTS

Within a short period following the opening of world markets, factories began to add canned tomatoes to their processing lines. According to the Taiwan Canners' Association, the export quantity of processed tomatoes increased from 5,250 standard cases in 1968 to over 1.6 million. The export value of tomato products increased from US$37 thousand to US$1.3 million (Table 4). Export value of tomato products ranked 7th among other products (Table 5).

The major export markets for Taiwan's canned tomato products in 1976 were Japan and Canada, with 40% and 38% of the total, respectively (Table 6). The major tomato product exported in 1976 was paste, with 53% of the total. Peeled tomatoes came second with 43% of the total export.

Although the tomato processing industry has been greatly developed in recent years, Taiwan's share of the world processed tomato market is small. There is still much room for expansion in foreign markets.

Table 4. The quantity and value of Taiwan's canned tomato exports, 1968-76.[a]

	Production	Export quantity	Export value	Total canned food exports
	---1000 standard cases---		-million US$-	-%-
1968	5.2	5.2	.037	0.04
1969	53.0	41.5	.187	0.19
1970	65.2	62.7	.124	0.12
1971	82.8	63.6	.290	0.24
1972	70.2	60.1	.364	0.28
1973	387.8	316.6	2.872	1.67
1974	1,275.3	832.7	9.214	4.34
1975	1,946.8	1,324.0	12.316	6.05
1976	1,648.4	1,556.3	13.128	4.76

[a]Ref.3.

Table 5. Taiwan's production and export of major canned food products in 1976.[a]

Commodity	Production	Export quantity	Export value
	----million standard cases---		-million US$-
Asparagus	3.569	3.899	97.020
Mushroom	3.006	2.670	55.430
Marine products	.624	.586	18.968
Bamboo shoot	3.098	3.034	18.550
Fruit juice	2.299	2.107	18.096
Pineapple	1.132	1.351	13.628
Tomato products	1.648	1.556	13.127
Totals	18,835	18,386	275.745

[a]Ref. 3.

CONTRIBUTION OF THE TOMATO PROCESSING INDUSTRY TO FARM INCOME AND RESOURCE USE

The food canning industry buys tomatoes from many small farms for processing into various canned products for export. Tomato is a winter crop grown from Aug to the following May, and provides raw material for processing from Nov-May. In Taiwan, the tomato processing industry

Table 6. Principal countries importing canned tomato products from Taiwan in 1976.[a]

	Total	Peeled tomato	Tomato paste	Tomato puree	Tomato sauce	Tomato
	------------------	------------	1000 standard cases	------------	------------	------------
Japan	617.7	89.8	516.5	4.9	6.5	
Canada	592.9	519.4	67.2	5.2	1.1	
U.S.A.	122.8	1.3	121.3		.2	
Saudi Arabia	68.6	11.5	32.4			24.6
Puerto Rico	26.8		26.8			
Singapore	24.4		16.9		7.4	.1
Philippines	22.4		22.4			
Australia	21.6	18.3	2.8	.4		
Hongkong	18.4	.2	2.2		15.8	.2
Suva	13.5	13.5				
Totals	1,556.3	662.0	824.3	11.0	31.4	27.5

[a]Ref. 3.

organizes the growers through a farmer-factory contract system. The contract is signed through the local farmers' association for the benefit of farmers.

Between 1967-75 planting areas for tomato expanded from a few hectares to 4,560 ha. However, the lack of reliable large export channels and a big carry-over stock forced a reduction in both the number of factories contracting with growers and the number of contracted hectares per factory in 1975/76 (Table 7).

Factors influencing farmers' decisions on planting tomato are the comparative advantages, farmers' available inputs, and natural environment. The common cropping patterns which include tomato in Taiwan are: late rice -tomato - (fallow) - late rice; late rice - tomato -mungbean (or kaoling) - late rice; sugarcane - tomato - late rice, (Fig. 1). Tomato also is intercropped with sugarcane and orchard trees (Fig. 2). By fully using farm resources, these cropping patterns can increase farmers' cash income significantly. According to AVRDC, the producers' net profit from tomato was approximately US$134/ha with a guaranteed price of US$28/t in 1976, which was advantageous compared to other winter crops.

The farmers' total share of exported tomato earnings can be calculated from the farmer-factory contracted quantity and price. From Table 7 we can see that tomato farmers' share increased steadily from US$8,144 in 1967/68 to US$7 million in 1974/75, and then dropped to US$4 million in 1976 because of the reduction in the number of contracted hectares

Table 7. Contracted acreage, production, and contract price of processing tomatoes in various years[a].

Year	Area	Production	Price	Farmer's share
	-ha-	-1000t-	-US$/t-	-1000 US$-
1967/68	18	.5	16	8.1
1968/69	146	4.8	16	77.0
1969/70	149	7.1	16	114.2
1970/71	193	6.7	15	100.1
1971/72	285	7.1	15	106.9
1972/73	742	35.9	24	860.6
1973/74	1,549	90.7	31	2,812.5
1974/75	4,560	244.0	29	7,076.0
1975/76	2,925	146.2	28	4,095.0
1976/77	2,432	275.8[b]	28	7,722.2

[a]Ref. 1. [b]Estimated by author.

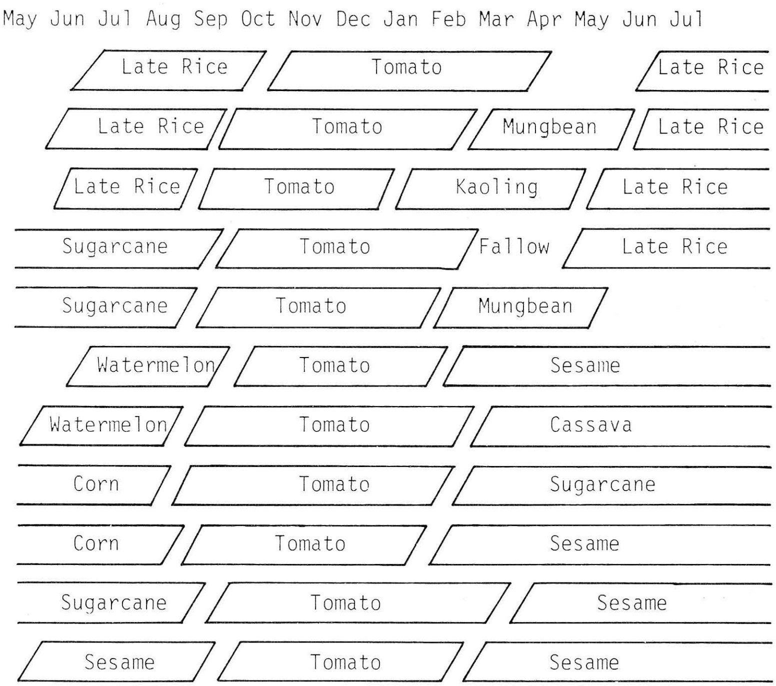

Fig. 1. Cropping patterns that include monoculture processing tomato.

per factory. In 1976/77 the farmers' share again increased to US$7 million. It was a great contribution to farmers' cash income.

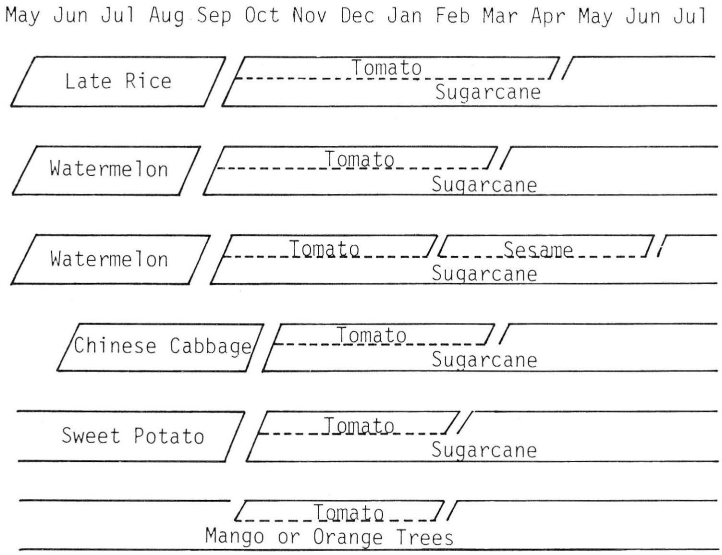

Fig. 2. Cropping patterns that include intercropped processing tomato.

SUMMARY AND CONCLUSION

Owing to the comparatively lower factory labor wage, industrious workers, low cost but good quality raw materials, and a wide range of processable agricultural products, the Taiwan tomato processing industry has shown a sharp expansion in recent years.

Processed tomato, one of the important export commodities among the canned food products, ranked 7th in 1976. We conclude that the major economic contributions of the tomato processing industry in Taiwan are:

1. Canning tomatoes enables a factory's processing line to operate year-round, and provides alternative employment for farm family members. It reduces the cost and increases factory revenue due to a more complete use of the facilities.

2. Farmers' income is guaranteed through contracts with the canneries.

3. On the national level, canned tomato product exports increase foreign exchange earned and make fuller use of agricultural resources.

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DISCUSSION SESSION V (MORNING)

Hubbell: What was the average temperature and what was the rainfall during the trial of SSD material planted in May, 1977?

Chai: In the MARDI station where the SSD materials were evaluated, temperature fluctuation is normally between 23-31°C. It is generally dry in May. Supplemental irrigation was provided to the plants as needed.

Hubbell: One SSD line showed fruit size of 80 g with a good yield. Have some seeds of this material been returned to AVRDC?

Chai: According to Dr. Villareal, AVRDC has most of these SSD materials.

Sunarjono: The SSD method of breeding tomato is surely surprising. However, it requires more seed handling with each generation. How effective is the bulk method up to the 4th generation when combined with the SSD method?

Villareal: Actually, we start with about 2,000 seedlings per cross. By natural selection, this number is reduced to about 500 in the F_5. We have used a modified SSD in which we subjected the F_2's to a wilt epiphytotic condition. Surviving plants are advanced by the SSD method. Other workers in the U.S., like Dr. Pierce, found this method equally effective in selecting for desirable genotypes.

Aclan: Under the Taiwan situation, what should be the yield to make seed production profitable?

Yu: I do not know.

Acosta: How much seed yield do you get from a ton of pollinated fruit?

Yu: It is difficult to base yield from tonnage of tomato fruit harvested. In Taiwan, we use hectarage instead. We obtain about 20 to 30 kg/0.1 ha.

Acosta: Does hand pollination reduce seed yield? By how much?

Yu: Sorry, we don't have data on this. Some scientists say, however, that yield could be reduced by 20-30%.

Villareal: In one growing season, how many farmers does Known-You Seed Co. contract to produce seed?

Yu: Known-You Seed Co. contracts at least 300 farmers per season.

Villareal: How many kilos of seeds can they produce?

Yu: This year, maybe about 12 t.

Acosta: How long will you be pollinating and when do you start pollinating to get good set in a plant?

Yu: We start with the second cluster of every plant and continue pollinating until the 5-7th cluster.

Acosta: Do you stagger your planting to spread your labor force?

Yu: Yes, we stagger our planting dates.

Acosta: How much heterosis in terms of yield do you get from F_1 compared to ordinary varieties?

Yu: This varies according to the combination and year. Factors such as uniformity, growth, vigor and early maturity contribute to the advantage of F_1 hybrid. The yield may be 10-30% better than standard varieties. We have some hybrids that yield 50% more.

Chai: Do the parental materials that you use for F_1 seed production carry any bacterial wilt resistant genes? If yes, do you observe any heterosis effect?

Yu: We don't know if the materials we use carry bacterial wilt resistance since we receive both parents from foreign seed companies.

Chai: How does the cost of F_1 seed compare to the ordinary ones?

Villareal: F_1 tomato hybrid seeds are about 15-20 times more expensive.

Mansour: Can bacterial wilt be transmitted by seed?

Yu: No.

Sunarjono: How many flowers per day can be pollinated by a laborer?

Yu: We need 200 female workers per hectare.

Vorayos: What fruit color of F_1 varieties is the most popular in foreign countries?

Yu: Red.

Vorayos: What methods do you recommend to induce maximum seed content.

Yu: We use single stem to increase the fruit percentage. The second method is the use of calcium, which is needed for acid soils, to reduce root rotting. Another, is the use of borax. For example, on our farm, borax is applied at a rate of about 10 kg/ha. Boron deficiency severely reduces the seed content.

Riley: How many kilograms of seed are used by farmers per hectare?

Yu: About 200 g.

Afutiti: In tomato breeding, how long does it take from germplasm collection to the time hybrid seeds are ready for export? Are there any other practical ways that will take less time?

Villareal: The North Carolina and Hawaii tomato breeders took 30 and 25 years, respectively, to develop bacterial wilt resistant varieties. Of course, they started with a wild tomato, *L. pimpinellifolium* for their source of resistance. However, by using improved varieties from other breeding programs, much faster progress can be made, as at AVRDC. In addition, AVRDC scientists used an interdisciplinary approach in breeding for bacterial wilt and heat-tolerant tomatoes. In about 6 years, AVRDC has produced a number of breeding lines that have done well in several countries in the tropics.

Riley: The male sterility question was introduced. Is there any real possibility that it can be found in the tomato germplasm?

Villareal: Many male sterile plants have been observed in the tomato. However, their practical use has not been worked out satisfactorily. There are rumors that some seed companies have used male sterile lines on a semi-commercial scale.

Augustine: A stamenless tomato has been used by the Israelis in F_1 seed production.

Bell: We have heard that farmers in most countries of S.E. Asia save their own seed. At the same time, we observed the excellent and successful work of Known-You Seed Co. in producing vegetable seeds for sale to farmers. Obviously a few farmers are buying vegetable seeds of pedigreed origin, although their number may be small in proportion to the total farming population. Do you have an opinion about the trend in the future of the adoption rate of buying vegetable seeds by farmers who now save their own?

Yu: If the price is reasonable, farmers would like to use F_1 seeds. If the price is too high, they'll use their own seeds.

Luh: In Taiwan, farmers did not care about the price of OS cross (F_1 cabbage hybrid) even if the price was 20 to 30 times higher than ordinary cabbage seeds, as farming practices and the economy advance, more hybrid seeds will be used by farmers. If a country remains developing, like Bangladesh, I don't think farmers will be able to afford even ordinary seeds, much less F_1 seeds.

Bell: Do you know of any area that is an example of farmers increasing the adoption rate of buying vegetable seeds?

Castro: This might be a difficult question, because in Taiwan farmers rarely use their own seeds. You can refer to areas outside of Taiwan.

Anonymous: What about the future of the production and marketing of seeds by your company, do you expect an increase in the production and marketing of your seeds?

Yu: No, because with the rapid industrialization of Taiwan the cost of labor is getting higher and higher, so I think hybrid seed production in Taiwan will become more difficult after 5 years.

Bell: Do you see farmers increasing the buying of vegetable seed instead of saving their own? We understand that your company is producing seeds for ths U.S. and European market in a rather large quantity. Is the production of seeds for the Asian countries outside of Taiwan, Japan, and Korea increasing? Let's say, for example; Indonesia, Philippines, Thailand, and Malaysia?

Yu: I think it will be increasing. The farmers now see that hybrid seeds grow more vigorously and uniformly. So if the market requires more uniform tomatoes, I think they will grow hybrid tomatoes.

Bell: Which of the countries, Philippines, Thailand, Malaysia, Indonesia, is increasing their buying of seeds?

Yu: Very few Asian countries buy our seeds. The seeds are exported to U. S., Japan, and Holland. Almost none are exported to Malaysia, Singapore, and Philippines. They say it is expensive.

Villareal: The rate of adoption depends on how exciting the hybrid or variety is. For example when we introduced KK (a cabbage F_1 hybrid) in the Philippines in the late 1960's farmers complained about the cost of seed. Now, 10 years later, almost 100% of the area planted to lowland cabbage in the Philippines is in KK. Mr. Paner, would you know the seed yield of those tomatoes that survived wilt infestation?

Paner: No seed yield was obtained, since only a few plants survived. I was told, however, that many seeds were observed in fruits that were opened.

Riley: Don't you think it is risky to expand the acreage of this project, considering your experience in the first year?

Paner: I was told by Mr. Domingo, the seed grower, that the wilt problem may be partially solved by growing the tomatoes in fields previously planted to rice. He observed that male (pollen) parents planted this way had better survival than the female parents planted in another field. It is only an assumption that wilt infestation may be reduced by planting tomato after paddy rice.

Ho: Where was the trial conducted?

Paner: In Isabela, about 400 km northeast of Metro Manila.

Ho: Don't you think your sowing date of Jan 14 may be a little late?

Paner: It was sown Dec 14 and was transplanted to the field Jan 7-10. This time, however, we will trying sowing earlier; maybe as early as Nov.

Riley: Is the objective to produce hybrid tomato seeds for the Philippines only, or for export?

Paner: As I mentioned earlier in my paper, the demand for tomato seeds is for ordinary varieties and not for F_1 hybrid. This is true for other vegetables as well. In general, very few farmers buy seeds. Big companies produce their own seeds. We have to look for more outlets in other countries. Right now, we are preparing a program to look at the potential for vegetable seed industry development in the Philippines.

Acosta: It we can produce the F_1 seed, how much are you willing to pay for the seed? The prevailing Manila price will suffice?

Paner: The Manila price is US$80 per kilo. But I heard yesterday that Taiwan sells hybrid seeds to the US contracting company for US$54

Aclan: Considering the daily wage of farm workers in the Philippines, and other factors, what seed yield do you think is needed to make seed production economically feasible?

Paner: That is a good question, but hard to answer. I asked Mr. Yu, but he could not give me a figure. Anyway, it depends on factors such as availability of women pollinators, market demand, etc. Taiwan gets about 200 kg of seed per hectare. However, at US$80/kg in Manila, 100 kg seed yield per hectare in the Philippines will be good enough.

Acosta: Is there a difference in wages between female and male pollinators? If none, why do we employ only female pollinators?

Paner: Actually it is not the wages. Women have a lot of patience and are therefore more fitted to this work.

Riley: Is it because the female touch is better and she is paid less?

Yu: In Taiwan, the wage varies according to location. For instance, in the Pingtung area, male laborers are paid at NT$150 per day (US$4.2 /day), female NT$100 per day (US$2.80/day), whereas, in the Tainan area, males receive NT$200 per day (US5.60/day) and females NT$120 per day (US$3.40/day). Secondly, women, especially young ladies, have tender fingers and better eyes. Thus, Known-You prefers to hire young ladies. Even if the boys are willing to be paid less, the company does not want to hire them.

DISCUSSION SESSION V (AFTERNOON)

Riley: With the development of the tropical tomato, the potential for lengthening the production and processing season in Taiwan now exists. If production in Sep-Oct and Apr-May is initiated, with what products will tomato compete in the processing factory?

Kao: In Dr. Mao's paper, he shows that tomato processing period is Nov to Apr. In that case, bamboo shoots and asparagus are complementary with the tomato processing. If the operation is lengthened as you mentioned, tomato would compete for facilities with Mandarin orange, water chestnut, sweet corn, mushroom, pineapple and, to some degree, asparagus.

Guintu: Since establishing the tomato processing industry in Taiwan, how much has the average income of farmers increased?

Kao: This is a difficult question. The number of farmers who are growing tomato is rather small and it is hard to determine how much added income the tomato processing industry can give to a farmer. In Dr. Mao's paper, farmers' incomes are increased in two ways. First, because of contracting between farmers and canners, the price of tomato is guaranteed. Thus, their income is guaranteed if they can get a stable yield. Second, in some areas, land is idle during the winter. But because of the development of the tomato processing industry, some farmers are now growing tomatoes in the winter. Of course this increases their income. How much increase they get, I don't know.

Riley: How do the labor requirements for the processing tomato compare with those of mushroom and asparagus?

Lee: It is difficult to answer, because I am not an economist, I am a processing technologist.

Riley: You just stressed in your paper that tomato processing is labor intensive. Maybe you would know whether the number of people employed goes up during the time they are packing tomatoes. I am not asking for an exact figure, just wondering if tomato processing is a lot more labor intensive than the other 2 leading commodities here, asparagus, and mushroom.

Kao: I just asked the gentleman sitting beside me. I presume he comes from President Enterprise. He said that tomato processing requires no more labor than the processing of asparagus or mushroom.

Sunarjono: What treatments do you use in processing (i.e. chemical treatment for preservation)?

Lee: For peeled tomato, the treatments are: washing, coring, and peeling. But for tomato juice or paste: washing, pulping, and concentrating.

Anonymous: What kind of chemical do you add to the juice?

Lee: Only citric acid is added to adjust pH value.

Riley: Does the government help smaller companies make contact with foreign markets? Does President send representatives to the countries where it is trying to open markets for its products?

Chen: For the time being, the Government gives no direct assistance to tomato companies, but the Government always encourages the tomato companies to have their products exhibited in foreign countries to let foreigners learn about the Taiwan tomato industry so that they can contact Taiwan tomato companies for business. So there is no special help for either the small or the big companies.

Riley: Does President assign a representative to the country where it is trying to open a market for each product?

Chen: We don't have special representatives staying in foreign countries, but our people, like Mr. Shih our manager, or our President, go abroad to search for buyers and to investigate markets.

Mansour: For hundreds of years, the tomato was considered poisonous. It has been popularized nicely in the past 50 years. Today, several scientists have proposed the idea that tomato and other solanaceous crops are partially responsible for some types of arthritis and perhaps other similar ailments. The reason proposed by Norman Childers is a case in point:
Questions are: 1. What should the responsibility of the tomato scientists be to this proposal; 2. Does anyone have any evidence to either refute or to support this proposal; 3. How should tomato processing industry respond?

Johannesen: It is unfortunate that this book was published. The cover shows a picture of 2 cigarettes, an eggplant, a potato, peppers and tomatoes. These are all in the solanaceous group. Norman Childers believes, fervently, that eating potatoes and tomatoes causes his ankles to swell.....and that there is a problem with the...., well I won't use the word, but there are alkaloids, of course, in the solanaceous family, and we have known for a long time that some compound is produced in potatoes that gets green from exposure to light that is not good. I was very interested in this book because it presents the same type of potential problems as did "Silent Spring". Apparently he made a survey of about 600 people and asked them how they felt after eating solanaceous fruit. He publicized the result of the surveys he made in this book. But I don't think he presented any hard evidence that the solanaceous crops were, in fact, hurting the health of the people. I have been waiting for some reaction to the book, but apparently nobody is reading the book except those concerned.

Villareal: Dr. Childers was my professor in Horticulture at Rutgers. I have not read the book, but it seems to me that if it can be proved definitely that there are compounds in tomato that are responsible for arthritis, I think with the present technology in plant breeding, it would be possible to develop varieties which may contain less of these compounds.

Johannesen: In regard to the compounds in the tomato and the solanaceous family.......Allen Stevens mentioned today some of the insect resistance work that is being done.....to find higher levels of alpha-tomatine in the tomato, which is perhaps responsible for resistance to insects. We have a proposal from the Univ. of California to fund a research project on insect resistance. We have a lot of insect problems in California and we don't want really to introduce another one now, when we have priority projects like.....night shade, nut grass, variety development for disease resistance, and others. So we elected not to go into this topic. One of the reasons was that the timing for talk about tomatine was perhaps not just right and until the publication of that book we just avoided this particular project for the time being. Not that we aren't interested in insect resistance, we are, but Allen did point it out, and the reason he pointed it out was that he is aware of the same thing, I'm sure, that apparently in the tomato the tomatine disappears with maturity. We hope that is true and the indications are that it is, but we would just as soon side step that for the moment.

Acosta: Containers are very expensive here in Taiwan. Is there a plan to minimize the costs in the future?

Johanessen: If you are talking of the costs of the cans, I have never seen stronger cans than you have here in Taiwan. Most of the juices that we have in the mainland come in thin, very paper thin, aluminum, etc. I was thinking of the weight for shipping. I wonder if you'd be better off with the thinner cans? The cost of the container would be a lot less.

Riley: Your reference to the mainland is to the United States. If you have been here long enough to see how traffic is here, you need heavy cans for insurance.

Lee: Cans are expensive because the tin plate is imported from Japan.

Luh: The industry has thought about this and thinner tin plate will be used in the near future.

Bell: Do most of the tomato products from Taiwan enter the North American retail markets through North American brand names or through Taiwan brand names?

Mao: At least some Taiwan tomato products are sold to North American and other markets under their own Taiwan brand name; whereas, when small amounts of products are sold, they are sold under foreign names.

Castro: During the break time, I suggest you take a look at the tomato exhibition. Most of them are exported products. I think they use the President name.

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