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IMPROVED VEGETABLE PRODUCTION IN ASIA

IMPROVED VEGETABLE PRODUCTION IN ASIA

Food and Fertilizer Technology Center
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PREFACE

This book is the proceedings of the seminar on *Improvement of Vegetable Production in Asia*, held in Chiang Mai, Thailand on 21—23 October, 1986. The seminar was convened by the Food and Fertilizer Technology Center for the Asian and Pacific Region, with the co-sponsorship of Chiang Mai University, Thailand and the Outreach Programs in Thailand of the Asian Vegetable Research and Development Center (AVRDC), Taiwan ROC. We are most grateful to the staff of the Faculty of Agriculture of Chiang Mai University, who did such outstanding work in organizing the seminar and making all participants warmly welcome. The Center would also like to thank Dr. Charles Y. Yang, Director/Resident Scientist of the Thailand Outreach Programs, AVRDC for his fine work in arranging the seminar program and field tour. We are indebted to the Council of Agriculture, ROC, for its generous financial support of the seminar, and for providing the funds to publish this volume, which will be distributed free of charge to agricultural libraries throughout the Asian and Pacific region and in more than 50 countries outside the region.

Agriculture in the region is developing rapidly, as new cultivation techniques and varieties come into use. Vegetable production is a vital aspect of this development, since it is one of the most important means by which small-scale farmers can improve their incomes, while at the same time increasing national food output. The recent surplus of staple food crops in many Asian countries makes it all the more urgent to help small-scale farmers produce more diverse crops of higher value.

Most small-scale farmers in Asia live in the tropics or subtropics. If they are to improve their vegetable production, they need a range of hardy varieties which are heat and disease resistant, and production methods suitable for small farms with limited capital. The papers in this Proceedings bring together recent research into vegetable production from a number of Asian countries. They describe the breeding of new varieties, the development of improved cultural methods, and also recent work on the processing and marketing which is such a vital aspect of small farm development.

CH Huang

Cheng-Hwa Huang
Director/FFTC

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Production

VEGETABLE PRODUCTION IN THAILAND: CURRENT STATUS AND PROSPECTS

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ABSTRACT

The paper by an FAO Expert Consultant Group was compiled as part of a report on Improved Production of Tropical Vegetables. The current status of vegetable production in Thailand is described, and recommendations made for improvement. Thailand has developed a vegetable export industry which has great potential. The domestic vegetable market demand is strong, but returns to the farmers are poor, due to marketing difficulties and improper postharvest handling. Thailand imports a large percentage of her vegetable seeds, although conditions are potentially suitable for Thailand to become a major producer and exporter of seed.

(Chinese Abstract) 摘　要

本文係收錄在糧農組織專家顧問團之“熱帶蔬菜生產改進”報導中的一部分。內容包括泰國蔬菜生產近況的描述與改進意見。泰國的蔬菜出口工業具有很大的發展潛力。國內的蔬菜市場需求力很強，祇因市場運作困難及採收後的處理不適當，才造成農民的收入偏低。雖然泰國具有成爲種子主要生產與輸出國的發展潛力，但目前每年需進口高比例的蔬菜種子。

(Japanese Abstract) 摘　要

この論文はFAOの專門家顧門グループにより熱帶における野菜生産の改良についての報告の一部として編集された。

タイ國の野菜生產の現狀及びその改良についての勧告が述べられている。タイ國は野菜輸出產業を發展させたがこれは大きな将来性を持ついてる。國內での野菜の需要は大きいが、マーケツテイングの困難さや收獲後處理が不適當な爲に農民の收入は少ない。タイ國は主要な種子生產者や輸出者になるに適した可能性を持つているにも拘らず、タイ國で消費する種子の大部分を輸入している。

(Korean Abstract) 적　요

FAO자문단의 논문은 열대채소 생산개발에 관한 논문의 일부를 정리 한것이다. 현재 태국의 채소 생산현황을 설명하고 있으며 이에대한 개선 방향을 건의하고 있다. 태국은 채소수출산업이 발전해왔으며 큰 잠재력을 지니고 있다. 국내의 채소시장수요가 강세 인데도 농민의 수익은 보잘것 없는데, 이것은 유통상의 어려움과 수확후의 조작이 적절하지 못한데에 기인한다. 태국은 종자의 주요 생산자이면서 수출국이 될수있는 잠재력을 가지고 있지만, 많은 비율의 종자를 수입하고 있다.

VEGETABLE PRODUCTION IN THAILAND: CURRENT STATUS AND PROSPECTS

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INTRODUCTION

Vegetables are an important source of food for people of all levels of income in Thailand, but particulary for the middle and low income groups. The *per capita* income of Thais averages U.S.$600 per year, so that a large proportion of people cannot afford to consume meat as their main source of protein. For low income groups in the north of Thailand, most of the dishes eaten with rice are made from boiled vegetables mixed with pepper paste and fermented fish. Many kinds of insects are used as a source of protein. The major food eaten with rice by low income groups in Northeast Thailand is raw papaya mixed with vegetables and fermented fish.

Over 30 kinds of vegetables are grown for local consumption. There are many kinds of trees of which the young shoots are used as vegetables. A few kinds of vegetables are grown for export, such as Chinese cabbage, tomato, cabbage, shallot and ginger: many of these are processed for export. Processed vegetables are the largest export item (by volume), and fresh vegetables are second in terms of both volume and value.

Thailand has a great potential for producing fresh vegetables and vegetable seeds. Variations in Thailand's climate make it possible to produce fresh vegetables all year round, and also to produce a range of vegetable seeds from crops which require different climates for flowering. Fresh vegetables are successfully exported to neighboring countries such as Malaysia and Singapore, while processed vegetables are exported to Japan, the United States and Europe. One example of successful vegetable seed production has been the F_1 hybrid tomato seed business in Northeast Thailand. The hybrid seeds are all exported. Although many open pollinated vegetable seeds are produced in Thailand, most of these are for local use. Only a few open pollinated seed items, such as water convolvulus and watermelon, are exported.

There are many constraints involved in fresh vegetable production, the most important of which is the limited number of varieties adapted to Thailand's climatic conditions. Most of the improved varieties have been introduced from temperate and subtropical countries such as Japan, Taiwan, the United States and Europe. They are not well adapted to a hot climate and tropical diseases. Lack of farming skills and suitable technology is also important. As our own interviews with farmers in the North and Northeast showed clearly, there are many farmers who do not understand even very simple cultivation techniques. This lack of skill leads to low yields and poor quality produce. Poor quality produce is also due to poor postharvest handling of vegetables, which results in a loss of 50–60% when vegetables are transported from northern Thailand to Malaysia.

Vegetable seed production is limited by many constraints. There are two main types of seed production: open pollinated seed production and F_1 hybrid seed production. The production of open pollinated varieties faces more problems than that of F_1 hybrid varieties. The open pollinated varieties are produced for local use, while F_1 hybrid varieties are produced for export. There is no firm market for open pollinated varieties and the price of seeds is extremely low, while F_1 hybrid varieties are produced under contract and the price of seeds is quite high. The quality of open pollinated varieties is not always good or standardized, compared to that of F_1 hybrid varieties, because of poor seed technology in production and poor postharvest handling.

SOCIO-ECONOMIC IMPORTANCE OF VEGETABLE CROPS

The acreage of vegetables grown in Thailand is rather low. The vegetable and flower growing area is only 1% of the total cultivated area (Fig 1, Table 1). The central part of the country has the biggest vegetable and flower growing area (0.05%) while the southern part has the smallest (0.01%) and the north and the northeast have 0.02%. The area of vegetable and flower production has not changed over the last ten years, while 'Forestland' has been declining from 39% to 30% of total land area over the same period. The area in 'Other farm holdings' has increased from 35% to 39%. This is mainly paddy fields, but also includes housing areas, field crops, fruit trees, tree crops, grassland, idle land and other land.

The total area of vegetable production may be low, but vegetables are very important, in the diet of local people, especially of low income groups. *Per capita* income in Thailand is rather low (US$637 per year in 1983) compared

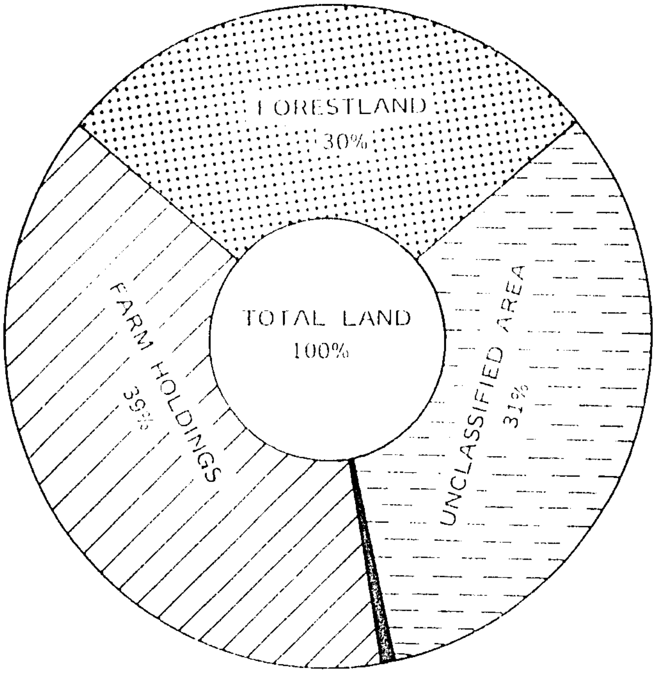


Fig 1 Land utilization in Thailand, 1983

Table 1 Land utilization and type of land holding (by region) in Thailand, 1976-1983

Unit: ha

Region	Year	Total land[1]	Forest land[2]	Farm holdings: Vegetables and flowers	Farm holdings: Other crops, housing etc.	Unclassified
Northeastern	1976	16,885,434(33)[3]	4,149,400(8)	12,289(0.02)	7,786,294(15)	4,937,451(10)
	1977	16,885,434(33)	3,626,074(7)	12,093(0.02)	7,715,070(15)	5,532,197(11)
	1978	16,885,434(33)	3,122,100(6)	12,558(0.02)	7,875,633(15)	5,875,143(12)
	1979	16,885,443(33)	2,976,776(6)	12,197(0.02)	7,918,059(15)	5,978,402(12)
	1980	16,885,434(33)	2,839,763(6)	12,385(0.02)	8,002,493(16)	6,030,793(12)
	1981	16,885,434(33)	2,710,534(5)	12,060(0.02)	8,261,210(16)	5,901,630(12)
	1982	16,885,434(33)	2,588,600(5)	14,438(0.03)	8,442,184(16)	5.840,212(11)
	1983	16,885,434(33)	2,531,562(5)	14,561(0.03)	8,508,653(17)	5,830,658(11)
Northern	1976	16,964,429(33)	10,232,700(20)	15,564(0.03)	3,657,746(0.07)	3,058,419(0.06)
	1977	16,964,429(33)	9,852,003(19)	13,499(0.02)	3,766,265(0.07)	3,332,662(0.07)
	1978	16,964,429(33)	9,493,700(19)	12,554(0.02)	3,891,512(0.08)	3,566,663(0.07)
	1979	16,964,429(33)	9,306,469(18)	11,786(0.02)	4,011,124(0.08)	3,635,050(0.07)
	1980	16,964,429(33)	9.124,511(18)	12,201(0.02)	4,151,833(0.08)	3,675,884(0.07)
	1981	16,964,429(33)	8,947,621(17)	10,819(0.02)	4,253,078(0.08)	3,752,911(0.07)
	1982	16,964,429(33)	8,775,600(17)	12,221(0.02)	4,400,196(0.09)	3,776,412(0.07)
	1983	16,964,429(33)	8,652.400(17)	12,381(0.02)	4,458,002(0.09)	3,841,646(0.07)
Central	1976	10,390,121(20)[3]	3,445,700(7)	24,528(0.05)	4,469,704(9)	2,450,189(5)
	1977	10,390,121(20)	3,287,678(6)	23,694(0.05)	4,533,429(9)	2,545,320(5)
	1978	10,390,121(20)	3,146,300(6)	25,330(0.05)	4,659,212(9)	2,559,279(5)
	1979	10,390,121(20)	3,009,309(6)	22,458(0.04)	4,656,832(9)	2,701,522(5)
	1980	10,390,121(20)	2,881,733(6)	21,938(0.04)	4,628,148(9)	2,858,302(5)
	1981	10,390,121(20)	2,762,744(5)	21,148(0.04)	4,566,807(9)	3,039,422(6)
	1982	10,390,121(20)	2,651,600(5)	23,434(0.05)	4,583,661(9)	3,131,426(6)
	1983	10,390,121(20)	2,607,243(5)	23,270(0.05)	4,563,216(9)	3,196,392(6)
Southern	1976	7,071,519(14)	2,013,900(4)	4,783(0.01)	2,127,015(4)	2,925,821(6)
	1977	7,071,519(14)	1,886,090(4)	4,004(0.01)	2,139,376(4)	3,042,049(6)
	1978	7,071,519(14)	1,760,300(3)	5,200(0.02)	2,148,599(4)	3,157,420(6)
	1979	7,071,519(14)	1,730,323(3)	3,788(0.01)	2,180,216(4)	3,157,192(6)
	1980	7,071,519(14)	1,700,991(3)	3,793(0.01)	2,207,040(4)	3,159,695(6)
	1981	7,071,519(14)	1,672,290(3)	3,980(0.01)	2,277,912(4)	3,117,337(6)
	1982	7,071,519(14)	1,644,200(3)	4,561(0.01)	2,293,192(5)	3,129,566(6)
	1983	7,071,519(14)	1,611,574(3)	4,673(0.01)	2,292,084(5)	3,163,188(6)

Source: 1. Royal Thai Survey Department

2. Royal Forest Department: Forest 1 and from LANDSAT 2 and 3: 1976, 1978, and 1982

3. % total land area

Table 1 Land utilization and type of land holding by region in Thailand, 1976-1983. (continued)

Unit: ha

Region	Year	Total land[1]	Forest land[2]	Farm holding land		Unclassified
				Vegetable flower	Other crops.	
Whole kingdom	1976	51,311,503(100)[3]	19,841,700(39)	57,164(0.1)	18,040,759(35)	13,371,880(26)
	1977	51,311,503(100)	18,651,845(36)	53,290(0.1)	18,154,140(35)	14,452,228(28)
	1978	51,311,503(100)	17,522,400(34)	55,642(0.1)	18,574,956(36)	15,158,505(30)
	1979	51,311,503(100)	17,022,877(33)	50,229(0.1)	18,766,231(37)	15,472,166(30)
	1980	51,311,503(100)	16,546,998(32)	50,317(0.1)	18,989,514(37)	15,724,674(31)
	1981	51,311,503(100)	16,093,189(31)	48,007(0.09)	19,359,007(38)	15,811,300(31)
	1982	51,311,503(100)	15,660,000(31)	54,654(0.1)	19,719,233(38)	15,877,616(31)
	1983	51,311,503(100)	15,402,779(30)	54,885(0.1)	19,821,955(39)	16,031,884(31)

Source: 1. Royal Thai Survey Department
2. Royal Forest Department: Forest land from LANDSAT 2 and 3: 1976, 1978, and 1982
3. Percentage of total land area

with neighboring countries like Malaysia (US$844 per year in 1983) (Table 2), and very much lower than in Japan, the United Kingdom or the United States. However, it is triple that of India. There is a large percentage of low income earners who cannot afford meat and meat products, for whom vegetables are a major source of food.

Table 2 Per capita income: Thailand and selected countries 1974-1983

Unit: US$

Year	Thailand	Malaysia	India	Japan	United States	United Kingdom
1974	268	811	137	3,494	5,986	3,159
1975	292	702	130	3,757	6,339	3,410
1976	322	865	138	4,357	6,985	3,401
1977	360	1,042	164	5,815	7,719	4,350
1978	417	1,271	176	7,815	8,590	5,348
1979	478	1,450	196	6,802	9,455	6,869
1980	574	1,620	227	8,638	10,121	8,532
1981	572	1,698	226	8,363	11,294	7,510
1982	601	1,728	222	8,141	11,513	6,953
1983	637	1,844	*	8,475	12,305	6,817

Sources: Thailand: National Statistical Office: National Income of Thailand 1984, by the National Economic and Social Development Board
Other countries: From United Nations, Monthly Bulletin of Statistics, July 1985

Many vegetable commodities are also exported. Total export value and quantity has increased over the last five years (Table 3). Export commodities are listed in Table 4. Preserved vegetables, fresh vegetables, fresh *Allium* species, ginger and baby corn were major export commodities in 1984. Although Thailand can produce almost any kind of fresh vegetable and many kinds of seeds, the country still imported some fresh vegetables and many kinds of vegetable seeds. However, the import quantity and value has decreased over the last five years (Table 3). Major import commodities in 1984 were dried shallots, dried beans, dried chilli and vegetable seeds (Table 5).

Processed vegetables are the biggest

Table 3 Import, export and net export of vegetable seeds and fresh and processed vegetables 1980–1984

Value: 1000 US$

Year	Imports		Exports		Net exports	
	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value
1980	12,459	7,662	28,496	7,431.1	16,037	−230.9
1981	12,769	9,749.54	40,365	11,438.8	27,596	1,689.3
1982	13,383	9,775.2	48,768	18,353	35,385	8,577.8
1983	8,856	9,487.2	65,357	24,229.2	56,501	14,742
1984	8,826	9,326.1	70,777	26,340.2	61,951	17,014.1

Exchange rate: 1 US$ = 27 Thai Baht
Source: Ministry of Commerce, Bangkok, Thailand

Table 4 Exports of vegetables and their products 1980 – 1984

Value: 1000 US$

	1980		1981		1982		1983		1984	
	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value
Veg. seed for planting	212	224	531	365	297	360	477	991	584	1,113
Bamboo shoot, fresh	119	32	35	17	231	84	289	190	339	325
Onion, shallot, garlic leek, fresh	1	0.4	203	47	1,946	381	6,144	1,178	7,715	1,441
Veg. fresh	10,352	1,874	15,900	2,358	13,514	3,192	16,684	3,722	17,120	4,000
Veg. chilled, frozen	37	26	348	99	2,341	490	65	77	194	134
Veg. dried, dehydrated, evaporated	717	499	676	404	375	295	266	355	699	811
Mushroom, dried	18	151	24	222	47	240	26	221	38	298
Shallot, dried	8,162	1,487	7,381	1,347	3,359	825	2,875	575	1,754	392
Onion, dried	102	19	94	25	9	5	434	48	378	96
Garlic, dried	11	4	1	0.6	1	0.8	1	1.6	1	0.2
Baby corn in airtight containers	916	792	1,229	1,070	1,521	1,357	4,014	3,318	4,482	3,746
Veg. prepared, preserved in airtight containers	2,396	997	2,680	1,445	5,100	2,841	6,643	3,518	9,166	3.913
Veg. prepared, preserved, not in airtight containers	3,819	949	5,741	2,101	12,237	5,377	19,263	7,893	21,076	8,095
Veg. juice	67	50	n.a.	0.2	n.a.	0.2	1	1.6	9	10
Potatoes	275	40	190	39	3	1	190	43	14	2
Tomato, fresh or frozen	3	0.7	123	25	173	62	1,360	296	2,123	460
Ginger, grey and white	1,239	244	5,152	1,787	7,331	2,551	6,584	1,755	5,017	1,425
Tomato paste	50	42	57	87	283	291	41	46	68	79
Garden crops and products	28,496	7,431.1	40,365	11,438.8	48,768	18,353	65,357	24,229.2	70,777	26,340.2

n.a.: data not available
Exchange rate 1 US$: 27 Thai Baht

Source: Ministry of Commerce, Bangkok, Thailand

Table 5 Imports of vegetables and their products, 1980 — 1984

Value: 1000 US$

	1980		1981		1982		1983		1984	
	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value	Quantity (mt)	Value
Potato, fresh	—	—	1	0.5	—	—	—	—	48	30
Potato for planting	110	65	149	90	132	84	71	39	87	42
Vegetables, fresh	56	38	30	28	28	37	64	70	90	109
Veg. salted, dried	733	713	718	803	576	813	734	942	695	921
Shallot, dried	3,097	764	2,025	535	3,256	921	1,143	320	3,138	1,154
Onion, dried	4,488	1,555	4,710	2,071	3,397	876	984	369	580	312
Garlic, dried	395	309	17	29	—	—	n.a.	0.2	5	2
Mushrooms and truffles, dried	47	689	56	918	42	628	69	1,105	77	1,407
Bamboo shoots, dried	107	338	218	418	136	431	182	582	120	408
Other beans, dried	1,332	486	661	274	696	291	1,023	375	1,149	443
Peas	379	121	240	97	679	296	649	277	671	325
Other roots and tubers	393	6	9	10	4	4	3	3	12	14
Veg. seed for planting	806	2,055	970	2,289	1,248	2,216	415	2,375	976	2,877
Tomato in airtight containers	200	115	762	673	938	642	460	317	18	14
Veg. prepared or preserved	66	123	37	81	54	115	38	83	56	109
Veg. juice	9	52	n.a.	0.04	n.a.	0.2	—	—	n.a.	0.1
Chilli, dried	221	221	1,474	1,386	2,154	2,351	2,901	2,505	1,095	1,137
Other pimentoes	20	12	692	47	43	70	120	125	9	22
Garden crops and products	12,459	7,662	12,769	9,749.54	13,383	9,775.2	8,856	9,487.2	8,826	9,326.1

n.a.: data not available
Exchange rate 1 US$: 27 Thai Baht
Source: Ministry of Commerce. Bangkok, Thailand

vegetable commodity for export. There are at least 13 kinds of vegetables which are processed into different forms (Table 6). Of these processed products, asparagus, baby corn, cucumber, ginger, pea and sweet corn are processed mostly for export, while Chinese radish, leaf mustard, tomato and white cabbage are processed mostly for local consumption. There are many processing plants, located all over Thailand where vegetables are produced.

Fresh vegetables are second to processed vegetables in tems of export quantity and value. Fresh vegetables are exported to neighboring countries such as Malaysia, Singapore and Hong Kong. Malaysia is the biggest market. Fresh vegetables and fruit from all regions of the country are transported to a central market at Nakorn Srithamaraj called Hoa It market. The market was established in 1969 by a group of fruit and vegetable merchants. The products from this market are exported to Malaysia and Singapore. Agricultural products that come to Hoa It market are as follows:

January : cabbage, chilli, watermelon
February : cabbage, chilli, mango, watermelon
March : cabbage, chilli, lime, mango, orange, pomelo
April : cabbage, chilli, lime, orange, pineapple, pomelo
May : cabbage, champadak, lime, orange, pineapple
June : champadak, chilli, durian, jackfruit, mangosteen

Table 6 Some major types of vegetables processed in Thailand

Vegetable	Type of product	Container type
Asparagus	Packed in brine	Can
Baby Corn	Packed in brine	Can
Chinese Radish	Dried and salted	Plastic bag
Cucumber	Pickled in various substances	Glass jar
Garlic	Dried whole	Not packaged
	Pickled whole garlic	Glass jar
		Plastic jar
		Plastic bag
	Pickled garlic sections	Glass jar
		Plastic jar
		Plastic bag
Ginger	Powder	Tea bag
		Glass jar
	Pickled	Glass jar
		Plastic jar
		Plastic bag
	Dried whole	Not packaged
Leaf mustard	Salt pickled	Can, plastic bag
	Sour pickled	Can, plastic bag
	Sweet pickled	Can, plastic bag
Mushroom	Dried whole	Plastic bag
Peas (garden/green)	Packed in brine	Can
Potato	Chips	Metal can
		Paper can
		Plastic bag
		Foil bag
Sweet Corn	Cream style	Can
Tomato	Paste	Can
	Catsup	Can
		Glass bottle
		Plastic bottle
	Juice	Can
White Cabbage	Dried, salted, chopped	Ceramic jar
		Glass jar
		Plastic bag

Source: Payap University, Chiang Mai, Thailand

July : durian, langsat, logan, mangosteen, rambutan
August : chilli, durian, langsat, longan, mangosteen, orange, pomelo, rambutan
September: chilli, durian, langsat, longan, mangosteen, orange, pomelo, rambutan sator
October : chilli, durian, langsat, longan, mangosteen, orange, pomelo, rambutan, sator
November : cabbage, lime, pomelo, sator
December : cabbage, lime, pomelo
Source : Mr Bden Maneepruk Phutphonkasetthai Ltd. Importers Exporters.

Seed Production

About 30% (by weight) of vegetable seeds used in Thailand are imported from the United States, Japan, Taiwan, and Europe (Table 7)[1]. There is great potential in Thailand for the production of most kinds of vegetable seed[2]. About 70% of vegetable seed used in Thailand is produced domestically, all of open pollinated varieties of crops such as sweet corn, water convolvulus, watermelon, cucumber, tomato, pumpkin, yard long bean and pea. Of these crops, water convolvulus and watermelon are major export items.

F1 hybrid seed production for tomato was introduced into Northeast Thailand in 1979. Within five years the business became very successful, with farmers earning gross incomes of US$6,000 10,900/ha. Investment into field supplies and labor was about US$300/ha. Farm income from seed production is high, compared with average farm incomes per family in Northeast Thailand (US$442 in 1982: cf. average national farm income of US$747 in 1982[3]).

TOTAL VEGETABLE PRODUCTION AND YIELD

Over 30 kinds of vegetables are grown in Thailand. Harvested areas of 28 vegetables from 1977 to 1984 are shown in Table 8 and the scientific names of the vegetables in Appendix I. Among the different kinds of vegetable grown in 1984, bird pepper, garlic, chilli and yard long bean accounted for the largest areas planted. Over the past eight years, the area cultivated

Table 7 Import of various kinds of vegetable seeds into Thailand, 1983 – 1984

	1983		1984	
	Quantity (mt)	Value (US$1,000)	Quantity (mt)	Value (US$1000)
Cucurbitaceae				
Cucumber	0.01	0.11	33.18	0.37
Watermelon	n.a.	n.a.	20.70	176.37
Cruciferae				
Broccoli	n.a.	n.a.	0.40	28.85
Cabbage	n.a.	n.a.	7.82	381.98
Cauliflower	n.a.	n.a.	8.91	173.67
Chinese cabbage	14.14	261.35	69.58	354.56
Chinese kale	34.29	75.93	149.93	259.8
Chinese radish	11.06	141.93	69.41	213.3
Leaf mustard, Chinese	9.81	28.26	32.67	88.36
Pak choi	n.a.	n.a.	69.95	92.48
Solanaceae				
Pepper	0.63	14.46	0.91	17.92
Tomato	1.2	37.12	2.53	71.49
Other families				
Chinese convolvulus	10.0	164.99	127.32	152.36
Lettuce	n.a.	n.a.	3.22	28.75
Onion	n.a.	n.a.	3.43	129.61
Pea	60 93	32.12	104.12	66.94
Sweet corn	0.14	0.26	0.24	2.14

n.a.: No data available
Exchange rate: 27 Baht = US$1
Source: Ministry of Agriculture, Bangkok, Thailand

Table 8 Harvested area of vegetables in Thailand, 1977 – 1984

Crop	Harvested Area (ha)							
	1977	1978	1979	1980	1981	1982	1983	1984
Angled Luffa	n.a.	n.a.	n.a.	5,401	6,886	5,543	5,870	5,882
Baby Corn	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7,040	6,357
Bird Pepper	36,432	35,690	40,783	46,866	41,104	40,902	38,007	41,906
Bitter Gourd	n.a.	n.a.	n.a.	2,708	3,196	2,404	2,917	2,955
Cabbage	10,153	11,728	9,872	9,849	11,166	9,695	10,766	11,024
Chilli	32,402	34,063	34,194	33,072	36,380	32,388	22,094	24,560
Chinese Cabbage	n.a.	n.a.	n.a.	9,115	9,263	10,519	8,492	8,372
Chinese Kale	n.a.	n.a.	n.a.	10.438	10,540	10,708	10,674	10,328
Chinese Radish	10,163	9,531	9,085	7,430	6,730	5,888	7,158	5,814
Cucumber (large)	n.a.	n.a.	n.a.	13,513	13,603	12,219	9,193	9,799
Cucumber (small)	n.a.	n.a.	n.a.	19,676	22,433	17,784	17,641	17,038
Garden Pea	2,424	2,094	1,998	2,151	2,332	1,884	2,122	2,114
Garlic	40,025	38,774	32,574	41,442	30,332	32,585	39,267	35,570
Ginger	5,698	6,510	6,031	3,564	4,004	6,504	7,043	7,345
Leaf Mustard, Chinese	n.a.	n.a.	n.a.	10,201	10,114	9,476	8,517	9,834
Lettuce	n.a.	n.a.	n.a.	1,906	2,392	2,714	2,234	2,564
Multiplier Onion	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4,716	7,216

n.a.: No data available

Table 8 Harvested area of vegetables in Thailand, 1977 – 1984 (contuned)

Crop	Harvested Area (ha)							
	1977	1978	1979	1980	1981	1982	1983	1984
Onion	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	468	2,033
Pak choi	n.a.	n.a.	n.a.	6,952	9,189	10,059	9,824	8,860
Pumpkin	n.a.	n.a.	n.a.	12,896	14,022	13,355	13,185	10,907
Shallot	22,269	17,856	20,262	23,832	19,602	33,299	23,191	16,626
Taro	n.a.	n.a.	n.a.	6,592	7,522	6,458	5,461	7,054
Tomato	6,382	6,049	7,760	9,898	9,240	8,110	8,465	7,906
Water Convolvulus	n.a.	n.a.	n.a.	10,798	13,281	13,011	2,867	3,046
Water Spinach	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10,452	9,816
White Gourd	n.a.	n.a.	n.a.	7,834	7,541	8,070	7,517	7,432
Yam Bean	n.a.	n.a.	n.a.	4,343	6,170	5,651	n.a.	n.a.
Yard Long Bean	n.a.	n.a.	n.a.	21,094	24,765	22,465	19,927	18,816

n.a.: No data available

Source: Department of Agricultural Extension, Ministry of Agriculture, Bangkok, Thailand

in bird pepper has been increasing, while garlic, chilli, and yard long bean have all been decreasing. A decrease in production area has also been observed for baby corn, Chinese cabbage, Chinese radish, cucumber, garden pea, Chinese leaf mustard, pumpkin, shallot, tomato, water convolvulus, water spinach and white gourd. Increased production areas were observed for angled luffa, bitter gourd, cabbage, ginger, lettuce, multiplier onion, onion, pak choi and taro.

The average yield of the main vegetable crops grown in Thailand is shown in Tables 9 and 10. Total production of vegetables does not necessarily follow trends in production area. Garlic, leaf mustard, and shallot are a good example of this: total production has increased while production area has decreased, because average yields per hectare have been increasing (Table [illegible]). Chinese cabbage is another crop for which yield has increased.

Varietal improvement, changes in the location of planting and improved technology are the main causes of yield improvement. Seed companies have played an important role in introducing better varieties of leaf mustard, Chinese cabbage and other crops Competition between seed companies in Thailand is quite high, which encourages the production of good quality seeds. The Department of Agriculture has carried out several improvement programs for vegetables through which many good open pollinated varieties of vegetable have been released. Changes in the location of planted areas is quite important: recently highlands have been used for cabbage and Chinese cabbage instead of the lowlands. Shallots are produced better in Northeast Thailand than in the North, while tomato yields have been increased by changing the location from lowland to highland, and improvements in field technology.

Declining yields over recent years have been observed for many crops, including angled luffa, bitter gourd, cucumber, taro, water convolvulus, water spinach and yam bean. Most of the seeds used for these vegetables are produced in Thailand itself. The seeds are exchanged between farmers and local merchants, and there is not much improvement in the varieties used. Taro and yam bean are propagated vegetatively, and there is no improvement program for these vegetables.

Price fluctuations for some vegetables, such as cabbage, Chinese kale, garlic, ginger

Table 9 Total production of vegetables in Thailand, 1977 — 1984

Crop	Production (Ton)							
	1977	1978	1979	1980	1981	1982	1983	1984
Angled Luffa	n.a.	n.a.	n.a.	31,261	29,266	16,602	19,488	17,207
Baby Corn	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	46,909	41,628
Bird Pepper	60,849	55,254	57,507	82,072	65,666	54,128	67,614	75,067
Bitter Gourd	n.a.	n.a.	n.a.	13,928	13,799	8,822	11,180	12,181
Cabbage	87,662	87,896	67,790	96,009	108,293	89,709	110,524	106,271
Chilli	66,140	66,564	60,686	70,204	65,729	69,010	45,108	49,346
Chinese Cabbage	n.a.	n.a.	n.a.	52,548	52,703	61,823	60,537	64,266
Chinese Kale	n.a.	n.a.	n.a.	75,039	70,644	69,968	83,106	84,359
Chinese Radish	105,265	98,537	93,312	77,812	77,682	60,103	77,939	64,452
Cucumber (large)	n.a.	n.a.	n.a.	140,929	106,102	82,730	67,507	70,124
Cucumber (small)	n.a.	n.a.	n.a.	162,225	164,744	127,928	137,386	122,651
Garden Pea	4,462	4,460	4,285	5,844	7,567	4,149	5,979	5,477
Garlic	309,098	305,190	225,344	434,082	264,587	287,544	360,674	353,309
Ginger	74,462	97,653	73,745	50,205	46,152	88,612	112,266	92,192
Leaf Mustard, Chinese	n.a.	n.a.	n.a.	59,306	66,554	62,337	61,613	72,867
Lettuce	n.a.	n.a.	n.a.	6,688	9,065	10,934	7,993	42,629
Multiplier Onion	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	27,493	42,629
Onion	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3,219	22,283
Pak Choi	n.a.	n.a.	n.a.	40,465	50,508	60,157	68,488	62,070
Pumpkin	n.a.	n.a.	n.a.	180,293	187,402	171,242	180,387	150,019
Shallot	136,688	105,623	106,055	169,809	123,353	296,450	185,584	142,680
Taro	n.a.	n.a.	n.a.	85,166	81,691	62,068	55,803	73,928
Tomato	28,736	29,144	31,576	94,968	68,134	70,193	96,295	61,893
Water Convolvulus	n.a.	n.a.	n.a.	55,001	59,226	54,685	11,458	11,270
Water Spinach	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	60,613	50,709
White Gourd	n.a.	n.a.	n.a.	89,487	84,908	85,667	86,758	79,138
Yam Bean	n.a.	n.a.	n.a.	60,873	88,452	55,628	n.a.	n.a.
Yard Long Bean	n.a.	n.a.	n.a.	88,660	112,501	80,350	75,336	64,818

n.a.: No data available

Source: Department of Agricultural Extension, Ministry of Agriculture, Bangkok, Thailand

Table 10 Average yield of vegetables in Thailand, 1977-1984

Crop	Yield (mt/ha)							
	1977	1978	1979	1980	1981	1982	1983	1984
Angled Luffa	n.a.	n.a.	n.a.	5.8	4.2	2.8	3.3	2.9
Baby Corn	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.7	6.6
Bird Pepper	1.7	1.6	1.4	1.8	1.6	1.3	1.8	1.8
Bitter Gourd	n.a.	n.a.	n.a.	5.1	4.3	3.7	3.8	4.1
Cabbage	8.6	7.3	6.9	9.8	9.7	9.2	10.3	9.6
Chilli	2.0	2.0	1.8	2.1	1.8	2.1	2.0	2.0
Chinese Cabbage	n.a.	n.a.	n.a.	5.8	5.7	5.9	7.1	7.7
Chinese Kale	n.a.	n.a.	n.a.	7.2	6.7	6.5	7.8	8.2
Chinese Radish	10.4	10.3	10.3	10.5	11.5	10.2	10.9	11.1
Cucumber (large)	n.a.	n.a.	n.a.	10.4	7.8	6.8	7.3	7.2
Cucumber (small)	n.a.	n.a.	n.a.	8.2	7.3	7.2	7.8	7.2
Garden Pea	1.8	2.1	2.1	2.7	3.2	2.2	2.8	2.6
Garlic	7.7	7.7	6.9	10.5	8.7	8.8	9.2	9.9
Ginger	13.1	15.0	12.2	14.1	11.5	13.6	15.9	12.6
Leaf Mustard, Chinese	n.a.	n.a.	n.a.	5.8	6.6	6.6	7.2	7.4
Lettuce	n.a.	n.a.	n.a.	3.5	3.8	4.0	3.6	3.8
Multiplier Onion	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.8	5.9
Onion	n.a.	n.a.	n.a	n.a.	n.a.	n.a.	6.9	11.0
Pak Choi	n.a.	n.a.	n.a.	5.8	5.5	6.0	7.0	7.1
Pumpkin	n.a.	n.a.	n.a.	14.0	13.4	12.8	13.7	13.8
Shallot	6.1	5.9	5.2	7.1	6.2	8.9	8.0	8.6
Taro	n.a.	n.a.	n.a.	12.9	10.9	9.6	10.2	10.5
Tomato	4.5	4.8	4.1	9.6	7.4	8.6	11.4	7.8
Water Convolvulus	n.a.	n.a.	n.a.	5.1	4.5	4.2	4.0	3.7
Water Spinach	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.8	5.2
White Gourd	n.a.	n.a.	n.a.	11.4	11.2	10.6	11.5	10.6
Yam Bean	n.a.	n.a.	n.a.	14.0	14.3	9.8	n.a.	n.a.
Yard Long Bean	n.a.	n.a.	n.a.	4.2	4.5	3.6	3.8	3.4

n.a.: No data available

Source: Department of Agricultural Extension, Ministry of Agriculture, Bangkok, Thailand

and tomato, reflect seasonal changes in the yield of these vegetables. Prices are always low in winter (January, February, and March) when these vegetables grow well. They are mainly produced in lowland areas, and high prices are observed during the hot, rainy season. High temperature is also a limiting factor in the production of cabbage, Chinese kale, ginger, and tomato, while short day length is a limiting factor for garlic.

IMPROVEMENT OF VEGETABLE YIELD AND QUALITY

Varieties, field management and postharvest handling are key factors in improving the yield and quality of vegetables. Many government institutions, such as the Department of Agriculture, Kasetsart University, Chiang Mai University, Khon Kaen University, Prince of Songkhla University and Ramkumhang University, are involved in varietal collection, varietal testing, breeding programs and field management studies. Varietal collection and selection are their main jobs. Many open pollinated varieties have been released for commercial use. No hybrid varieties are available from these government institutions. Good varieties of chilli, baby corn, Chinese radish, leaf mustard and shallot have been released by the Department of Agriculture. Among these crops, chilli and shallot are the most popular. Kasetsart University has released good varieties of tomato, Chinese radish and sweet corn which are widely used in Thailand. Chiang Mai University and Khon Kaen University have released heat tolerant tomato varieties.

Location testing of varieties and extension activities are operated by the Department of Agricultural Extension. Good varieties released from other government institutions are tested in various locations in the country by this department. It has a network of extension programs throughout the country, and has excellent facilities for the seed processing which has not yet been fully extended into many regions. Although there are extension programs in all regions, the deficiency in farmers' know-how remains quite obvious.

Seed companies play an important role in varietal improvement. Since there are 53 importers and 33 exporters of vegetable seeds[4], competition is fairly high. These companies introduce new varieties, both open pollinated and hybrid. They do their own location testing, and a few seed companies are now involved in research for varietal development.

Pesticide companies introduce new fungicides and insecticides to farmers, carrying out their own promotion. Some chemicals are dangerous and expensive, but farmers do not known enough to be wary of them. Sometimes there is no need to use an expensive chemical, because it may be no more effective than a cheaper one. Very often farmers in the North and Northeast were seen to mix insecticides and fungicides together in one spray, believing the mixture to be more effective than the individual components applied separately. The use of insecticides, fungicides and herbicides has increased in the past few years (Table 11), especially for vegetable production, and chemical residues on vegetables are a serious problem. Some farmers even sprayed their vegetable crops the day before harvesting. There are several reasons for this practice. They may want to keep the young plants free of insects, or sometimes the time of harvest cannot be predicted because buyers come at any time. The government should have an effective program to prohibit the use of hazardous chemicals, and to test for chemical residues on produce.

Vegetable quality depends largely on postharvest handling. Since Thailand has no refrigerated storage for fruit and vegetables, postharvest loss and damage are always observed. Postharvest losses may be as high as 60% of the original weight. Chinese cabbage wholesalers at Chiang Mai (Northern Thailand) claim that middlemen lose two to three tons per eight ton truck load when Chinese cabbage is transported from the North to the South of Thailand.

Table 11 Farm pesticides used in Thailand, 1975-1984

Unit: mt

Year	Insecticides	Fungicides	Herbicides	Fumigants
1975	4,830.00	1,155.00	1,874.00	166.00
1976	6,251.00	1,270.00	2,225.00	169.00
1977	10,198.24	1,702.24	3,745.92	192.48
1978	14,264.37	2,736.31	5,545.30	222.18
1979	16,557.00	2,787.50	5,295.25	4.00
1980	15,030.25	2,721.25	6,377.00	331.50
1981	14,068.89	2,565.27	9,697.86	487.35
1982	11,601.00	2,447.25	9,824.25	598.00
1983	9,639.00	3,891.00	7,270.00	586.96
1984	12,288.50	3,546.00	9,166.00	324.00

Source: Center for Agricultural Statistics, Ministry of Agriculture, Bangkok, Thailand

Infrastructure and facilities for transportation need to be set up. More research on postharvest losses is needed. Personnel trained in postharvest handling are lacking.

In improving yield and quality, each vegetable must be addressed individually, because each differs in disease and insect susceptibility. Sometimes physiological factors have a more serious effect on yield and quality than pests. Tipburn on head lettuce is a physiological disorder which causes serious damage in terms of both quality and yield. Heat susceptibity in tomato can also seriously reduce yield and quality. Most varieties of tomato are susceptible to bacterial wilt, late blight and yellow leaf curl. Bacterial wilt is caused by *Pseudomonas solanacearum*, late blight by *Phytophthora infestans*, and yellow leaf curl by a virus; these three diseases are the major diseases of tomato in tropical areas. Resistance in tomato varieties will have a pronounced effect on the yield and quality of their fruit.

Basic technology for vegetable seed production has not yet been established in Thailand. Mismanagement at various stages of production, whether in the field or in postharvest handling, leads to low yield and poor seed quality. A few government institutions are involved in seed production studies e.g. Chiang Mai University, the Ministry of Agriculture and Khon Kaen University.

MAJOR CONTRAINTS IN VEGETABLE PRODUCTION

Pest injury, unavailability of suitable varieties, deficiency in farmers' skills, deficiency in postharvest technology, and poor marketing are the major constraints to vegetable production in Thailand. Other problems are:

1. The lack of adequate research programs capable of developing new, improved varieties/hybrids adapted to local needs.
2. Lack of infrastructure and support from the government for fresh vegetable and vegetable seed production.
3. Lack of postharvest facilities and technology for fresh vegetables (although excellent processing and storage facililies have been set up for harvested seed).
4. Poor marketing for both fresh vegetables and open pollinated seeds.

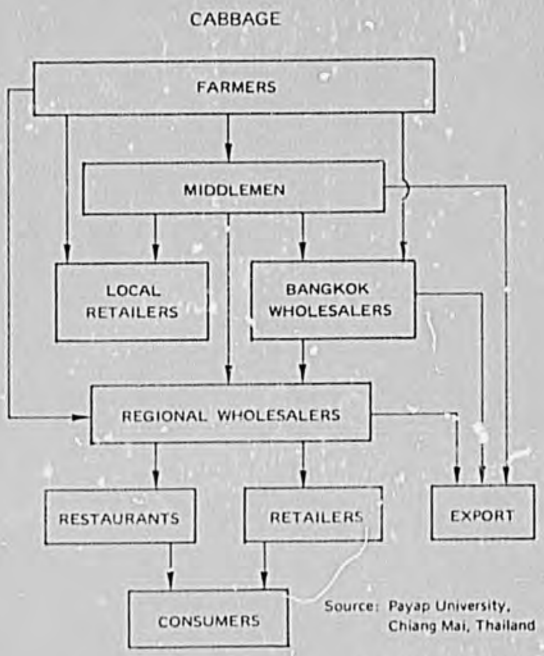
Adaptable varieties of vegetables with disease resistance and stress tolerance are needed for fresh vegetable and seed production. Introduced varieties from other countries, whether temperate or subtropical, are susceptible to tropical diseases and sometimes to high temperatures. Hybrid sweet corn varieties introduced from the United States and other countries are rarely suited to Thai climatic conditions, nor do the young kernels of most of these varieties have a sweet taste, while they are all susceptible to corn leaf blight caused by *Helminthosporium maydis.* Tomato varieties are susceptible to bacterial wilt, late blight and high temperatures. Lettuce varieties are susceptible to tip burn symptoms, caused by high temperature stress. Many Cruciferous family vegetables are susceptible to soft rot caused by *Erwinia carotovora.*

Deficiencies in farming skills lead to the misuse of pesticides. Farmers do not pay enough attention to seedling preparation and weed control.

The supply of fresh vegetables does not match with demand. Farmers produce their crops without knowing the level of market demand. Product price depends on the quantity of that product available at a central market, and the level of demand for it. A continuous flow of any product is rarely seen. Open pollinated seeds do not have good market outlets, so that farmers tend to sell their crop as fresh produce if the price is good, rather than wait for the seed. This does not happen with F_1 hybrid seed production, which is carried out under contract.

VEGETABLE MARKETING

Fresh vegetables have local markets, two central markets, Pak Klong Talad, in Bangkok and Hoa It market in Nakorn Srithamaraj. Any surplus of fresh vegetables from local markets is transported to Pak Klong Talad for distribution to other places. Some farmers produce only for the two central markets. There are a few other markets besides Pak Klong Talad and Hoa It, but the quantity of vegetables going to these markets is much lower than for the two central ones. Pak Klong Talad market distributes fresh vegetables to nearby provinces, while Hoa It market not only distributes fresh vegetables to other provinces but also exports them to Malaysia. Common marketing channels for vegetables are shown in Figs. 2 and 3.



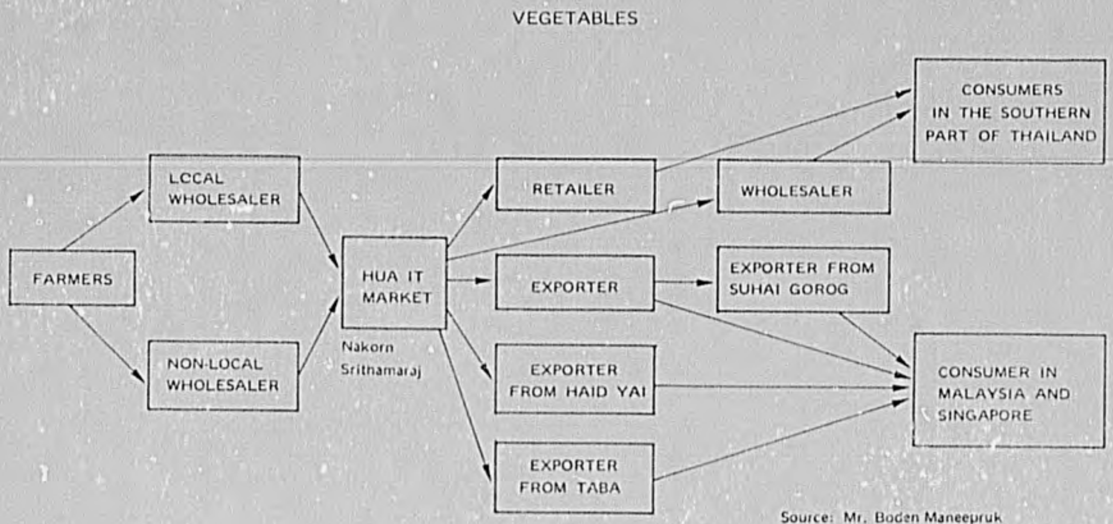
Source: Payap University, Chiang Mai, Thailand

Fig. 2 Marketing channels for fresh cabbage

Tomatoes have a different marketing system. They are rarely sold through Pak Klong Talad or Hoa It markets. Most processing tomatoes are sold to processing plants near the production area, a few are sold fresh to local markets, and quite a large number are exported fresh to Hong Kong and Malaysia. (Figs. 4 and 5).

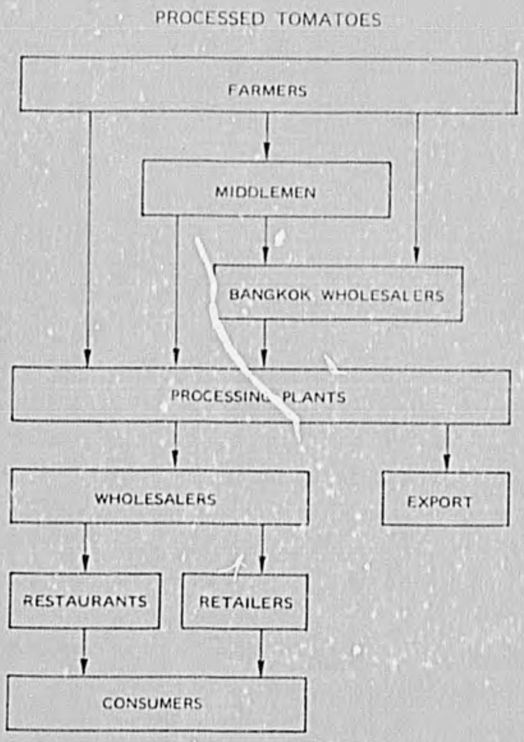
RESEARCH AND INFRASTRUCTURE

Research into vegetable varietal improvement, field management, and postharvest handling of fresh vegetables is scattered over a number of different government institutions and seed companies. It is very difficult to coordinate these research programs to specific objectives,



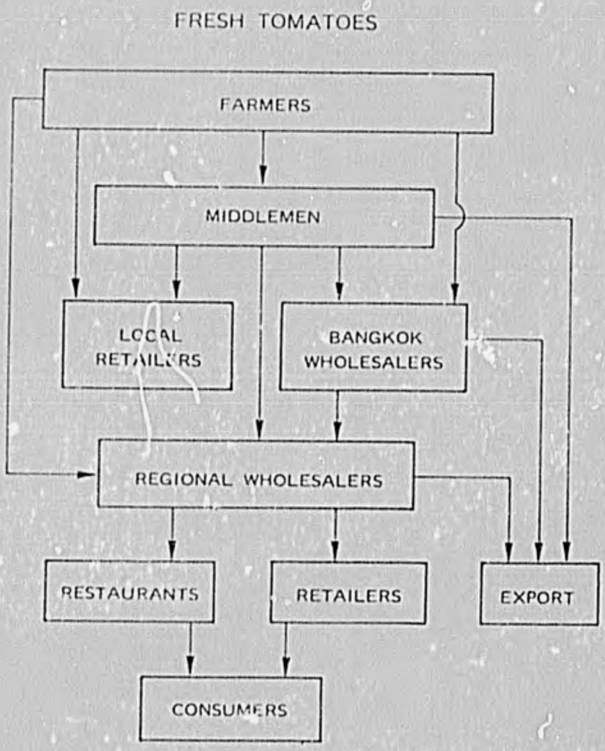
Source: Mr. Boden Maneepruk
Phutphonkasetthai
Ltd.

Fig. 3 Marketing channels of vegetables to Hoa It central market in the South of Thailand



Source: Payap University
Chiang Mai, Thailand

Fig. 4 Marketing channels for processed tomato



Source: Payap University
Chiang Mai, Thailand

Fig. 5 Marketing channels for fresh tomato because their budgets come from different sources. Efforts have been made to coordinate research programs into tomato and Chinese radish in Thailand, but to little effect.

Government infrastructure for fresh vegetable production, postharvest facilities and market organization should be set up. At present, the production of fresh vegetables is not under any kind of control body except for a few vegetables such as potato and onion. Vegetable prices fluctuate day by day, depending on supply and demand. If a contract system can be set up and postharvest facilities improved, farmers will get better returns than they are receiving now.

The government has not yet assisted in the problems involved in transporting fresh vegetables for export. The problems are both domestic and international. There are too many police guards along Thailand's highways, who often hold trucks without good reason. Produce crossing the Thai-Malaysian border must be transferred to Malaysian trucks, which is costly and time consuming. If the government could reach an agreement with the Malaysian government to allow Thai trucks to deliver the produce into Malaysia, there would be great savings of both time and quality.

The Thai government has recently organized a group of vegetable experts to advise the government on locations suited to vegetable production and the kinds of vegetables to be grown. The government is interested in replacing rice with vegetables, because farmers get only very low returns from rice.

There is no infrastructure for seed production of open pollinated varieties of local vegetables. Production of the seeds depends on local seed merchants and farmers. No breeder seeds or stock seeds are available for farmers. Training in seed production and technology is not available to all farmers. A good infrastructure exists for F_1 hybrid seed production, in which farmers are supervised throughout the growing season and postharvest period. Seed companies form a nucleus of a small group of farmers. Very probably, this infrastructure can be applied to open pollinated varieties as well.

SUMMARY OF MAJOR CONSTRAINTS

Major constraints to fresh vegetable production can be summarized as follows:

1. Lack of pest resistant varieties adapted to Thai conditions.
   - a. tomato – heat tolerant varieties
     – bacterial wilt resistant varieties
     – late blight resistant varieties
     – yellow leaf curl resistant varieties
   - b. Chinese cabbage – heat tolerant varieties
     – soft rot resistant varieties
   - c. leaf mustard – heat tolerant varieties
   - d. cauliflower – heat tolerant varieties
   - e. all cruciferous crops – diamondback moth resistant varieties
   - f. lettuce – tipburn tolerant varieties
   - g. sweet corn – leaf blight resistant varities
   - h. cucumber – downy mildew resistant varieties
2. Disorganized crop production e.g. farmers are ignorant of market demand and supply for particular crops.
3. Inadequate training in field technologies for farmers
   - a. Many farmers do not buy higher priced seeds, even though these give much better results.
   - b. Farmers in various regions mix many insecticides in one spray to control insects.
   - c. Farmers are ignorant of many useful cultural practices.
4. Poor postharvest technology, training, and facilities
   - a. A high percentage of postharvest losses and low quality produce is due to poor handling and transportation.
   - b. There is no postharvest treatment or cold storage facilities for vegetables in Thai-

land, and refrigerated trucks are lacking.
   c. Conditions and handling methods at central markets are very poor.
5. Disorganized marketing system. There is no central system for the transfer of produce from farmers to merchants: buying and selling depend on individual agreements.
6. Inadequate support from the government
   a. Inadequate infrastructure for production, transportation and marketing of produce.
   b. Too many police checkpoints along Thai highways.
   c. There is no agreement between the Thai and Malaysian governments to allow Thai trucks to deliver goods in Malaysia.

Major constraints to seed production for open pollinated varieties, which are produced mainly for local use, can be summarized as follows:

1. Inadequate research into varietal development, especially F_1 hybrid varieties.
2. Inadequate basic knowledge of seed production and postharvest handling.
   a. studies on suitable locations, planting dates and field management.
   b. studies on postharvest seed technology.
   c. studies on seed processing technology.
3. Lack of proper seed marketing systems.
4. Farmers and merchants are not yet able to use the seed processing facilities established by the Department of Agricultural Extension of the Ministry of Agriculture.

FUTURE PROSPECTS FOR VEGETABLE PRODUCTION

Demand for fresh vegetables, both domestic and for export, is very high. Stability in production and good quality products are required. If a good system can be arranged for the production, transportation, postharvest handling and marketing of vegetables, they will become of very great economic importance.

Climatic conditions in Thailand, especially in the mountaineous areas, are suitable for the production of temperate vegetables. Temperate vegetables grown on mountain slopes in the north of Thailand yield produce of good quality, comparable to Australian products. However, extending the technology to farmers is slow.

Tropical vegetables can be produced in the Thai lowlands. The Thai government is interested in increasing vegetable and fruit growing areas, to replace some of the paddy fields. Fallow riceland in Central and Northeast Thailand, where irrigation systems are already established, is being converted to vegetable growing, but farmers are hesitant to produce these new crops because of marketing problems.

F_1 hybrid vegetable seed production has a bright future. A few foreign seed companies are producing their hybrid seed in Thailand. Cheap labor and suitable climatic conditions are key factors, and the Thai government also supports foreign investment in this field.

Processed vegetables have a very good future. Many processing plants are successful in their business. Many products are successfully exported, and with some improvement in technology and procedure in the plants, standardization of products can be achieved.

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APPENDIX I. SCIENTIFIC NAMES OF VEGETABLES

	Crop	Scientific name
1.	Angled Luffa	*Luffa acutangula*
2.	Baby Corn	*Zea mays* var. *rugosa*
3.	Bird Pepper	*Capsicum annuum*
4.	Bitter Gourd	*Momordica charantia*
5.	Cabbage	*Brassica oleracea* var. *capitata*
6.	Chilli	*Capsicum frutescens*
7.	Chinese Cabbage	*Brassica pekinensis*
8.	Chinese Kale	*Brassica oleracea* var. *allboglaba*
9.	Chinese Radish	*Raphanus sativus* var. *longipinnatus*
10.	Cucumber (large)	*Cucurmis sativus*
11.	Cucumber (small)	*Cucurmis sativus*
12.	Garden Pea	*Pisum sativum*
13.	Garlic	*Allium sativum*
14.	Ginger	*Zingiber officinale*
15.	Chinese Leaf Mustard	*Brassica juncea* var. *rugosa*
16.	Lettuce	*Lactuca sativa* var. *crispa*
17.	Multiplier Onion	*Allium cepa* var. *aggregatum*
18.	Onion	*Allium cepa*
19.	Pak chai	*Brassica chinensis*
20.	Pumpkin	*Cucurbita pepo*
21.	Shallot	*Allium ascalonicum*
22.	Taro	*Colocasia esculentum*
23.	Tomato	*Lycopersicon esculentum*
24.	Water Convolvulus	*Ipomoea aquatica*
25.	White Gourd	*Benincasa cercifera*
26.	Yam	*Dioscorea* spp.
27.	Yard Long Bean	*Vigna sesquipedalis*

DISCUSSION

Q. (D.J. Murphy)
What type of potato varieties do you recommend for planting in Northwest Thailand?

A. What is being used is a variety from the Netherlands. It is not ideal for processing; it is better for the fresh market. We tried introducing varieties such as *S. burbank* from the United States, but we have difficulty in producing these varieties here. Dr. Tongchai Tonguthaisri is the head of the potato project.

Q. (P Rowell)
Much of the work you presented on sweet corn, peppers, tomato and Chinese cabbage seems to be concerned with the development of F_1 hybrids. Is this emphasis because the hybrid seed is more profitable to the farmers who produce seed, or because it has been determined that the hybrids provide a better return? If the latter case, does the yield advantage justify the extra cost for the vegetable growers?

A. This is not my own work, but rather a report on that done by seed companies. They work on both open pollinated and F_1 hybrid varieties. Growers can benefit from the F_1 varieties but so far these are not widely distributed here in Thailand.

In F_1 tomato hybrid seed production in Thailand, there is a problem of a low germination rate - less than 85%.

NH_4-N TOXICITY AND CALCIUM DEFICIENCY IN TIPBURN AND INTERNAL ROT IN CHINESE CABBAGE

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ABSTRACT

Research done at AVRDC indicates that ammonia (NH_4-N) toxicity, rather than calcium deficiency is a more direct cause of tipburn in summer grown Chinese cabbage. NH_4-N toxicity results in limited root development, root damage and too rapid initial plant growth. Effective measures to reduce tipburn are suppressing the initial plant growth by covering outer leaves with rice straw, using split nitrogen fertilizer applications, avoiding NH_4-N application at heading initiation, avoiding heavy nitrogen fertilizer application at any growth stage, increasing soil CEC and minimizing soil moisture fluctuations by compost application, water management and mulching. Causes of internal rot in Chinese cabbage are limited Ca^{++} translocation to the inner leaves, and vigorous growth in heading particularly in the round heading types. Measures which reduce internal rot are foliar spray of citric acid, covering outer leaves before head formation, split application of nitrogen fertilizer, selection of long headed cultivars and acceleration of rooting by water management.

(Chinese Abstract)

摘　要

亞蔬中心的研究指出：直接造成夏作結球白菜頂燒症(Tipburn)之因子爲銨(NH_4−N)毒害，而非缺鈣。銨毒害會造成植物根的生長受阻，使根受傷害以及植株初期生長過速。有效減輕頂燒症的方法包括下列數種：以稻草覆蓋外葉以抑制初期生長；使用氮肥分施法；避免於結球始期施用銨態氮肥；於生長期間避免施用過量氮肥；及水分管理、施用堆肥和覆蓋方法來提高土壤陽離子交換能量並減少土壤水分劇烈變化等。引起結球白菜內腐症(Internal rot)之因子爲鈣之轉移至內葉受阻及結球期快速的生長，尤其圓球形之品系。減輕內腐症之方法則爲：葉面噴施檸檬酸液；於結球期前覆蓋外葉；採用氮肥分施法；選擇長球形的品種栽培；和利用水分管理促進生根。

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(Japanese Abstract)

摘　要

AVRDCで行われた試験結果によれば、夏期栽培のハクサイの先端枯れ上がりの直接的な原因はカルシウム不足というよりはアンモニヤの毒性である。アンモニアの毒性により根の發達は不良となり、根は損傷をうけ、また初期の徒長を招く。先端枯れ上がりを效果的に防止する方法は、外葉を稻藁でまいて初期生長を抑えること、窒素肥料を分施すること、結球開始期にアンモニヤ態窒素の施用をさけること、全生育期にわたり窒素肥料を施用しすぎないこと、堆肥施用、水管理、マルチングにより土壌CECを增加させ、土壌水分の變動を最少にすることである。ハクサイの心ぐされの原因は内部の葉におけるCa^{++}の轉移が制限されること、結球の生育の良すぎることであり、これは丸型の結球をする品種に多い。心ぐされを防止する方法はクエン酸の葉への散布、結球前の外葉をカバーすること、窒素肥料の分施、長型品種の選擇、水管理によって根の發達を促進させることである。

(Korean Abstract)

적　요

아세아 채소연구센타(AVRDC)가 연구한 바에 의하면, 배추 잎끝이 타는 병(Tipburn)의 직접적인 원인은 칼슘결핍보다도 암모니아 (NH_4 - N)해독이라고 지적되었다. 암모니아 해독은 뿌리의 생장저해 및 상해와 초기의 생장과속화를 촉진한다. Tipburn 증세를 약화시킬 수 있는 효과적인 방법은 볏짚에 의한 초기생장 억제, 질소비료의 분할시비, 결구기의 암모니아 시비 금지, 생장중 질소비료 과다사용금지, 퇴비사용과 수분관리 및 멀칭에 의한 토양 CEC 의 증가외에 토양수분의 급변을 막는 것이다.

배추의 내부 부패증(Internal rot)은 내엽으로의 C^{++} 이전이 제한되고 결구기에 생장이 과속되는 데에 기인한다. Internal rot 의 억제방법으로는 잎면에 구연산을 뿌려주고 결구기전에 외엽을 덮어주며, 질소비료의 분할시비와 구형이 긴 품종의 선택과 물관리에 의한 뿌리의 생장촉진등이다.

NH_4-N TOXICITY AND CALCIUM DEFICIENCY IN TIPBURN AND INTERNAL ROT IN CHINESE CABBAGE

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INTRODUCTION

Tipburn in summer grown Chinese Cabbage is a serious problem confronting most growers. Since the first paper was published on this subject in the U.S.A. in 1946[1], many publications have appeared which indicated that tipburn was associated with high levels of nitrogen, temporary water stress and high growth rates[2,3,4,5]. However, the cause was generally attributed to calcium deficiency due to a variety of environmental, physiological or nutritional factors[6,7,8,9,10,11]. The calcium deficiencies were traced either to low available soil calcium, or to inhibited calcium absorption and translocation in the plant.

Soil science research at AVRDC has recently confirmed that ammonia toxicity, which causes root damage and subsequent water stress, is the direct cause of tipburn in summer grown Chinese cabbage[12,13]. It is the root damage which inhibits calcium uptake, and thus the association of calcium deficiency with tipburn. Internal rot in Chinese cabbage is also caused by excess application of nitrogen, but is unaffected by soil calcium levels. In terms of crop damage internal rot is in fact a more serious problem than tipburn as it causes a greater decrease in market value of the cabbage head.

Based on these findings a series of experiments were conducted to develop cultural practices for soil, water and fertilizer management which could minimize the occurrence of tipburn and internal rot in summer grown Chinese cabbage crops.

EXPERIMENTS AND RESULTS

Ammonium Nitrogen Toxicity

Effect of nitrogen source on tipburn and internal rot in Chinese cabbage

Experiment

In the autumn of 1983, at the AVRDC greenhouse, Tainan sixteen day old seedlings of Chinese cultivar *Fong-luh* were transplanted to sand filled pots and irrigated with the culture solutions as described in Table 1. The leachate of the culture solution was collected every three days and analyzed for NO_3-N, NH_4-N, Ca^{++} and pH in order to assess the nutrients absorbed at each growth stage. After harvest, at 47 days after treatment (DAT), the cabbage heads and outer leaves were weighed separately and then divided into blade and midrib portions for analysis of nutrient uptake.

Results

Growth and yield parameters

Plants grown with NO_3-N throughout their growth period had the highest yields, and those grown in NH_4-N the lowest (Table 2). Although the yields of plants started with 8 meq of nitrate until head formation stage (BHF growth period) and finished with 16 meq to harvest (AHF growth period), were almost as high as those with 16 meq of nitrate throughout their growth (BAHF

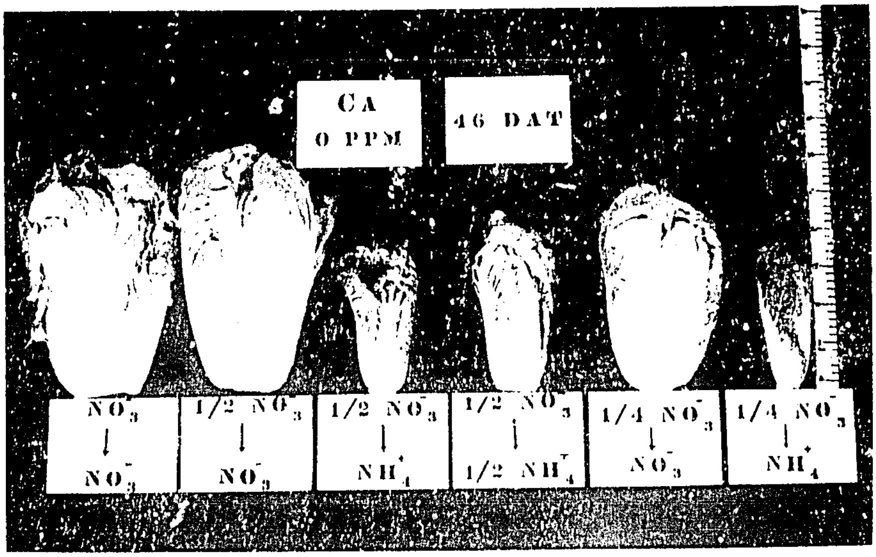
Table 1 Constitution of culture solution

Element*	Salts used	Respective concentrations as element (ppm)
N	$NaNO_3$, $(NH_4)_2 \cdot SO_4$	224, 112 or 56 (depending on treatment)
P	K_2HPO_4, $Ca(NO_3)_2 \cdot 4H_2O$	41
K	K_2SO_4, KNO_3, $Mg(NO_3)_2 \cdot 6H_2O$	313
Ca	$CaCl_2 \cdot 2H_2O$, $CaSO_4 \cdot 2H_2O$	320 and 160
Mg	$MgSO_4$ are mixed	49
Fe	EDTA Fe	3
Mn	$MnSO_4 \cdot H_2O$	0.5
Zn	$ZnSO_4 \cdot 7H_2O$	0.05
Cu	$CuSO_4 \cdot 5H_2O$	0.02
Mo	$Na_2MoO_4 \cdot 2H_2O$	0.01
B	H_3BO_3	0.5

* pH was adjusted to 6.0 using 0.2 N H_2SO_4

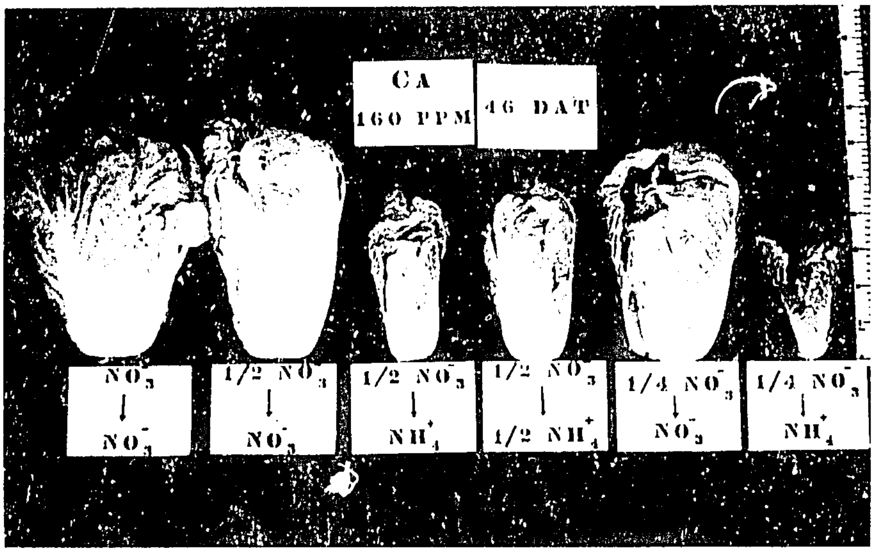
Tabe 2 The effect of form and concentration of nitrogen and Ca^{++} concentration on the head yield of Chinese cabbage

N form and concentration (meq/l)				Dry weight of the head (g)			Average
before head formation		after head formation		Ca 0 (meq/l)	Ca 8 (meq/l)	Ca 16 (meq/l)	
NO_3	16	NO_3	16	61.8a	57.2a	59.7a	59.5a
NO_3	8	NO_3	16	54.1ab	57.7a	55.0a	55.6a
NO_3	8	NH_4	16	17.0cd	18.0c	20.2b	18.4c
NO_3	8	NH_4	8	21.3cd	34.1b	28.9b	28.1b
NO_3	4	NO_3	16	35.3b	35.6b	27.3b	32.7b
NO_3	4	NH_4	16	9.5cd	10.2c	7.9c	9.2d
NH_4	16	NO_3	8	15.3c	5.6cd	5.9c	8.9d
NH_4	16	NH_4	8	3.1d	1.7cd	1.1c	2.0e
NH_4	8	NO_3	8	13.4cd	14.5c	3.5c	10.4d
NH_4	8	NH_4	8	4.3d	4.6cd	2.9c	3.9de
Average				23.5a	23.9a	21.2c	



Effect of nitrogen treatment on Chinese cabbage head yield (no Ca applied)

NO_3 → NO_3 indicates NO_3-N 16 meq BHF ;NO_3-N 16 meq AHF
1/2 NO_3 → NO_3 indicates NO_3-N 8 meq BHF ;NO_3-N 16 meq AHF
1/4 NO_3 → NH_4 indicates NO_3 4 meq BHF ;NH_4-N 16 meq AHF



Effect of nitrogen treatment on Chinese cabbage head yield (160 ppm of Ca supplied)
Abreviations as in Plate 1

growth periods); however, generally plants receiving less nitrate before head formation stage (BHF) – i.e. 4 meq or 8 meq – grew more slowly and had reduced head yields. The opposite was true for plants grown with ammonia: plants grown with NO_3-N 8 meq and with NO_3-N 4 meq showed healthy growth with both treatments until head formation stage, but where the nitrogen source was switched from nitrate to ammonia a sudden reduction in plant growth could be observed and the yields of such treatments were considerably less than those carried through with nitrate after the head formation stage (AHF).

Yield losses were greatest for treatments

NO_3-N 4 meq (BHF): NH_4-N 16 meq (AHF),
NO_3-N 8 meq (BHF): NH_4-N 16 meq (AHF),
NO_3-N 8 meq (BHF): NH_4-N 8 meq (AHF),

in that order. This indicates that a given level of ammonia application after heading stage will cause greater loss in yield where nitrogen application levels before heading were lower. It also indicates that for a given rate of nitrogen application before heading stage higher rates of application of ammonia after heading stage will cause more pronounced yield losses. Both treatments

NH_4-N 16 meq (BHF): NH_4-N 8 meq (AHF)
NH_4-N 8 meq (BHF): NH_4-N 8 meq (AHF)

had very low yields and no significant difference between their yields.

For the two treatments

NH_4-N 16 meq (BHF): NO_3-N 16 meq (AHF)
NH_4-N 8 meq (BHF): NO_3-N 16 meq (AHF)

the plants recovered dramatically when changed to the nitrate solutions; however, their yields still fell far short of the treatments receiving nitrate solution irrigation throughout their growth (BAHF). Whether 8 meq or 16 meq nitrate was applied AHF, there was little difference in yield; and even the root damage done by 8 meq ammonia BHF was too severe for nitrate application to ameliorate.

In most cases, the addition of 8 meq Ca^{++} increased yields slightly, but not to a statistically significant degree (Table 2). Adding 16 meq Ca^{++} raised salt concentration in the nutrient solution to levels detrimental to yield; however, no direct correlation could be established. The primary cause of tipburn in Chinese cabbage was NH_4-N toxicity, rather than Ca^{++} deficiency.

Levels of total nitrogen in plant tissue

Total nitrogen content was much higher in the leaves of plants grown with NH_4-N both before and after the heading stage (BAHF), than with nitrate solution (Table 3). Even though in some cases the nitrogen uptake of plants in the NH_4-N treatments was slightly accelerated by increased calcium application, this did not affect the nitrogen concentration in the inner leaf blade (ILB). The head yields suggest that increased Ca^{++} aggravated the root damage caused by ammonia toxicity, increasing tipburn symptoms by suppressing nutrient uptake.

Calcium levels in plant tissue

Calcium levels were also greatly affected by the nitrogen source. Plants grown with NO_3-N BHF and with NH_4-N AHF had much less calcium in the inner leaf blades than plants grown with NO_3-N throughout their growth.

Increased rates of calcium application brought corresponding increases in the Ca^{++} content of the inner leaf blades. Thus, although Ca^{++} uptake and translocation in the leaf tissue is easily suppressed competitively by NH_4-N and by monovalent cations such as K^+, the reverse is not true; because of its relative immobility in plant tissue, Ca^{++} has little effect upon the uptake and translocation of NH_4-N or K^+.

In plants irrigated with NO_3-N throughout their growth (BAHF), increasing the rate of Ca^{++} brought about corresponding increases of Ca^{++} content in the inner leaves, but only slight increases in the outer leaves (Table 4).

Table 3 Total nitrogen content (T N%) of Chinese cabbage leaves

N form and concentration (meq/l)				Total nitrogen (dry weight basis) (%)			
before head formation		after head formation		head leaf		outer leaf	
				blade	midrib	blade	midrib
NO_3	16	NO_3	16	4.29b	3.31bcd	4.51bc	4.09a
NO_3	8	NO_3	16	4.14b	3.13cd	4.51bc	3.84ab
NO_3	8	NH_4	16	4.94a	4.01a	3.91bcd	2.70e
NO_3	8	NH_4	8	4.26b	3.02d	3.88cd	2.09f
NO_3	4	NO_3	16	4.33b	3.36bcd	4.54b	3.65bc
NO_3	4	NH_4	16	4.33b	3.64ab	3.85d	2.30ef
NH_4	16	NO_3	8	4.12b	3.04d	4.45bcd	3.14d
NH_4	16	NH_4	8	5.28a	3.60b	5.65a	3.33cd
NH_4	8	NO_3	8	4.43b	3.09cd	4.22bcd	3.42bcd
NH_4	8	NH_4	8	5.08a	3.48bc	5.14a	2.64e

Table 4 CaO content of Chinese cabbage leaves

Treatment No. (Ca meq/l)		CaO %				Treatment No. (Ca meq/l)		CaO %			
		ILB	ILM	OLB	OLM*			ILB	ILM	OLB	OLM*
	0	0.21	0.52	3.17	1.98		0	0.08	0.18	1.80	0.64
1	8	0.30	1.27	6.00	4.21	6	8	0.09	0.42	2.59	1.73
	16	0.23	1.23	6.42	3.65		16	0.22	0.63	3.16	2.83
	0	0.23	0.55	3.38	2.37		0	0.28	0.58	3.25	2.26
2	8	0.38	1.29	6.65	4.42	7	8	0.13	0.65	3.39	3.01
	16	0.42	1.23	6.47	4.17		16	0.21	0.94	4.55	4.26
	0	0.11	0.36	1.90	0.82		0	0.13	0.45	1.22	0.66
3	8	0.11	0.41	3.32	2.93	8	8	0.42	0.47	2.26	2.04
	16	0.14	0.56	3.68	3.28		16	0.27	0.38	3.08	2.64
	0	0.07	0.21	2.25	0.86		0	0.36	0.72	3.22	2.15
4	8	0.16	0.52	3.70	3.24	9	8	0.41	1.10	4.85	4.16
	16	0.14	0.60	4.03	3.36		16	0.41	0.93	5.51	4.09
	0	0.20	0.57	3.42	2.39		0	0.14	0.38	1.21	0.50
5	8	0.48	1.14	6.36	5.18	10	8	0.38	0.63	2.61	0.98
	16	0.37	1.21	5.85	4.22		16	0.50	0.70	3.17	1.10

ILB = inner leaf blade
ILM = inner leaf midrib
OLB = outer leaf blade
OLM = outer leaf midrib

The opposite was true, however, for plants irrigated with NO_3-N BHF and NH_4-N AHF. Thus, while NO_3-N accelerated Ca^{++} translocation into the inner leaves BHF, NH_4-N suppressed its translocation into the inner leaves AHF.

Internal rot and its relationship to tipburn

Even when there are no symptoms of tipburn, the edges of the inner leaves are often rotten; somewhat different to tipburn, this phenomena is referred to as internal rot. Among the treatments, internal rot was noted only in plants receiving high concentrations of NO_3-N throughout their growth, in which cases the Ca^{++} content correlated well with the rate of Ca^{++} application. Thus it could be seen that there was no correlation between the Ca^{++} content and the incidence of internal rot among these treatments.

Nitrogen Fertilizer Timing, Form and Concentration

Experiment

In an experiment conducted in the spring of 1984, seedlings of cabbage cultivar ASVEG #1 were transplanted on April 13th and irrigated at different timings with culture solutions of different nitrogen sources and concentrations (Figure 1).

Results

Effect of timing and concentration

Plants grown with NH_4-N throughout their growth periods produced the lowest yields irrespective of concentration (Table 5). The second highest yields were obtained from plants irrigated with NO_3-N throughout their growth (Treatment 19), and the highest yields with NH_4-N for the first week only and from then on irrigated with NO_3-N (Treatment 1). NH_4-N is superior to NO_3-N in accelerating plant growth, and thus higher yields were obtained when it was used in initial growth periods (Treatment 17) than when NO_3-N was supplied throughout growth (Treatment 19). Hence, application of NH_4-N in early growth periods is recommended.

Table 5 Effect of N treatment on total and head yields

Treatment	Total dry weight	Head dry weight
1	77.20 a	42.10 a
2	64.55 bcde	36.25 abc
3	61.25 cdef	34.55 bcd
4	50.95 fg	28.30 de
5	69.65 abcd	34.55 bcd
6	57.40 ef	30.70 cde
7	38.35 hi	18.55 gh
8	58.30 def	31.15 cde
9	65.95 abcde	29.80 cde
10	62.30 cdef	34.75 bcd
11	25.05 j	9.25 ij
12	26.55 j	11.15 ij
13	24.15 j	8.90 ij
14	29.75 ij	12.40 i
15	54.25 efg	25.25 ef
16	28.40 ij	12.90 hi
17	75.65 ab	34.95 bc
18	19.20 j	5.80 j
19	72.90 abc	39.90 ab
20	44.20 gh	21.25 fg

Moving the time of ammonia application week by week, to later in the growing period (Treatments 1 through to 5), resulted in progressively reduced yields up until Treatment 4, in which ammonia was applied in the fourth week. Cabbage head formation started during the second week of the treatments, and it was only on the plants which received ammonia treatment in the third week that tipburn occurred on the young leaves. Thus, it is the head

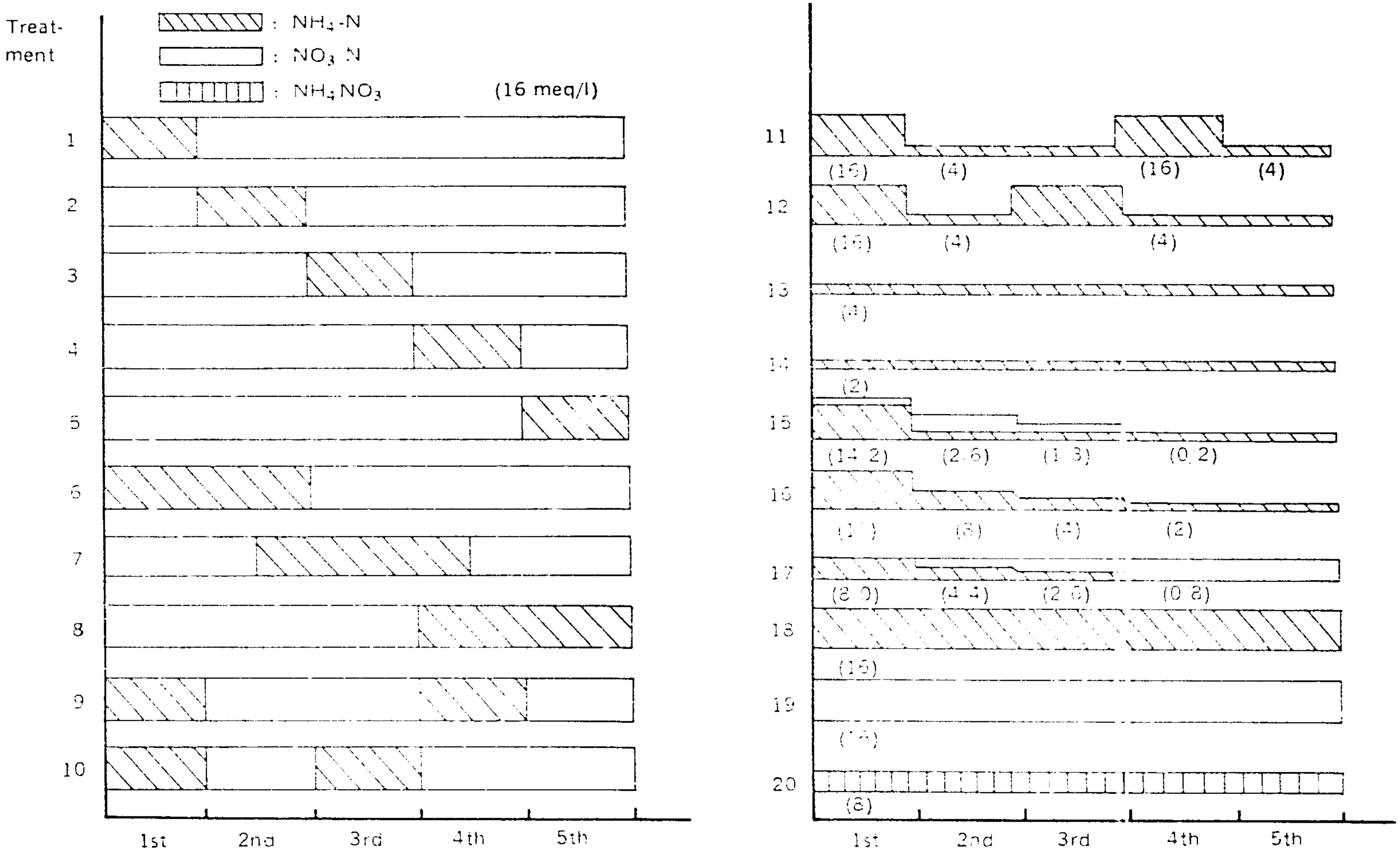


Fig. 1 Nitrogen treatments
Numerical values in parenthesis show nitrogen concentration in meq/l

formation stage during which Chinese cabbage is most susceptible to tipburn. However, the plants which suffered the greatest yield loss due to ammonia toxicity were those which received more ammonia during the fourth week of treatment (Treatments 4, 7, 11).

The incidence of tipburn occurring in treated plant is recorded in Table 6. Tipburn symptoms were found in Treatments 3, 7, 10, 11, 12, 13, 14, 15, 16, 17, and 18. In Treatments 3, 7 and 10, NH_4-N was fed during the head initiation period, while in Treatments 11 18, NH_4-N was fed from initial growth stage either until head formation stage or harvest. Good yields were achieved in Treatment 17, from plants which were started on NH_4-N and changed over gradually to NO_3-N; however, in Treatment 17, as in Treatment 16 in which NH_4-N was simply reduced in application rate without substitution of NO_3-N, tipburn still occurred though concentration of NH_4-N was as low as 28 ppm. This indicated that as a cause of tipburn, the nitrogen source is more important than total application rate.

Table 6 CaO contents in leaves and frequency of tipburn and internal rot in ASVEG #1

Treatment	CaO % (dry wt. basis)								Internal rot	Tip-burn
	Head blade		Head midrib		Outer blade		Outer midrib			
1	0.27	ab	1.20	a	7.07	ab	3.03	ab	**	
2	0.18	cdef	1.18	a	6.66	abc	3.27	abc	****	
3	0.18	cdef	1.17	a	6.56	abcd	3.01	bcd	***	**
4	0.23	bc	1.05	abc	7.23	a	3.60	a	****	
5	0.19	cde	0.87	d	6.25	cdef	2.94	bcd	****	
6	0.32	a	1.16	a	6.39	bcde	3.03	bcd	*	
7	0.26	b	0.96	bcd	5.12	g	1.87	g		****
8	0.14	ef	0.66	e	5.75	efg	2.71	de	****	
9	0.17	cdef	0.88	d	5.57	fg	2.39	ef	****	
10	0.18	cdef	1.08	ab	5.89	def	2.42	ef		****
11	0.16	def	0.47	f	1.79	j	0.79	h	**	****
12	0.16	def	0.47	f	2.38	ij	0.78	h	**	****
13	0.14	ef	0.55	ef	2.94	hi	1.02	h	**	****
14	0.12	f	0.62	ef	3.41	h	2.16	fg	**	****
15	0.13	ef	0.68	e	5.60	fg	3.50	a	**	****
16	0.14	ef	0.50	f	2.87	hi	0.98	h	***	****
17	0.16	def	0.91	cd	6.26	cdef	3.25	abc		****
18	0.17	cdef	0.47	f	2.22	ij	0.69	h	**	***
19	0.22	bcd	0.07	ab	7.11	ab	3.56	a	***	
20	0.21	bcd	0.98	abcd	6.26	cdef	2.90	cd	****	

Effect of nitrogen treatments on Ca^{++} and N uptake

The distribution of Ca^{++} in the leaf blades and midribs of treated plants together with the frequency of tipburn and internal rot occurrence are recorded in Table 6. Ca^{++} content of the outer leaves was much higher than that of the head leaves, especially Ca^{++} content of the leaf blades of the outer leaves was 10 to 30 times that of the head leaves. It can be seen that regardless of NH_4-N concentration, plants supplied NH_4-N throughout their growth had lower Ca^{++} contents (Treatments 11-14, 16, and 18). NH_4-N application suppresses Ca^{++} uptake by Chinese cabbage because of severe root damage and/or because of competitive inhibition of Ca^{++} uptake.

Total nitrogen content in the leaf blades of the head leaves was always found to be higher than in the midribs. A lot of nitrogen accumulated in the head leaves of plants treated in the fourth week of treatment with NH_4-N (Table 7).

Both Ca/N ratio and Ca content correlate closely with the head weight (Table 8).

Table 7 Effect of N treatment on total N contention in leaves of ASVEG #1

Treatment	Total nitrogen (%)							
	Head				Outer leaf			
	Blade		Midrib		Blade		Midrib	
1	3.86	efgh	3.22	cdef	4.01	bcd	4.61	a
2	4.03	efgh	3.38	cd	4.24	bcd	4.19	abc
3	4.35	def	3.51	bc	4.47	b	3.91	bc
4	5.23	ab	3.95	a	4.33	bc	4.13	bc
5	4.23	defg	4.00	a	4.14	bcd	4.33	ab
6	4.03	efgh	3.16	cdef	4.14	bcd	4.30	ab
7	4.82	bcd	3.98	a	4.62	b	3.39	de
8	4.82	bcd	4.18	a	3.98	bcd	3.81	cd
9	4.30	def	3.83	ab	4.57	b	3.81	cd
10	4.37	def	3.55	bc	4.53	b	3.80	cd
11	4.44	cde	2.85	fg	3.26	ef	2.28	f
12	4.34	def	2.74	g	3.62	de	2.13	fg
13	4.15	efg	2.99	defg	2.32	fg	2.01	fg
14	3.43	h	1.53	j	2.17	h	0.99	g
15	3.77	fgh	1.97	i	2.15	h	1.10	h
16	3.65	gh	2.36	h	2.81	fg	1.81	h
17	4.10	efg	2.95	efg	3.67	cde	3.03	e
18	5.04	bc	3.97	a	5.59	a	4.02	bc
19	4.15	efg	3.30	cde	3.70	cde	4.31	ab
20	5.74	a	4.15	a	3.07	ef	3.30	e

Table 3 Correlation coefficients among leaf nutrient content and head dry weight

Nutrient content		Head dry weight	
		Variety	
		Fong-luh	ASVEG #1
T — N (%)	Head leaf blade	−0.445 **	−0.127 ns
	Head leaf midrib	−0.246 ns	0.293 ns
	Outer leaf blade	−0.137 ns	0.290 ns
	Outer leaf midrib	0.494 **	0.648 **
CaO (%)	Head leaf blade	0.049 ns	0.385 *
	Head leaf midrib	0.469 **	0.821 **
	Outer leaf blade	0.575 **	0.904 **
	Outer leaf midrib	0.418 **	0.859 **
Ca/N	Head leaf blade	0.149 ns	0.462 **
	Head leaf midrib	0.472 **	0.561 **
	Outer leaf blade	0.533 **	0.571 **
	Outer leaf midrib	0.209 ns	0.080 ns

Effect of nitrogen treatments on internal rot

It is difficult to clarify the relationship of the incidence of internal rot and the factors involved in the treatments, as internal rot occured in all treatments except Treatments 7, 10 and 17. Internal rot was seen to be aggravated by later application of NH_4-N; however, it occurred even when plants were fed NO_3-N and no correlation could be established between Ca^{++} content of the head and internal rot frequency. It was confirmed that internal rot could be avoided by additional Ca^{++} application, and, that compact heads associated with excessive growth following heavy basal nitrogen application, contributed to the incidence of internal rot. Therefore, to minimize both tipburn and internal rot in Chinese cabbage, nitrogen of the correct source should be applied in four to five split applications, rather than as a basal application.

Intergrated Cultural Practices

Experiment

Six greenhouse experiments were conducted to develop intergrated cultural practices which would minimize the incidence of tipburn and internal rot in Chinese cabbage (Tables 9-14). The experiments were carried out from summer 1984 to autumn 1985 at AVRDC, Taiwan.

Experiment 1 had a split-plot design with two replications with the cultivar as the main plot and foliar spray application as the subplot. Seedlings of either ASVEG#1, on October 30th, or Fong luh, on November 2nd, were transplanted into plastic containers, 50 x 35 x 30 cm (20 cm soil depth). The ASVEG#1 were harvested on December 11th, and the Fong-luh on December 14th (Table 9).

Table 9 Effect of covering and foliar spray on Chinese cabbage tipburn and internal rot (Exp. 1, Autumn, 1984)

Treatment	Fong-luh[z]			ASVEG #1[z]	
	Head weight	Tipburn rot	Internal rot	Head weight	Internal rot
1. Liquid NH_4-N	939.0 ab			864.4 a	
2. Liquid NO_3-N	1049.0 ab			912.2 a	
3. Solid NH_4-N	656.5 bc	***		675.4 ab	***
4. Covering BHF[y]	631.0 bc	*	*	719.3 ab	**
5. Covering AHF[x]	359.0 c	****		565.3 b	**
6. Covering BAHF[w]	528.0 bc	***	*	573.2 b	**
7. Covering AHF + Ca-cit FS[v]	448.5 bc	*****		533.4 b	***
8. Covering + Ca-Cit FS, AHF	468.5 bc	****		475.7 b	***
9. Ca-cit FS	646.5 bc	*****		800.9 ab	**
10. $CaCl_2$ FS	686.5 b	******		550.9 b	****
11. Citric acid FS	801.5 ab		**	810.3 ab	**
12. Water FS	572.5 bc	*		776.1 ab	**
LSD (.05)	251.6			251.6	

[z] Symbols indicate the relative extent of tipburn and internal rot damage: * = Very slight; ** Slight; ***, **** = Medium; ***** = Severe; ****** = Very severe

[y] Before head formation

[x] After head formation

[w] Before and after head formation

[v] Ca-citrate foliar spray. 50 ml/pot of Ca-citrate at a concentration of 0.0005 *M* is sprayed twice a week over the whole period of growth

Table 10 Effect of N form, Ca foliar spray on Chinese cabbage tipburn and internal rot (Exp. 2, Sand Culture, Autumn, 1984)

Treatments				Fong-Luh[z]		ASVEG #1[z]		
$NH_4:NO_3$[y]		Ca (ppm)	Foliar spray	Head weight	Taipburn[w]	Head weight	Tipburn	Internal[z] rot
1	7:1	160	Ca-citrate	249.1 d	0	213.2 c	0.25	0.75
2	7:1	160	$CaCl_2$	163.4 e	1	309.2 c	0.75	0.25
3	7:1	160	—	214.4 de	2	279.7 c	2.00	0.25
4	7:1	0	—	56.1 f	4	205.5 c	3.50	1.75
5	1:7	160	Ca-citrate	906.4 b	0	788.4 ab	0	1.50
6	1:7	160	$CaCl_2$	909.3 b	0	710.7 ab	0	1.50
7	1:7	160	—	908.7 a	0	829.1 a	0	2.25
8	1:7	0	—	810.5 c	0	660.8 b	0	3.00

[z] Main plot

[y] Sub plot

[x] Sub-sub plot

[w] Numerals indicate the relative extent of tipburn and internal rot damage. The damage increases as the number grows

Table 11 Effect of nitrogen fertilization, foliar spray and IGETA GEL application on Chinese cabbage internal rot. (Exp. 3, Spring, 1985)

Variety: ASVEG#1

Treatments: Fertilization				Other treatments	Total weight (g/plant)	Head weight (g/plant)	Internal^{y} rot
	Basal	10 DAT^{z}	20 DAT				
1	Liquid NO_3-N, 0.25 g N is applied twice a week			NO	1375 c	850.0 bcd	1.5
2	2-1.5-2.5	1-0-0		NO	1430 abc	905 abcd	2.5
3	3-1.5-2.5	1-0-0	1-0-0	NO	1680 ab	1047.5 ab	2
4	3-7.5-2.5	1-2.5-0	1-2.5-0^{x}	NO	1525 abc	1042.5 ab	2
5	2-1.5-2.5	1-0-0		Foliar spray of Ca-citrate BHF^{w}	1410 abc	897.5 abcd	2
6	"	"		FS Citrate BHF	1500 abc	952.5 abcd	1.5
7	"	"		FS Malate BHF	1690 a	1005 abc	2
8	"	"		Covering BHF	1395 bc	770 de	0
9	"	"		Leaf typing BHF	1095 d	587.5 e	0
10	"	"		IGETAGEL (5%)^{v}	1420 abc	802.5 cd	2
11	"	"		" (2%)	1440 abc	900 abcd	2
12	3-7.5-2.5	1-2.5-0	1-2.5-0	" (5%)	1645 abc	1085 a	1.5
LSD					259	190	

^{z} Days after transplanting. Transplanted on April 2, 1985, harvested on May 8, 1985

^{y} Numerals indicate the relative extent of internal rot damage

^{x} N and P are applied together in the form of $(NH_4)_2HPO_4$

^{w} Ca-citrate foliar spray before head formation

^{v} IGETAGEL is mixed with soil mass (15 cm dia x 10 cm depth) prior to seedling transplanting

Table 12 Effect of Ca-chelate application and increasing water holding capacity in soil by materials incorporation on Chinese cabbage tipburn and internal rot. (Exp. 4, Summer, 1985)

Treatments	Total weight (g/plant)	Head weight (g/plant)	Extent of*	
			Tipburn	Internal rot
Main plot				
1. $CaCl_2$	1069.6 a	401.2 a	1.1	2.4
2. Ca-citrate	1038.8 a	422.9 a	1.5	2.2
LSD (.05)	1949.3	1427.7		
Sub-plot				
1. Check	1015.5 a	386.5 a	2.5	5.0
2. SRH	1071.3 a	388.4 a	2.0	4.5
3. Quartz sand	1188.8 a	557.5 a	1.5	4.0
4. Gypsum granular	1101.1 a	501.3 a	3.5	4.5
5. Vermiculite	1104.6 a	403.9 a	3.5	6.0
6. Compost	1025.5 a	322.4 a	2.0	4.5
7. IGETA GEL, 1%	884.2 a	332.7 a	2.0	4.5
8. " , 2%	1127.2 a	485.2 a	2.0	4.0
9. " , 5%	1015.3 a	420.0 a	3.5	4.0
10. " , 7.5%	1108.5 a	422.8 a	1.5	5.0
LSD (.05)	370.7	286.8		

* Numbers listed are relative extent value of tipburn and internal rot. The higher the value, the severer symptom appeared

Table 13-a Experimental design for Experiment 5

Treatment No.	Material[V] added	Covering[W]	Sub-surface drip Irrigation[X]	Fertilizer[Y]	Boric[Z]
1	NO	Red film 2	No	Solid	Yes
2	QS	"	"	"	"
3	NO	"	Yes	"	"
4	NO	Red film 1	"	"	"
5	NO	Blue film 2	No	"	"
6	QS	"	"	"	"
7	NO	"	Yes	"	"
8	NO	Blue film 1	"	"	"
9	NO	Rice straw 2	No	"	"
10	QS	"	"	"	"
11	NO	"	Yes	"	"
12	NO	Rice straw 1	"	"	"
13	QS	No	No	"	No
14	QS	"	"	"	Yes
15	GG	"	"	"	No
16	GG	"	"	"	Yes
17	NO	"	Yes 1 pipe at 10 cm	"	No
18	NO	"	Yes 1 pipe at 20 cm	"	"
19	NO	"	Yes 2 pipes at 10, 20 cm	"	"
20	NO	"	Yes 2 pipes at 10, 20 cm	"	Yes
21	NO	"	Yes	Liquid	No
22	GG	"	"	"	"
23	QS	"	"	"	"
24	NO	"	No	Solid	"

Duration: Transplanted on Aug. 20, '85 and harvested on Sept. 24, '85

[Z] Boric: Yes; 500 mg of boric acid is added to each plant
No; No

[Y] Fertilizer: Solid: Solid fertilizer is applied in the following ratio:
Fertilization (N-P_2O_5-K_2O, g/pot)

Basal	Top 1 (10 DAT)	Top 2 (20 DAT)
1.0-1.5-1.0	1.0-0-1.0	1.0-0-0

Liquid; 0.25 g N dissolved in distilled water is applied 3 times a week
All the P, K are added to as basal fertilizer

[X] Irrigation pipe: Water is applied
Yes; through a irrigation pipe buried at the depth of either 10 cm or 20 cm
No; Ordinary watering

[W] Covering:
Red film 1; Plant is covered with red plastic film for 2 weeks from 1 week after transplanting (Aug 28-Sep 11)
Red film 2; Covered for 2 weeks from 2 weeks after transplanting (Sep 4 Sep 19)
Blue film; Covered with blue plastic film
Rice straw; Outer leaves of plant are covered with rice straw
Numerals following covering materials have the same meaning as the red film treatment.

[V] Material added: GG, Gypsum granule, QS; Quartz sand. These materials are mixed with soil at the ratio of 2 to 50 by weight

Experiment 2 was a sand culture experiment with a split-split plot design, in which the cultivar was the main treatment, NH_4-N:NO_3-N ratio as the subplot and the foliar spray of Ca^{++} salts as the sub-subplot. Both ASVEG#1 and Fong-luh cultivars were planted on November 16th, 1984 but were harvested separately on January 4th and 11th, respectively (Table 10).

Experiment 3 was conducted by Randomized Complete Block Design (RCBD) with two replications. ASVEG#1 was transplanted in spring, on April 2nd, 1985 and harvested on May 8th, 1985 (Table 11).

Experiment 4 was conducted in the summer of 1985 to examine the effect on the indicence of tipburn in Chinese cabbage of combining different material with the soil to increase soil water holding capacity. Seedlings of ASVEG#1 were transplanted on June 27th, and harvested on August 2nd, 1985. The main plot was $CaCl_2$ or Ca-citrate application. The subplot was composed of ten treatments (Table 12).

Table 13-b Effect of covering materials, watering method and boron on Chinese cabbage (Exp. 5, Late summer, 1985)

Treatments	Total weight	Head weight	Marginal rot	Internal rot
1. Red 2, Borate	1020 hi	435 f	*	
2. Red 2, Borate, QS	1015 hi	460 ef	***	
3. Red 2, Borate, Pipe	1060 ghi	520 def		*
4. Red 1, Borate, Pipe	1165 fgh	555 def		
5. Blue 2, Borate	630 k	205 g	***	
6. Blue 2, Borate, QS	720 jk	230 g	***	
7. Blue 2, Borate, Pipe	685 jk	225 g	***	
8. Blue 1, Borate, Pipe	870 ij	215 g		
9. Rice straw 2, Borate	1220 fgh	550 def	*	
10. Rice straw 2, Borate, QS	1215 fgh	545 def		
11. Rice straw 2, Borate, Pipe	1285 efg	690 bcd		*
12. Rice straw 1, Borate, Pipe	1210 fgh	560 def		
13. Quartz sand	1355 cdef	740 bcd		*
14. Quartz sand, Borate	1495 abcde	700 bcd	*	**
15. Gypsum granule	1230 fgh	615 def		**
16. Gypsum granule, Borate	1290 efg	665 cde	**	**
17. Pipe at 10 cm	1525 abcd	855 abc		*
18. Pipe at 20 cm	1575 abc	855 abc		*
19. 2 pipe at 10, 20 cm	1605 a	965 a		*
20. 2 pipe at 10, 20 cm, Borate	1590 ab	905 ab		*
21. Pipe, Liquid-F	1600 a	955 a		*
22. Pipe, Liquid-F, GG	1480 abcde	730 bcd		**
23. Pipe, Liquid-F, QS	1365 bcdef	670 cde		*
24. Check	1310 def	610 def		***

Experiment 5 evaluated the effects of different covering materials and watering methods. The experiment done in the late summer of 1985, commenced on August 20th and terminated September 24th. ASVEG#1 was the cultivar used (Tables 13a & 13b).

Experiment 6 also evaluated covering materials and watering methods and commenced October 21st and terminated at harvest on November 29th, 1985 (Tables 14a & 14b).

Results

Effects of foliar spray of Ca salts and organic acids

In Experiment 1, difference between the two cultivars in susceptibility to tipburn and internal rot was shown. Neither foliar spray of $CaCl_2$ nor calcium citrate prevented tipburn of Fong-luh cultivar, and foliar spray of $CaCl_2$ actually aggravated the damage (Table 9).

Table 14-a Experimental design for experiment 6

Subplot:

Treatment No.	Covering[x]	Irrigation[y] pipe	Fertilizer[z]
1	Red film	No	Solid
2	"	2 pipes at 10 & 20 cm	"
3	"	"	Liquid, 0.25 g $NaNO_3$
4	Yellow	No	Solid
5	"	2 pipes at 10 & 20 cm	"
6	"	"	Liquid, 0.25 g $NaNO_3$
7	No	1 pipe at 10 cm	Liquid, 0.25 g $(NH_4)_2SO_4$
8	"	"	Liquid, 0.25 g $(NH_4)_2HPO_4$
9	"	"	Liquid, 0.25 g $NaNO_3$
10	"	"	Liquid, 0.75 g $(NH_4)_2SO_4$
11	"	"	Liquid, 0.75 g $(NH_4)_2HPO_4$
12	"	"	Solid

Duration: Transplanted on Oct. 21, 1981. Harvested on Nov. 29, 1985

Main plot: Cultivar

1) Hybrid 82-157, 2) ASVEG#1

[z] Fertilizer:

Solid; Solid fertilizer is applied in the following ratio; (N-P_2O_5-K_2O, g/pot) Basal 2.0-1.5-2.0, Top (10 DAT) 1.0-0-0

Liquid 0.25 g $NaNO_3$; $NaNO_3$ (0.25 g as N) dissolved in water is applied 3 times a week through the irrigation pipe. P_2O_5 and K_2O are applied all as basal fertilizer at the ratio of 1.5 g and 2.0 g/pot, respectively.

Liquid 0.25 $(NH_4)_2SO_4$; Same as above except for the nitrogen form

Liquid 0.25 $(NH_4)_2HPO_4$; Same as above, but only K_2O is applied as basal fertilizer.

Liquid 0.75 $NaNO_3$; $NaNO_3$ (0.75 g as N) dissolved in water is applied once a week through the irrigation pipe.

[y] Sub-surface drip Irrigation pipe: Water is applied

2 pipes at 10 & 20 cm; through a irrigation pipe buried at the depth of 10 cm from the transplanting to the head formation time, and 20 cm after the head formation

1 pipe at 10 cm; through the pipe buried at the depth of 10 cm throughout the growth period

No ; Ordinary watering

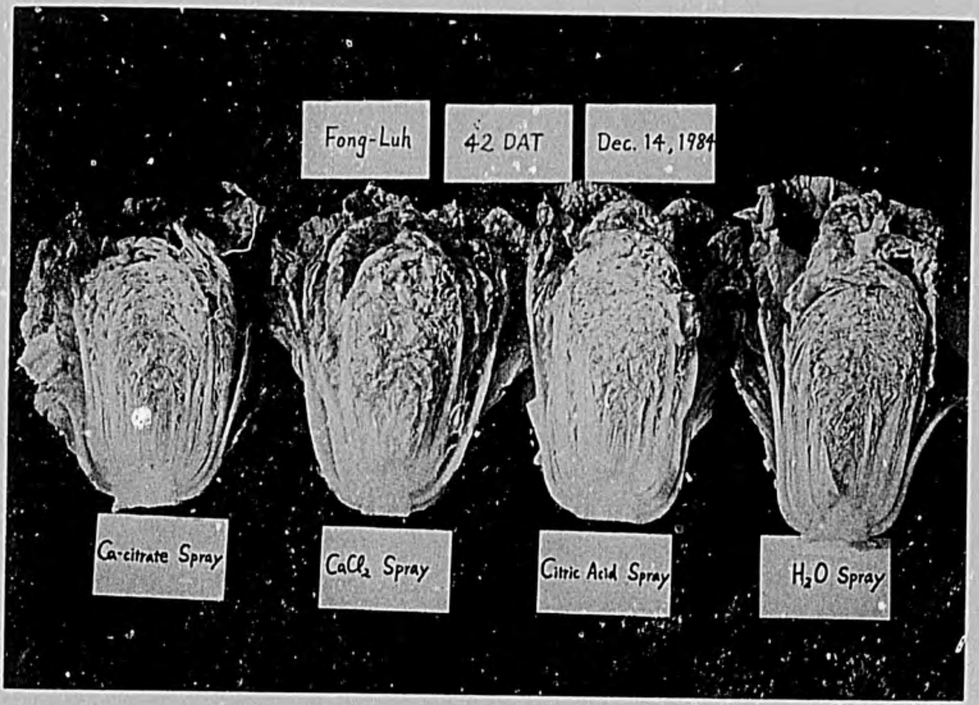
[x] Covering:

Red film; plant is covered with red plastic film for 2 weeks from 1 week after transplanting

Yellow film; Similarly, covered with yellow plastic film

Table 14-b Effects of covering, sub-surface drip irrigation method and fertilizer form on Chinese cabbage internal rot in ASVEG#1 and hybrid 82-157 (Exp. 6, Autumn, 1985)

Treatments	ASVEG#1		Hybrid, 82-157	
	Head weight	Internal rot	Head weight	Internal rot
Covering, pipe, fertilizer				
1. Red film, no pipe, Solid $(NH_4)_2SO_4$	872.5 ef	***	749.0 bc	*
2. Red film, 2 pipes, Solid $(NH_4)_2SO_4$	913.5 def		696.5 c	
3. Red film, 2 pipes, Liquid $NaNO_3$	1101.5 abc		765.0 abc	
4. Yellow, no pipe, Solid $(NH_4)_2SO_4$	801.0 f	***	850.0 ab	
5. Yellow, 2 pipes, Solid $(NH_4)_2SO_4$	989.0 cde		733.0 bc	*
6. Yellow, 2 pipes, Liquid $NaNO_3$	1006.0 bcde		867.0 ab	
7. No, 1 pipe, 0.25g $(NH_4)_2SO_4$	1034.0 bcd		770.0 abc	*
8. No, 1 pipe, 0.25g $(NH_4)_2HPO_4$	970.0 cde		817.0 abc	*
9. No, 1 pipe, 0.25g $NaNO_3$	1147.0 ab		874.0 ab	
10. No, 1 pipe, 0.75g $(NH_4)_2SO_4$	1206.0 a		904.0 a	
11. No, 1 pipe, 0.75g $(NH_4)_2HPO_4$	1062.5 abcd		849.5 ab	
12. No, 1 pipe, Solid $(NH_4)_2SO_4$	1155.0 ab		815.5 abc	****
LSD (.05)	150.7		150.7	

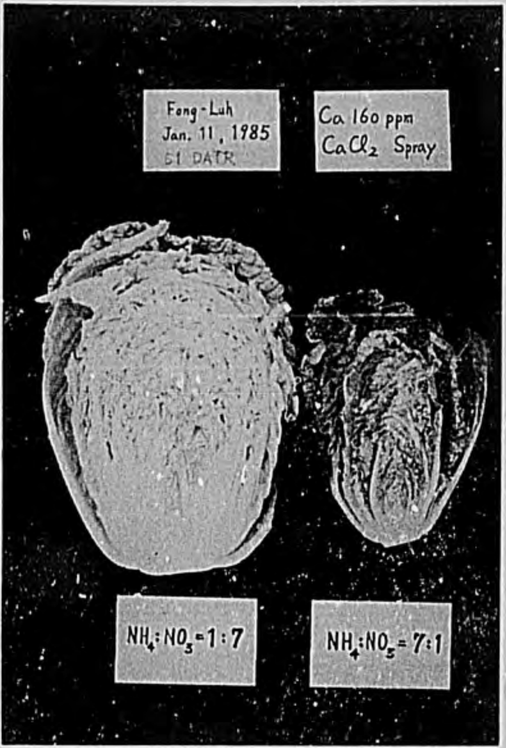


Effect of Ca salts and citric acid on Chinese cabbage tipburn
Cultivar: Fong-Luh

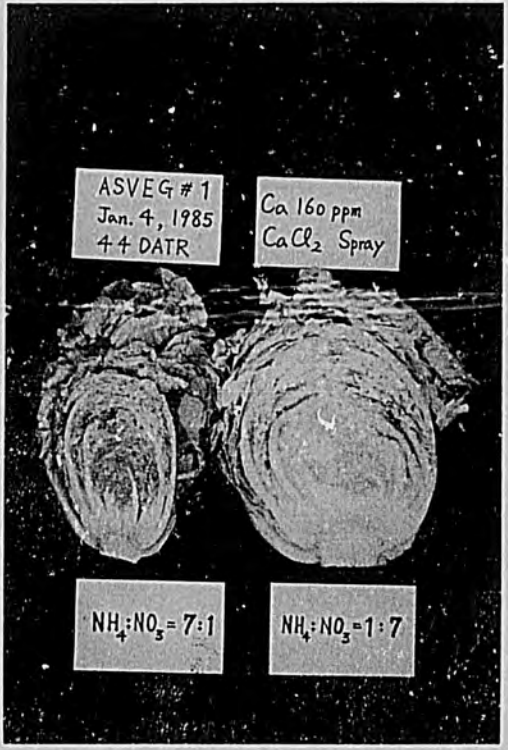
However, foliar spray of citric acid did increase yield and significantly decreased the incidence of tipburn. ASVEG#1 was very tolerant to tipburn. On the other hand all applications of calcium salts tested had no effect on protecting ASVEG#1 cultivar against internal rot. Fong-luh was very tolerant to internal rot. Internal rot is closely related to varietal characteristics of head type, and amelioration by foliar spray alone is ineffective.

In Experiment 2, Ca^{++} applications significantly increased the head weight. Foliar spray of Ca^{++} salts eased tipburn damage in both cultivars, and Ca-citrate was more effective than $CaCl_2$ in reducing the incidence of serious tipburn damage due to NH_4-N toxicity (Table 10). Ca^{++} foliar spray also slightly reduced the incidence of internal rot damage in ASVEG#1; mainly by effecting a change in the head from a round to an elongated shape. Tipburn in both cultivars only occurred in plants grown in solutions with NH_4-N as their predominant nitrogen source, while internal rot occurred in the cultivar ASVEG#1, regardless of growth medium nitrogen source. Thus factors causing tipburn and internal rot are different, with internal rot closely related to head type.

In Experiment 3, foliar spray of citric acid reduced internal rot, but malic acid and Ca-citrate sprays had no effect (Table 11). Citric acid is a strong legand, and after entering the plant tissues through foliar spray it forms chelate compounds with Ca^{++} ions converting them to translocatable water soluble forms; malate being a weaker chelating agent had no significant effect.



Cultivar: Fong-Luh



Cultivar: ASVEG#1

Effect of Ca foliar spray on Chinese cabbage tipburn under different NH_4-N to NO_3-N ratios

Effect of split nitrogen fertilizer application

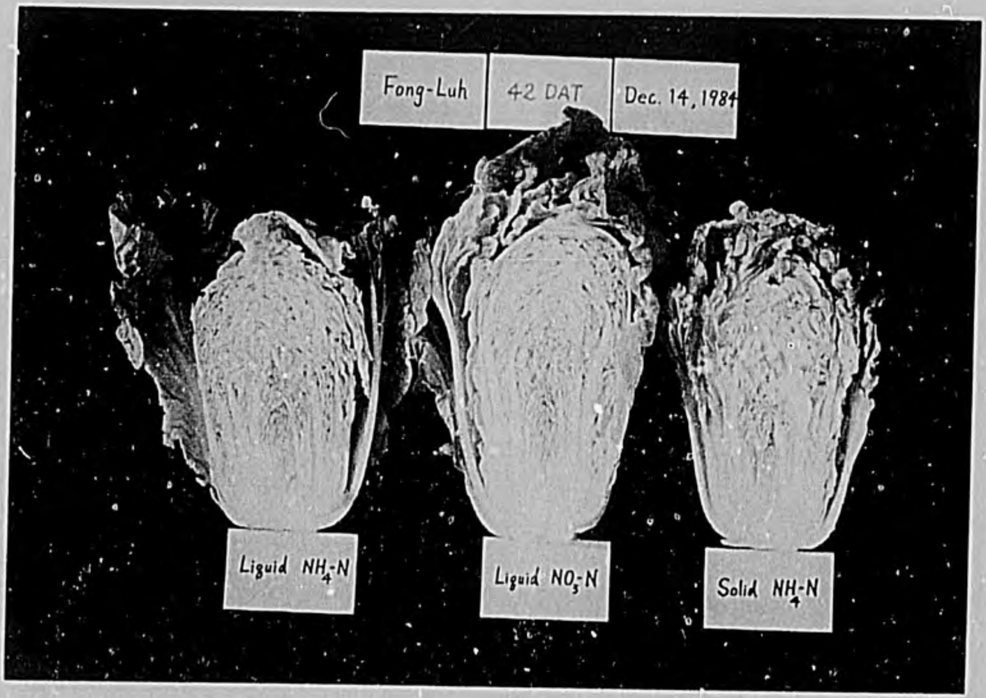
In Experiment 1, split applications of nitrogen fertilizer solution produced the heaviest heads without symptoms of tipburn or internal rot (Treatments 1 & 2, Table 9). The split nitrogen applications controlled any marked increase in soil nitrogen concentration, hence avoiding NH_4-N toxicity and excessive initial growth.

Split applications of nitrogen also resulted in increased Ca^{++} content in the head leaves indicating that the outer leaves activity was kept higher by this treatment even after head formation (data not shown).

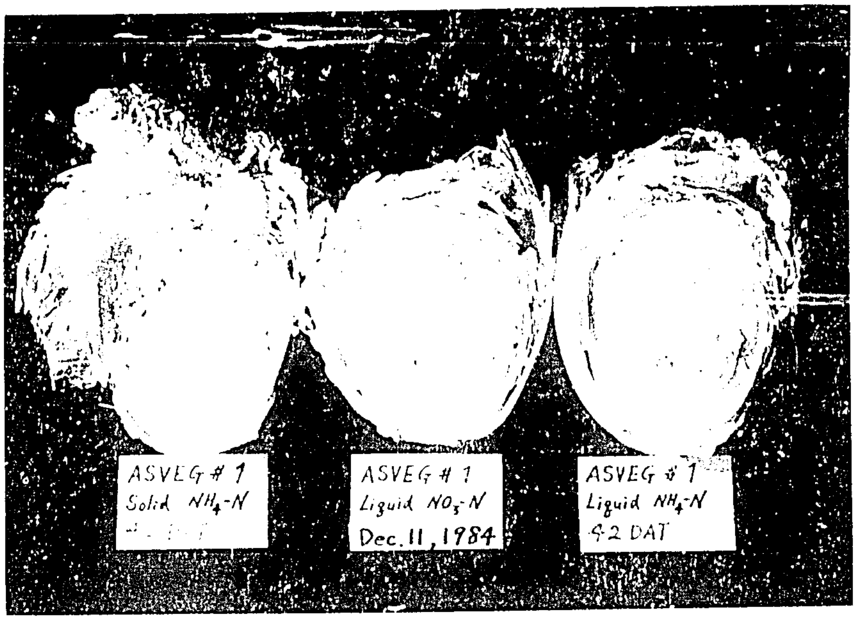
In Experiment 3, the application of 3 g per plant as a basal fertilizer stimulated initial growth and resulted in great total and head weight, but the plants suffered seriously from internal rot (Table 11). Although the split nitrogen fertilizer application slightly eased the incidence of internal rot, it could not eliminate the condition as in the autumn trial. In this spring cultivation both temperature and light intensity were high from head initiation stage, further despite the split nitrogen application, since the pots were undrained the nitrogen levels would have gradually accumulated; which factors combined to accelerate inner leaf growth AHF. It has been shown that split nitrogen applications can greatly affect the incidence of both tipburn and internal rot, but its use in their control must be combined with other cultural practices such as drainage and allowance for seasonal variations.

Regulation of growth rate by covering

Supression of initial growth in Chinese cabbage can effect change in head shape and reduce the incidence of internal rot. In these experiments the Chinese cabbage plants were also covered with various materials at different stages of growth to study this effect.



Cultivar: Fong-Luh



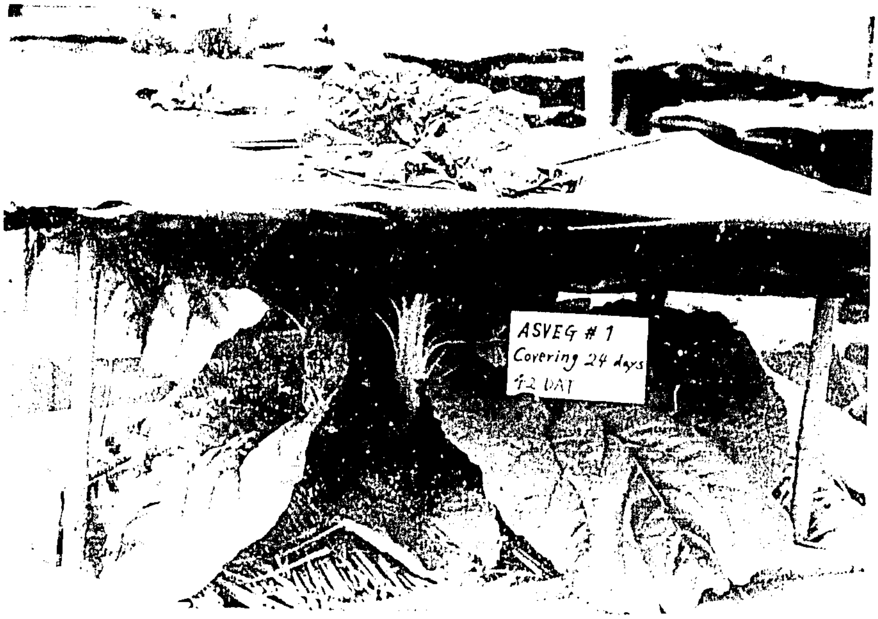
Cultivar: ASVEG#1
Effect of split nitrogen fertilizer application

In Experiment 1, the outer leaves were covered with black vinyl sheet in Treatments 4 8. Covering of these leaves from transplanting to the head formation stage both gave higher yield than any other covering practice and also greatly reduced the incidence of tipburn. However, it had no effect on the incidence of internal rot. Covering of the outer leaves after head formation caused a great decrease in head weight and aggravated both tipburn and internal rot (Table 9).

In Experiment 5, covering with black vinyl film (Treatment 6) or tying (Treatment 9) of the outer leaves BHF completely eliminated internal rot, though with some decrease in both total and head weights (Table 11).

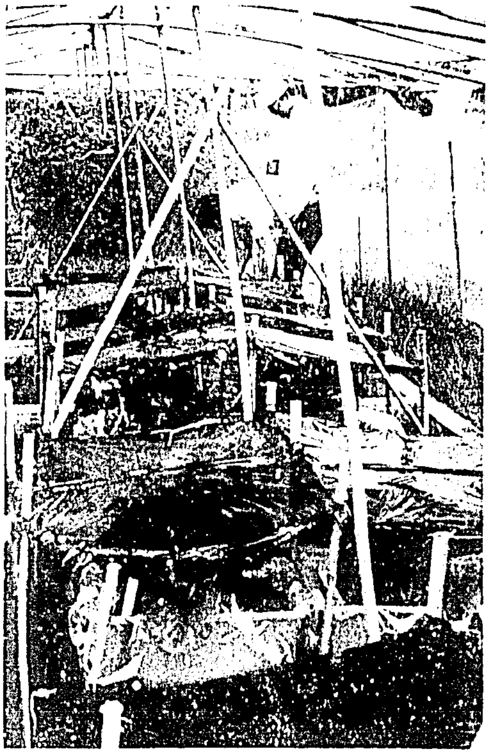
In Experiment 5 Chinese cabbage plants were either covered by rice straw placed on the outer leaves or entirely sheltered under blue or red colored film at a height of 30 cm above the plants at one or two weeks after transplanting (WAT) (Table 13a). The rice straw covering was effective in controlling both tipburn and internal rot. The rice straw can be used as covering from one week after transplanting and then mulched onto the bed surface after two weeks of covering. The red film was also effective in reducing both tipburn and internal rot, but not as practical in use as the rice straw. Although blue film cover treatment eliminated internal rot, it also aggravated tipburn and caused significant yield loss in weight. It was noted that the time of covering is important and it is recommended that this should commence at one week after transplanting and be removed no later than head formation initiation.

In Experiment 6, covering with either red or yellow film alone did not eliminate internal rot in either cultivar (Table 14b). A combination of covering with film and subsurface drip irrigation could, however, control internal rot completely. Growth rates could be suppressed by covering, or enhanced by supplying nitrogen fertilizer through a drip irrigation nutrient solution as required. Thus, tipburn and internal rot could be eliminated without significant decrease in yield by weight.



Outer leaves only covered with black vinyl sheet

Outer leaves covered with rice straw

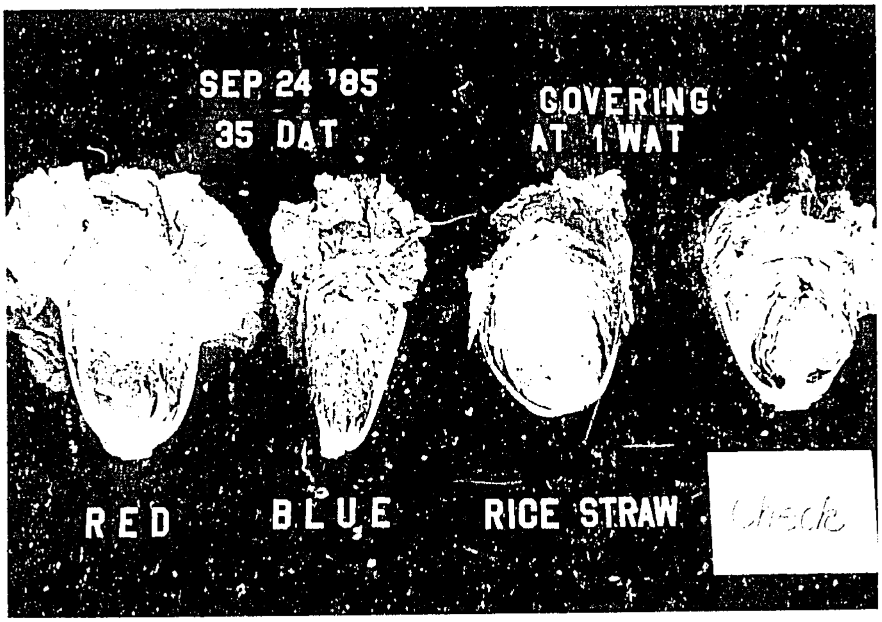


Plant covered with red or blue colored film

Effect of water management

In Experiment 4, various materials wer tested as soil ammendments which when applie to the soil would increase water holding capacity to study the effect of their use on the incidenc of tipburn and internal rot in Chinese cabbag All plants in these treatments suffered seriou tipburn and internal rot symptoms (Table 14b The resultant increase in available water increase the initial top growth of the plants, but limite root growth with the result that soil moistur fluctuations in the medium became greater tha in the non amended soil.

In Experiment 5, subsurface drip irrigatio at 10 or 20 cm depth was effective in reducin both tipburn and internal rot in Chinese cabbag (Table 13b) Initial growth was slightly retarde as the roots grew down to the water source, process which accelerated root elongation an ensured the establishment of sufficient roo mass. This combined with minimal soil moistur fluctuation during the growth periods resulte in decreased tipburn and internal rot.



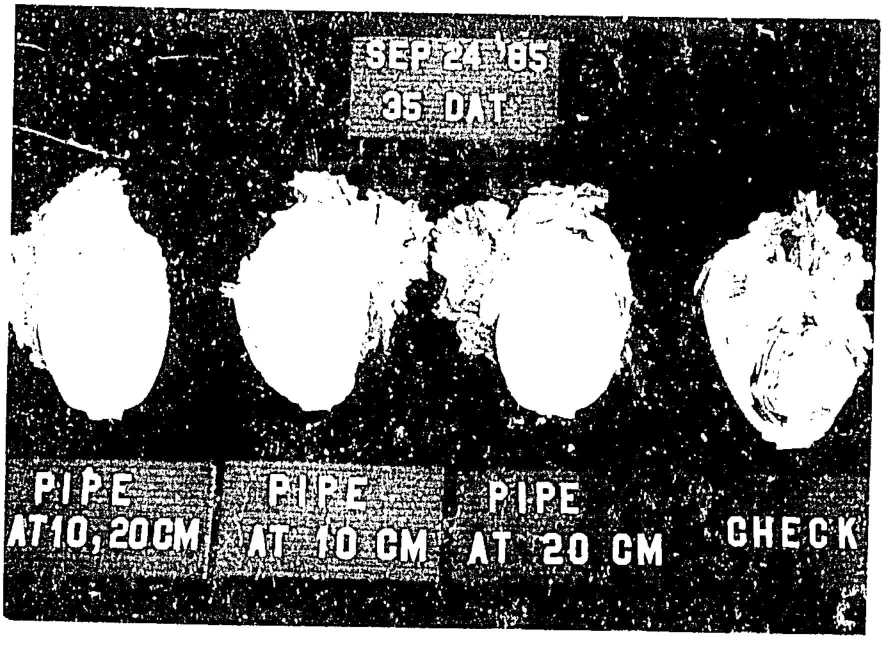
Regulation of growth rate by covering
Cultivar: ASVEG#1

Regulation of growth rate by subsurface irrigation

In Experiment 6, subsurface drip irrigation proved superior as a means of applying nitrogen fertilizer for Chinese cabbage, it both enhanced rooting and regulated the head growth rate. Combined with control of growth by covering, subsurface drip irrigation, subsurface drip split applications of nitrogen fertilizer, gave high heart weight yields without any symptoms of tipburn or internal rot.

Chinese cabbage varietal susceptibility to tipburn and internal rot

The susceptibility of the round headed ASVEG#1 variety and the tolerance of the long headed Fong luh variety to internal rot had previously been established. The Fong luh head is composed of many leaves with similar growth rates and leaf weights, but the ASVEG#1 head is composed of fewer, heavier, thickened leaves, the inner leaves of which close in upon themselves, with the head ballooning as additional inner leaves develop within forming a very compact heart. As heading progresses the pressure produced by



Effect of water management

additional inner leaf formation is not easily released, and tends to concentrate in the area between the utmost head leaves and the region of most active growth. It is in this area where the symptoms of internal rot are seen. Internal rot in Chinese cabbage variety ASVEG#1 is attributable to the physical pressure associated with fast growth. Any treatment which accelerated the head growth in ASVEG#1 cultivars, for example increased nitrogen fertilizer application rates, increased water supply or even compost soil amendments, resulted in increased incidence of internal rot due to inner pressure within the ballooning head.

In the case where Ca^{++} foliar spray treatment reduced the incidence of internal rot in Chinese cabbage cultivar ASVEG#1, the effect of the Ca^{++} addition on the N/Ca ratio of the heading leaves delayed heading time and resulted in an elongated head shape from which the pressure could be released.

SUMMARY

The following flow diagram summarizes the countermeasures shown to be effective in these experiments against factors which cause tipburn and internal rot in Chinese cabbage.

Hazard	Factors involved	Countermeasures
Internal rot	Limited Ca translocation	Foliar spray of citric acid
	Fast growth rate	Covering outer leaf BHF N split application Underground Pipe irrigation
	Balloon head type	Ca foliar spray Select adequate cultivar
	Decreased outer leaf activity	Continuous N application
Tipburn	NH_4-N toxicity	Avoid applying NH_4-N at head initiation time
	Root damage	Increase soil CEC Keep soil moisture constant Avoid heavy fertilization
	Limited root mass	Increase soil mass Enhance rooting by water management
	Rapid initial growth	N split application Covering outer leaf with rice straw Underground pipe irrigation

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DISCUSSION

Q. (P. Wivutvongvana)

Ammonia toxicity is recognised as a cause of tipburn and internal rot on Chinese cabbage. However, since NO_3^- sources of nitrogen fertilizer are scarce and expensive, especially in Thailand, the farmers will be forced to continue using the NH_4^+ sources of nitrogen fertilizer. However, it seems to me that using the NH_4^+-N should not be a big problem on well drained soils in the tropics, because such soils should have relatively high redox potential and the NH_4^+ should be nitrified to NO_3^- fairly quickly. Do you have any information on the rate of nitrification under field conditions in the tropics?

A. Information is available on the kenetics of nitrification but most is the result of bench work. It is impossible to transfer laboratory data directly to the field. Nitrification under field conditions is very location specific, so that only work on nitrification kinetics done for a specific location would be meaningful.

Q. (P. Wivutvongvana)

Would one encounter serious problems using NH_4^+-N fertilizer sources at a normal rate of application in the field on Chinese cabbage under tropical conditions?

A. Nitrogen fertilization application for Chinese cabbage must be considered location specific, depending on soil type, cultural practices, season and cultivar, so your normal rate must be 'normal' for the given location. Generally as you say, tipburn and internal rot are less serious problems on well drained soils.

However, under the following conditions they become a serious hazard:

1. poorly drained soils
2. soils with a high water table
3. after heavy rain, especially at head formation

Under such conditions, it is necessary to:

1. avoid heavy applications of NH_4^+-N
2. avoid NH_4^+-N top dressing at head formation initiation
3. drain these soils well if possible, or use raised bed cultivation

Comment: (R.T. Opeña)

The recommendation that Chinese cabbage with cylindrical heads should be bred for the tropics to avoid internal rot will result in looser heads compared to the density achieved in the round headed cabbage. However, in the Southeast Asian markets, especially those traditionally used to the Wong Bok type Chinese cabbage, this may not be any significant limitation. AVRDC is now developing heat tolerant elongated head varieties that should in fact be preferred in these countries.

Q. (R.L. Villareal)

Do you have sufficient data to show a clear relationship between temperature and the incidence of tipburn and internal rot in Chinese cabbage?

A. If your question specifies a direct relationship between high temperature and the incidence of tipburn and/or internal rot, I have not seen data that establishes this. However, there is a lot of data concerning the secondary effects of high temperature, which include acceleration of the growth rate, and especially initial growth, which in turn can result in tipburn and internal rot.

Q. (R.L. Villareal)
Have you considered doing a similar series of experiments studying the effects of calcium on blossom end rot in tomato?

A. Yes, we have done a similar experiment on this problem and can now control it satisfactorily.

Q. (C.Y. Yang)
I congratulate Dr. Imai for clarifying that tipburn and internal rot of Chinese cabbage are physiological disorders, and not pathogenic disease problems. Dr. Imai, could you make it clear whether tipburn is caused by ammonium or nitrate nitrogen fertilizer application? Which type of nitrogen source do you recommend in order to reduce the nitrogen toxicity which causes tipburn?

A. As I state in my paper, NH_4^+-N causes tipburn, and both NH_4^+-N and NO_3-N cause internal rot whenever a heavy basal application of nitrogen fertilizer is applied. NH_4^+-N topdressing at head formation should therefore be avoided. It is not that nitrogen fertilizer containing NH_4^+-N should not be recommended, but when used, the following factors must be kept in mind: to avoid heavy applications at all times; to avoid any application of NH_4^+-N at heading time; and when using it, ensure that the crop is well drained.

Q. (K. Piluck)
As fast growth is the reason for tipburn and internal rot, is it possible that a plant growth regulator which limits root and leaf development could be used to control the condition, and if so, at what stage would you apply the regulator?

A. I have not tested this, but in theory I would expect a retardant could be applied one week after transplanting; two weeks would be too late.

Q. (B. Khatikain)
In this experiment, the use of urea is not specifically considered, but this is the form of nitrogen source most commonly used in Thailand. How does urea as a nitrogen source fit into your results?

A. Using urea has the same effect as using NH_4^+-N, as the urea is converted to NH_4^+-N, and then nitrified to NO_3-N. The two forms NH_4^+-N and NO_3-N represent various types of nitrogen fertilizers available to farmers.

WEED CONTROL IN VEGETABLE FIELDS IN JAPAN

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ABSTRACT

The special features of weed control in vegetable fields in Japan are analyzed, and the dominant weeds which compete with Japan's upland and vegetable crops are discussed. Chemicals registered as herbicides in Japan are given, together with current and future trends of herbicide development for use on vegetable crops in Japan.

(Chinese Abstract) 摘　　要

文內分析日本蔬菜之栽培、田間雜草特性及討論對蔬菜及旱作競爭之最主要雜草。文內附有登記爲殺草劑之化學藥劑種類以及目前和未來用於蔬菜殺草劑之發展趨勢。

(Japanese Abstract) 摘　　要

日本の野菜生産における雑草防除の特徴を述べる。日本の普通畑と野菜畑での優先雑草を示した。また野菜における登録除草剤とその使用法を紹介し、雑草防除の現状と将来について論じた。

(Korean Abstract) 적　　요

일본의 채소분야에서 잡초제거의 특성을 분석하고 밭작물 및 채소작물과 경쟁이 현저한 잡초에 대하여 논하게 된것이다. 또한 일본에서 채소작물에 사용하는 제초제를 비롯하여 제초제로 등록된 약제와 앞으로의 제초제 개발동향에 관한것을 첨부하였다.

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* Before December 1, 1986, known as Vegetable and Ornamental Crops Research Station

WEED CONTROL IN VEGETABLE FIELDS IN JAPAN

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INTRODUCTION

Increased labor costs in Japan have accelerated the general acceptance of chemical weed control methods for vegetable crops, although they are still less popular for vegetables than for grain crops like rice. Vegetable growers generally prefer cultural practices, such as intertillage, sidedressing, manual weeding plastic mulching and application of multipurpose soil fumigants1). However, herbicide use is increasing in vegetable production, and can be expected to have a greater impact on vegetable production in the future.

DOMINANT WEEDS OF JAPANESE CROPS

Weed emergence is affected by the combined influence of climate and soil, and also by cultural practices, including the cropping history of the field. For Japan's upland crops, the most important of which are wheat and soybean, broadleaf weeds are dominant in the cold Hokkaido region, while grasses are dominant in the warmer Kanto and Kyushu regions (Table 1). However, the dominant weeds of vegetable fields are rather different. Since vegetable fields are small and intensively

Table 1 Dominant weeds in the districts of Japan

District	Weed		Family name
Hokkaido	Grasses	24%	Echinochloa
	Broadleaf weeds (BLW)	73%	Chenopodium, Polygonum, Stellaria, Commelina, Senecio, Veronica Solanum, Rorippa
Tohoku	Grasses	48%	Echinochloa, Digitaria, Setaria
	BLW	47%	Chenopodium, Commelina, Portulaca, Cyperus, Senecio, Acalypha
Kanto & Tokai	Grasses	67%	Digitaria
	BLW	29%	Chenopodium, Portulaca, Cyperus, Acalypha, Amaranthus, Mollugo
Kyushu	Grasses	87%	Digitaria, Echinochloa
	BLW	9%	Chenopodium, Polygonum, Acalypha, Amaranthus

managed, there tends to be less weed emergence but a greater proportion of broadleaf weeds.

Weeds emerge and grow most vigorously in Japan from May to July, when there are moderate temperatures and abundant rainfall. The summer annual weeds during this period can cause serious crop losses. Thus, control during spring and early summer is critical in vegetable fields throughout Japan, whereas control of winter weeds is critical only in the warmer regions. The effects of weeding on the growth of various vegetables is shown in Table 2. Late weeding of spring planted carrots and lettuces resulted in greatly decreased yields, and early weeding also caused some losses. Weeding time for summer planted Chinese cabbage and Japanese radish was not as critical as for the spring planted crops[1]. Generally, weeding time is most critical for spring planted crops and in the early stages of crop growth.

WEED CONTROL IN VEGETABLE PRODUCTION

In Japan, vegetable growing is very specialized and skilful. High returns are obtained from small, intensively farmed plots which need heavy inputs of labor and materials to achieve harvests of high yield and quality. Weed control of vegetables is very different from that of other crops, as vegetables are very susceptible to agricultural chemical injury: even slight contamination or injury may result in quite unmarketable produce. Japanese growers are reluctant to use chemical weed control methods, and simple measures still remain popular – weeding with hand tools, the application before planting of soil fumigants, and direct spraying of paraquat (1, 1'-dimethyl-4, 4'-bipyridinium ion).

Plastic film, used for mulching and covering, has revolutionized the growing of vegetables in Japan, enabling farmers to produce vegetable crops all year round. Vegetables grown under structures now account for 11.1% of the total supply, although they cover only 4.8% of the total area planted in vegetables. This has led to a variety of complex 'cropping systems' (sakugata in Japanese); In warmer seasons, both plastic tunnels and open field cultivation may be employed. In winter, structures are used, and various combinations of cropping systems give year-round production of different vegetables (Fig. 1).

Table 2 Time of weeding and yield of direct seeded vegetables

Crop	Planting date	Time of weed removal (No. of days after planting)					Complete weeding
Lettuce	May 1	25	32	39	46	53	
Head wt. (g)		0	243	367	457	297	587
Cabbage	July 3	1.30	1.25	0.58	0.16	0	1.62
Head wt. (kg)							
Carrot	May 23	30	37	44	51	58	
Root wt. (g/m^2)		0.58	1.57	1.44	1.42	1.32	1.90
Chinese cabbage	Aug. 14	23	30	37	44	51	
Head wt. (kg)		2.58	2.66	2.77	2.47	2.42	2.63
Japanese radish	Aug. 19	20	27	34	41		
Root wt. (kg)		1.35	1.25	1.19	1.12		1.22

Vegetable	Cropping type	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
tomato	1. under structures	—	—	—	—	—	h	s	—	s, t	—	t, h	—
	2. under structures	s, t	—	t	h	—	—	h				s	—
	3. plastic tunnel	s	s	t	t	—	h	—	—	h			
	4. open field			s	t	s	t	h	—	—	h		
	5. under structures	h					s	s, t	t	h	—	—	—
Japanese radish	1. spring planting		s	—	s, h	—	—	h (with mulch & tunnel)					
	2. summer planting						s	s, h	—	—	h		
	3. autumn planting	h							s	s	h	—	—
	4. winter planting	s	—	h	h							s	—
cabbage	1. spring planting			s	t	s	t, h	—	—	h			
	2. summer planting	—	h					s	s, t	t, h	—	—	—
	3. autumn planting	—	—	—	h	—	h	—	—	s	s, t	—	t

s: sowing t: transplanting h: harvesting

Fig. 1 Cropping system for tomato, Japanese radish and cabbage.

The development of so many cropping systems complicates weed control for vegetable growers. Many growers continue to control weeds successfully by using soil fumigation or plastic mulch for vegetables grown under structures. However, the great diversity of environmental conditions created also results in highly diverse weed populations, which vary widely in both type and quantity in different places and at different times, so that simple measures may sometimes prove ineffective. Similarly in herbicide use, the diversity of environments produces different herbicidal effects, and a herbicide proven safe under one cropping system will not necessarily remain safe under another. Therefore, each herbicide must be separately tested and approved for each cropping system.

Herbicide effect varies from one vegetable crop to another, which creates problems when mixed cropping of vegetables or rotation of vegetable crops is practiced. Residual herbicide applied to a plot for a previous crop may cause injury to the following crop.

These problems mean that it is economically difficult for chemical companies to develop herbicides for such a limited market. As a result, most of the herbicides currently registered for use on vegetables have been primarily developed for some major crop.

CURRENT WEED CONTROL IN VEGETABLE PRODUCTION

Chemical weed control has greatly reduced production costs and labor input for cabbage growers in Japan (Fig. 2). In 1961, weeding labor input was 240 hr/ha, but in 1982 was only 67 hr/ha. In one comparison of the cost of manual weeding and herbicidal weeding carried out in 1982, it was shown that a vegetable grower could use herbicidal weeding for a cost of US$292 per ha (US$1 = Y160) and in doing so save 54% of the cost of manual weeding. Clearly, chemical weed control is cost effective in vegetable production[3].

Soil treatment agents are commonly used in vegetable production as herbicides. They are applied before or after sowing or transplanting, depending on their mode of action. They control weeds either by a differential action on the crop and weeds due to different germination rates, or as a result of the different physiological properties of the crop and the weeds. Herbicides of the former type can be applied to any kind of vegetable, and are thus attractive to herbicide manufacturers. Usually, the acreage of any one vegetable is insufficient to warrant production of a specific herbicide. Growers also prefer a single herbicide applicable to many vegetables, as they usually practice multiple cropping of vegetables within a small area. Presently, simazine (2-chloro-4,6-di (ethylamino)-1,3,5-triazine), trifluralin (α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) and IPC (isopropyl-N-(3-chlorophenyl) -carbamate) are commonly used as soil treatment agents. Growers apply only paraquat as a post emergence treatment during the crop growth stage. Herbicides with selective efficacy applied as a

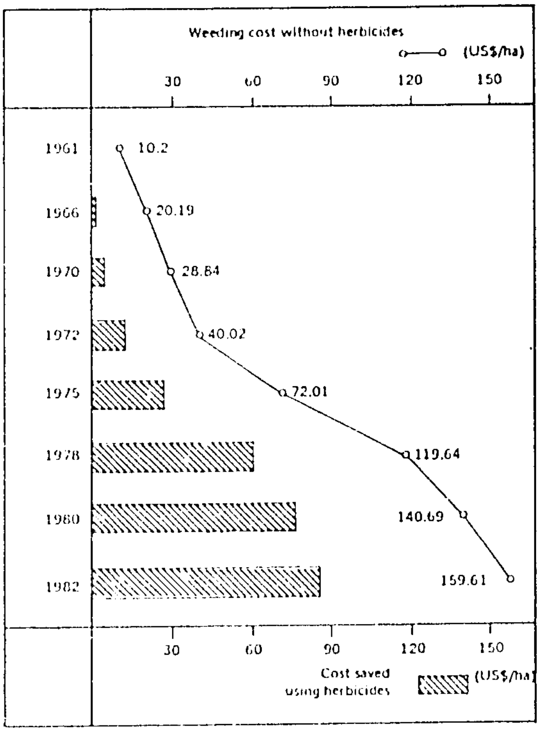

Fig. 2 Economic impact of chemical weed control (cabbage).

foliar spray were formerly highly recommended, but are not popular with growers today except for use on a few crops such as carrots, onions and the Solanaceae (tomato, eggplant, potato etc).

For vegetables grown under structures, chemical weed control is not common Soil sterilization with general purpose fumigants or heat not only controls most weeds, but also suppresses soilborne diseases, insects and nematodes. Mulching with plastic film after planting is also used as a further control. These controls are now being found effective by open field farmers.

In 1983, the area of vegetables grown in Japan under structures, plastic tunnels and in the open field were 29,000 ha, 61,300 ha and 518,000 ha, respectively. Of these, most of the areas under structures and plastic tunnels used plastic mulch, while 12.4% of open field cultivation was carried out with plastic mulching. Black plastic film is used to control weeds in summer vegetable crops, and on winter vegetables clear film is used with chemical weed control.

Weed Control for Different Vegetable Crops

Weed control methods vary according to the type of vegetable grown.

1. Onion, carrot and similar vegetables, which are planted at high density and form a leafy canopy slowly, require weed control throughout their growing period. Chemical control by selective herbicides is more commonly used for this group than for any other.
2. Parsley and garlic belong to a group which needs a very high labor input if hand weeding is used, so that chemical control is common. However, since vegetables of this group cover only a small total acreage, specific herbicides have not been developed.
3. Cabbage, Chinese cabbage, cucumber and tomato are major crops planted over a large area, but even so chemical control is not popular for these crops. They form two sub-groups.
   - i. Japanese radish, cabbage and Chinese cabbage are grown without much input of labor or materials. Weed control is critical only during their early vigorous growth stage, and can be kept to a minimum to save costs.
   - ii. Tomato and cucumber are grown intensively, and weeds are usually controlled by cultural practices such as mulching and soil fumigation. Growers of Cucurbitacae avoid herbicide use, as these crops are particularly susceptible to chemical injury.

WEED CONTROL FOR COMMON VEGETABLE CROPS

Table 3 lists the herbicides registered in Japan, the vegetable crops they are used for, and the application method(s)[2].

Amaryllidaceae

As onions grow relatively slowly to form a leaf canopy, weed control is required over a long growing period. However, since onions are planted at high density, manual weed control is difficult and chemical weed control is commonly used by onion growers, especially in Hokkaido where onions are planted on a large scale. Trifluralin, simazine and IPC are applied before or after bulb transplanting as preemergence controls for broadleaf and grass weeds. Ioxynl (3,5-diiodo-4-octnoyloxybenzonitrile) and alloxydim (3-(1-allyloxyaminobutylidene-6,6-dimethyl-2,4-dioxocyclohexanecarboxylate) are applied to remove grasses in the early stages of growth.

Compositae

As lettuce is a cold weather plant, its early growth is slow. Consequently, weed control is required over a longer period than with other leaf vegetables. Injury by weeds can be severe in the cropping systems whereby lettuce is planted in both spring and summer. Trifluralin, propanil

Table 3 Registered herbicides in Japan

Vegetable	Herbicide		Application method
	Name	Formulation[a]	
Onion	IPC	EC	soil, post-planting & crop growing
	MCC	G	soil, post-planting & crop growing
	trifluralin	G, EC	soil, pre-, post-planting & crop growing
	simazine	WP	soil, post-planting & crop growing
	IPC + DCMU	WP	soil, post-planting & crop growing
	simazine + IPC	WP	soil, post-planting & crop growing
	nitralin	WP	soil, post-planting & crop growing
	ioxinil	EC	weeds, crop growing
	alloxydim	WSC	weeds, crop growing
Garlic	simazine	WP	soil. post-planting & crop growing (inter-row)
	rinuron	WP	soil, post-planting
	trifluralin	EC, G	soil, post-planting & crop growing
	IPC	EC	soil, post-planting & crop growing
Asparagus	rinuron	WP	soil, dormant stage, crop growing & after harvest (inter-row)
	atrazine	WP	soil, dormant stage & crop growing (inter-row)
	paraquat	AS	weeds, crop growing (inter-row)
Japanese radish	simazine	WP	soil, post-sowing
	prometryn	WP	soil, post-sowing
	CNP	EC	soil, post-sowing
	trifluralin	EC	soil, post-sowing
	alachlor	EC	soil, post-sowing
	paraquat	AS	weeds, crop growing (inter-row)
Carrot	rinuron	WP	soil & weeds, post-sowing & crop growing
	IPC	EC	soil, post-sowing & crop growing
	trifluralin	EC, G	soil, post-sowing & crop growing
	CNP	EC	soil, post-sowing
	alloxydim	WSC	weeds, crop growing
	paraquat	AS	weeds, crop growing (inter-row)
Watermelon, melon	paraquat	AS	weeds, pre-planting, crop growing (inter-row) & after harvest
	trifluralin	EC, G	soil, pre-, post-planting & crop growing (inter-row)
	nitralin	WP	soil, pre-, post-planting & crop growing (inter-row)
Cucumber	paraquat	AS	weeds, pre-, post-planting & crop growing (inter-row)
	nitralin	WP	soil, pre- & post-planting
	trifluralin	EC	soil, pre-, post-planting & crop growing
Tomato, eggplant	diphenamid	WP	soil, pre-, post-planting & crop growing
	paraquat	AS	weeds, crop growing (inter-row)
	alachlor	EC	soil, pre- & post-planting
	trifluralin	EC	soil, pre-, post-planting & crop growing
	nitralin	MG, WP	soil, pre-, post-planting & crop growing
Chinese cabbage	trifluralin	EC, G	soil, pre- & post-sowing
	CNP	EC	soil, pre- & post-sowing
	alachlor	EC	soil, post-sowing & crop growing
	simazine	WP	soil, pre- & post-sowing
	paraquat	AS	weeds, crop growing
Cabbage	CNP	EC	soil, post-planting & crop growing
	simazine	WP	soil, pre- & post-planting & crop growing
	trifluralin	EC, G	soil, pre- & post-planting
	alachlor	EC	soil, post-planting
	nitralin	WP	soil, post-planting
	paraquat	AS	weeds, crop growing
	alloxydim	WSC	weeds, crop growing
Lettuce	IPC	EC	soil, post-planting
	trifluralin	EC, G	soil, pre-, post-planting & crop growing (inter-row)
	DCPA	EC	weeds, crop growing
	benthiocarp	EC	soil, pre-planting
	nitralin	WP	soil, pre- & post-planting
	paraquat	AS	weeds, crop growing
Spinach	alachlor	EC	soil, post-sowing
	simazine	WP	soil, post-sowing
	lenacil	WP	soil, post-sowing
	IPC	EC	soil, post-sowing
	paraquat	AS	weeds, crop growing

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[a] WP: wettable powder EC: emulsifiable concentrate WSC: water soluble concentrate
AS: aquatic solution G: granules MG: micro granules

(3′,4-dichloropropionanilide) and nitralin (N,N-dipropyl-2,6-dinitro-4-methyl sulfonyl aniline) are applied as preemergence, and also as pre- or post-planting, treatments.

Cruciferae

As Brassica spp. and Raphnus spp. grow rapidly, providing good soil cover with their leaves, weed control is only critical in the early growth period from planting to the five-leaf stage.

Cabbage and Chinese cabbage are planted either by direct seeding or by transplanting. Both transplanted seedlings and those established *in situ* by direct seeding are tolerant of many herbicides. Trifluralin, simazine, alachlor (N-methoxylmethyl-2,6-diethyl-α-chloroacetoanilide), nitralin and CNP (2,4,6-trichloropheyl-4′-nitrophenylether) are applied before weed emergence, or as a pre- and post-sowing or transplanting control.

Japanese radish grows more rapidly than cabbage and Chinese cabbage, and excellent weed control can be attained with herbicidal applications immediately before or after sowing. Prometryn (2,4-bis-(isopropylamino)-6-methyl-2-thio-s-triazine), trifluralin, CNP and alachlor are applied preemergence of weeds and post-sowing of Japanese radish.

Cucurbitaceae

Farmers grow these crops with a plastic mulch film, which controls weeds during the growth period. Trifluralin and nitralin are applied preemergence to weeds and pretransplanting of the crop, and may also be applied to the interrow space during the growing period.

Leguminosae

Peas are sown in autumn in the warm areas of Japan, and in spring in the cold areas. Simazine and IPC are applied as pre- and post-sowing weed controls.

Liliaceae

Asparagus is a perennial crop for which growers must provide year round weed control. As asparagus plants are deep rooted, manual weed control is adequate in winter when plants are dormant. During the growing period, herbicides are applied preemergence to weeds before the asparagus spears appear, and are applied again after harvest or fern development.

Solanaceae

This group of vegetables is grown intensively in Japan. Chemical control of weeds is less common than with carrots and onions, although an excellent selective herbicide, diphenamid (N,N-dimethyl-2,2-diphenyl acetamide), is available for use on these crops. Diphenamid, trifluralin, nitralin and alachlor are used preemergence of weeds and pre- or post-transplanting of the crop.

Umbelliferae

Seedlings of this group grow slowly. Consequently, weeds must be controlled over a long period, while weed control is especially critical up until the 4-5th leaf stage. One of the oldest selective weed controls is the highly refined petroleum solvent used to control annual weeds in crops belonging to the carrot family. Nowadays, of all vegetables, carrot is the vegetable for which chemical weed control is most commonly used, as it reduces the labor cost of weed control to as little as one tenth of the cost of manual control.

FUTURE DEVELOPMENTS IN WEED CONTROL FOR VEGETABLES

Chemical weed controls will play an increasingly important role in controling weeds in vegetable crops. Recently, growers have tended to rely increasingly on special cultural practices for weed control: combinations of these with chemical controls will develop.

In 1970, Nishi[4,5] recommended the development of herbicides along the following lines. Herbicides should:

1. leave no residue hazardous to the vegetable crop, other crops or the environment,
2. be effective at minimal dosage,
3. be safe to foliar crops,
4. be developed with adjuvants to make their effect more pronounced over a longer period,
5. be stable and durable under the high moisture conditions encountered in Japan's vegetable production,
6. include herbicides in granular form which remain stable when incorporated into the soil.

These requirements have not yet been met to any significant extent. Table 4 shows the formulation and methods of application of chemicals for which registration has been sought over the past 12 years as herbicides for vegetable crops. The Table indicates that established trends are still being followed. Many of the chemicals are for application on carrots, onions and cabbage, vegetables for which chemical weed control has already become common. Recent developments in herbicides tend to concentrate on new formulations and application methods. A new trend is the systematic application of herbicides, which are applied in conjunction with other chemicals at specific crop growth stages. Two new formulations have appeared recently, micro-granules and flowable forms. Micro-granule formulations have two advantages, they save labor and make herbicide treatments more uniform and stable. Flowable formulations make it possible to use as herbicides some chemicals which are difficult to dissolve in either water or organic solvents.

At present, paraquat is commonly used as a postemergence and contact foliage agent, but we can expect to see the development of herbicides which are safer to both crops and human beings.

Table 4 Number and use of chemicals for which testing for registration has been applied in the past 12 years in Japan

Vegetable		1974–76	1977–79	1980–82	1983–85
Onion		52	43	56	59
Asparagus		10	3	6	14
Japanese radish		6	8	7	9
Carrot		19	14	27	30
Watermelon		13	9	5	12
Tomato		8	7	5	13
Chinese cabbage		12	6	7	15
Cabbage		35	13	29	19
Formulation[a/]	EC	72	49	79	95
	AS	18	12	23	32
	G	41	12	25	24
	WP	103	74	56	25
	MG	0	2	5	22
	WSC	6	17	15	18
	F	0	0	1	24
Systematic application[b/]		0	9	30	43

[a/] EC: emulsifiable concentrate AS: aquatic solution G: granules WP: wettable powder MG: micro-granules WSC: water-soluble concentrate F: flowable

[b/] Application method involves combination with other chemicals at a specific growth stage of weed and crop

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DISCUSSION

Q. (W.N. Chang)
What are the advantages of the flowable forms and micro-granule forms of herbicides?

A. Micro-granules have the advantage of very stable and uniform activity, and are time saving with hand spreading application. Flowable formulations are used for chemicals which are difficult to dissolve in water or organic solvents. Many of these have not previously been used as herbicides.

Q. (W.N. Chang)
Can you give any example of the biological control of weeds?

A. Some researchers are thinking of using insects for weed control, but no practical example can be given as yet.

Q. (T. Tonguthaisri)
You were discussing 'Japanese radish'. Was this *Rhapanus sativus longipinatus*? Is there any difference between Chinese radish and Japanese radish?

A. Yes, I was referring to that species. There is no difference between them, only in the terms used by different scientists.

BOLTING IN RADISH

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ABSTRACT

Hybrid radishes have been bred in Korea to overcome the problem of bolting when radishes are grown out of season. Research on bolting in radish cultivars has shown that there is an endogenous rhythm which controls bolting in plants of nonvernalized seed. Long day length alone can initiate flower bud differentiation in radish, and this is accelerated by greater illumination. Plants grown from stored seed tend to bolt more readily when the seed has been stored for a long period and/or under relatively humid conditions. Developing radish seeds are sensitive to low temperature vernalization at about 10°C from thirty days after pollination.

(Chinese Abstract)

摘　要

在韓國已育成品種克服非正常栽培季節生產蘿蔔之抽苔問題，由當地品種抽苔的研究顯示，未春化種子的抽苔是由內在的生長周期因子控制。長日可誘導蘿蔔花芽分化與發育，高光度可加速分化。長時貯藏或在高相對濕度環境之種子在栽植時更易抽苔。發育中之種子於授粉後三十日對10°C春化便會有感應。

(Japanese Abstract)

摘　要

ダイコンの季節外栽培時におきる抽だいの問題を解決するために韓國で交雑ダイコンが育成された。ダイコンの諸品種の抽だいについての研究によれば、春化處理をしていない種子からのダイコンの抽だいをコントロールする內在リズムがある。長日だけでダイコンの花芽分化がおこりこれは光線の強さが増すにつれて促進される。種子が長期間貯藏されると共に，或は又は比較的高濕度で貯藏された時にその種子から生育したダイコンは抽だいしやすくなる。受粉後30日を過ぎた成長しつゝあるダイコンの種子は約10°Cの低温春化處理に感受性である。

(Korean Abstract)

적　요

한국에서 재배되는 무우는 비 재배기절에 생기는 Bolting 문제를 극복하는 품종이다. 무우품종의 bolting 에 관한 연구는 춘화처리 하지 않은 식물의 bolting을 억제하는 내재적 리듬이 있음을 나타내었다. 낮의 길이가 길면 무우의 꽃봉오리분화를 유도하고 고도의 조명은 이를 더욱 가속화 시킨다. 장기간 동안 상대적으로 습도가 많은 조건에서 저장된 종자는 보다 쉽게 bolting 경향을 나타낸다. 발육중의 종자는 수분 된후 30일로 부터 약 10℃ 의 저온 춘화에 매우 민감하다는 것을 알게 되었다.

BOLTING IN RADISH

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INTRODUCTION

Demand for out-of-season vegetables in Korea has led to the development of a late bolting radish variety with a big, round root which is hard and crisp in texture, as preferred by Korean people. Radish is one of the most important vegetables in Korea, but Korean varieties are sensitive to low temperatures, and bolt before reaching maturity if they are grown in the off season. The Japanese cultivar Tokinashi has a late flowering trait, but its slender, soft root is not to Korean tastes. In the late sixties, a hybrid variety of Tokinashi crossed to a Korean variety was released, and successfully adopted in winter cropping. However, the root texture remained a little too soft.

There are several cultivars in Korea suited to fall cropping with better texture characteristics than the new hybrid. Farmers tried these better textured cultivars in summer cropping, since it was expected that the high summer temperatures would suppress flower bud initiation. However, these fall radishes grown in summer often bolted prior to full maturity[2]. Thus, Korean horticulturalists realisted that the physiology of flower bud differentiation in radish was inadequately understood. This paper reviews the research carried out by Korean horticulturalists on the subject.

ENDOGENOUS CHANGE IN THE SEED

Until the early 1970s, low temperature was the only factor recognised as influencing flower bud differentiation in radish. In 1976, Yoo and Uemoto[4] revealed that radish flower buds could differentiate in plants grown from nonvernalized seed. The radish seeds were harvested in June and stored for up to two years at 25°C to avoid vernalization. The seeds were sown monthly, commencing from the first month of storage, under two treatments. In both treatments the plants were grown in controlled conditions at 25°C under 24 hour illumination, but in one of the treatments the seeds after germination were subjected to a low temperature of 5°C for ten days. The radish plants of this vernalized group consistantly flowered within 20 days of sowing throughout the trial, whereas days to flowering in the nonvernalized treatment varied in an annual pattern dependent on the sowing time after initial storage of the seeds (Fig. 1). In the treatment using nonvernalized seeds stored for seven to eleven months and stored for 19 to 23 months, plants flowered within 30 days of sowing, whereas plants of those stored for two to five months and for 14 to 17 months had delayed flowering of up to 60 days. These results indicated that in the radish there is an endogenous annual rhythm which controls flowering; this annual rhythm can be changed by vernalization of the seedling.

EFFECT OF DAY LENGTH AND LIGHT INTENSITY

It is known that long day length promotes flower stalk development in radish plants which have already initiated bud differentiation. In 1977, Yoo showed that long day length could also induce flower bud differentiation in non-vernalized radish[5]. Seeds of three radish cultivars,

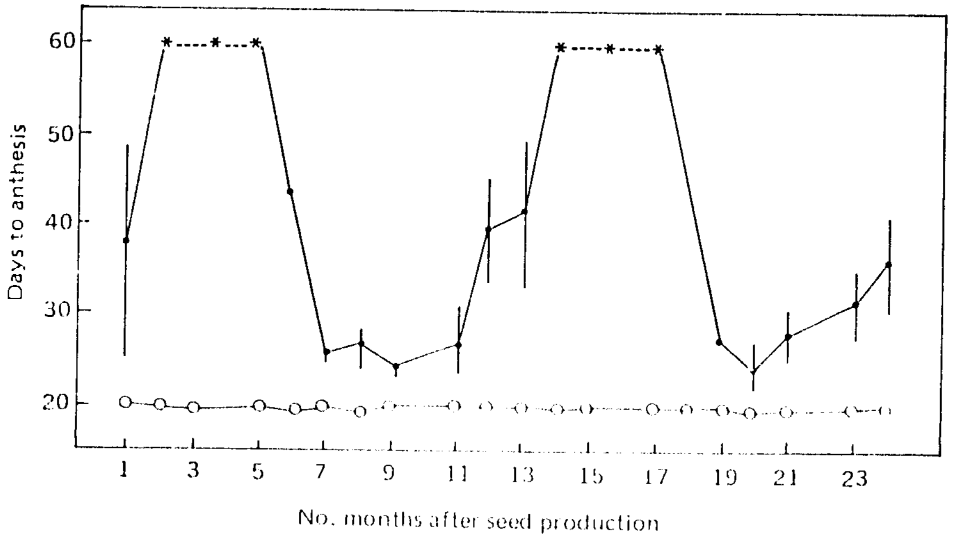

Fig. 1 Days to anthesis as affected by the period of seed storage.
The vertical lines indicate the period from the first to last anthesis. Vernalization was carried out for 10 days at 5°C (Yoo and Uemoto, 1976)[4]
● : Non-vernalized ○ : Vernalized * : No flower 60 days after sowing

Comet, Josaeng Jasibil and Baeksu-gunggung, were stored after harvest in June at 25°C. The seeds were planted in May of the following year in nonvernalized and vernalized (5°C for ten days after germination) treatments, and further split into three day length treatments of 24, 20 and 16 hours illumination. Within each day length treatment, the number of days to flowering was reduced by vernalization. However, in plants from nonvernalized seed, the number of days to flowering was affected by day length. In the Comet variety, plants of nonvernalized seed flowered within 25, 30 and 45 days after sowing in the 24, 20 and 16 hour illumination treatments, respectively. For the other two varieties, plants of nonvernalized seed flowered within 40 days after sowing in the 20 and 24 hour illumination treatments, but not until after 60 days in the 16 hour illumination treatment (Fig. 2). The results show that long day length without vernalization is sufficient to induce flowering in these radish varieties, and that the longer the day length the faster their bud differentiation.

In further experiments on the same three radish varieties, the effect of light intensity on bud differentiation was also studied. Using nonvernalized seeds in all treatments, the plants were grown under constant illumination at 25°C. While the variety Comet proved insensitive to light intensity, the number of days to flowering was significantly less in high light intensity treatments for the other two cultivars (Fig. 3).

EFFECT OF SEED STORAGE ON BOLTING

It is part of rural folklore in Korea that old radish seeds should not be planted, because their plants will bolt before they mature properly.

Studies were undertaken on the effect of length and conditions of storage on bolting in radish[7,8,9,10,11]. Seeds of variety Jinju-daepyeung, which had been stored either in a dessicator with calcium chloride ($CaCl_2.2H_2O$) or under room conditions for one and two years, were sown together with fresh seed on June 25th. Plants of seeds stored for longer periods of time,

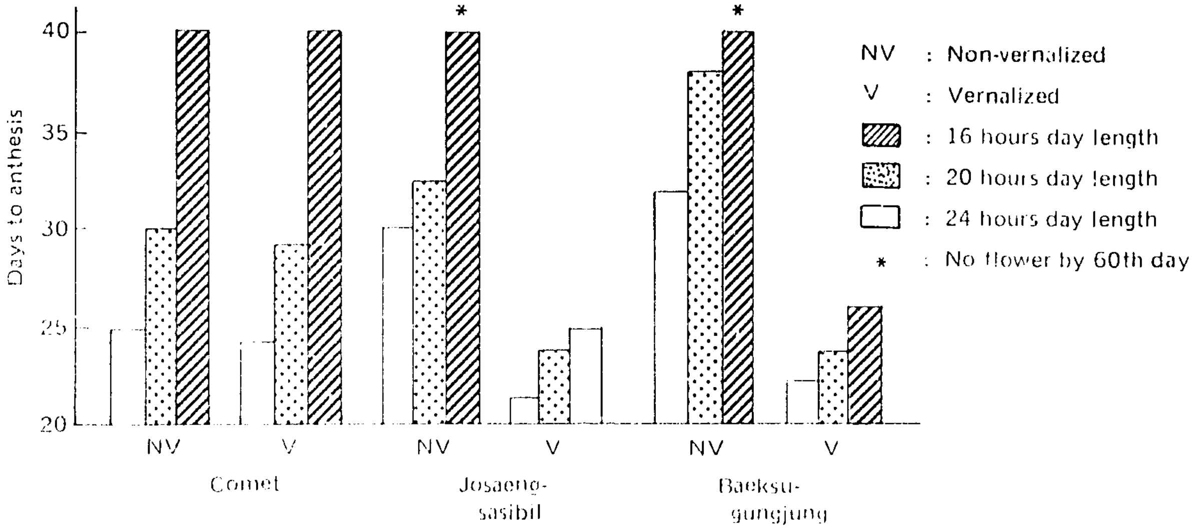

Fig. 2 Effect of day length and vernalization on the days to anthesis of radish (Yoo, 1977)[5]

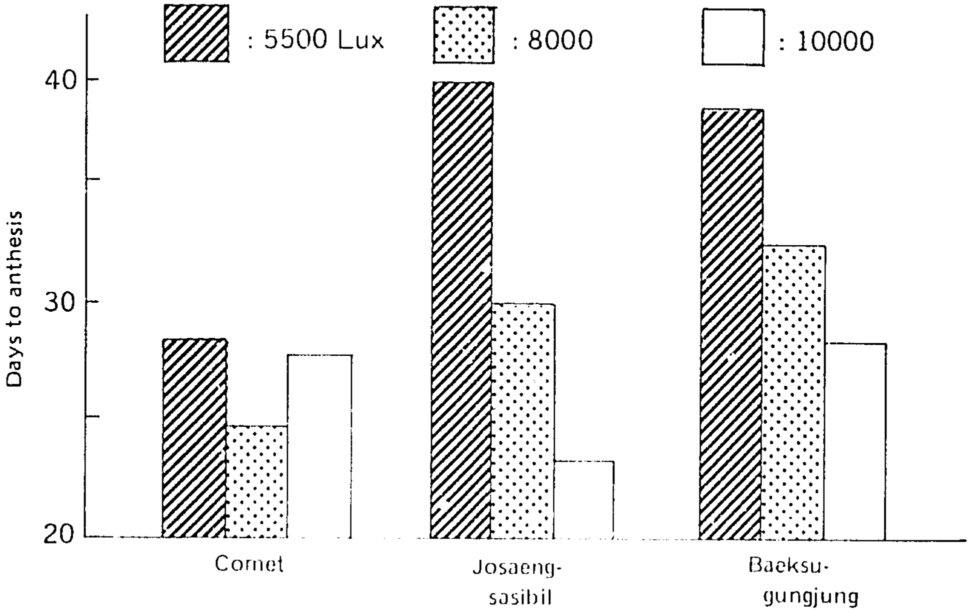

Fig. 3 Effect of light intensity on the days to anthesis of non-vernalized radish (Yoo, 1977)[5]

and especially seeds stored under room conditions, tended to bolt more readily (Table 1). This indicates that either the ambient temperature or the relative humidity in seed storage had a greater effect on bolting in older seeds. To determine the separate influence of temperature and relative humidity, seeds of the same cultivar were tested in a similar experiment. Seeds stored at two different relative humidities and at two temperatures, and also in a desiccator and under room conditions at ambient temperatures as a control, were stored for two years and then sown on July 6th. The seed moisture content at sowing varied according to the relative humidity in storage, being about 4.5% moisture in seed stored in the desiccator at 24% RH (Relative Humidity), and about 8% moisture in seeds stored at 66% RH and under room conditions (Table 2). Bolting in plants grown from seed with a higher moisture content occurred earlier than in plants grown from seed with a lower moisture content. The relative humidity in storage was more significant than temperature, but the highest incidence of early bolting was found in plants grown from seed stored at a high relative humidity but at a low temperature.

Table 1. Percentage of the bolted plants of radish as influenced by conditions and period of seed storage[z]

	Storage condition	Storage period (year)			
		0	1	2	LSD.05
1st trial	Desiccator	5.5	6.4	11.2	NS
	Room condition	5.5	30.3	40.0	5.3
2nd trial	Room condition	5.9	17.7	34.9	12.0
	Mean	5.7	18.1	28.7	

z: Cultivar: Jinju-daepyeung
Sowing: June 25
Observation: 60th day from sowing

Table 2. Moisture content and bolting rate of radish seeds as influenced by temperature and relative humidity in storage[z]

RH (%)	Temp. (°C)	Seed moisture content (%)	% bolting
24	4	4.5[y]	5.9
	25	4.2	8.4
66	4	8.0	52.3
	25	8.9	33.3
Desiccator	Room	4.7	11.2
Room	Room	7.6	40.0
LSD .05			15.0

z: Cultivar: Jinju-daepyeung
Storage: 2 years
Date of Sowing: July 6
Observation: 60th day from sowing
y: Moisture content of the seed before storage was 7.1%

To find out the limiting relative humidity in storage that could suppress bolting, seeds of the same cultivar were stored in a range of relative humidities at 4°C and 10°C for one year and planted on July 3rd. Seed moisture content increased with relative humidity in storage (Fig. 4). A linear regression was shown between the relative humidity of seed storage, seed moisture content and the incidence of early bolting (Table 3).

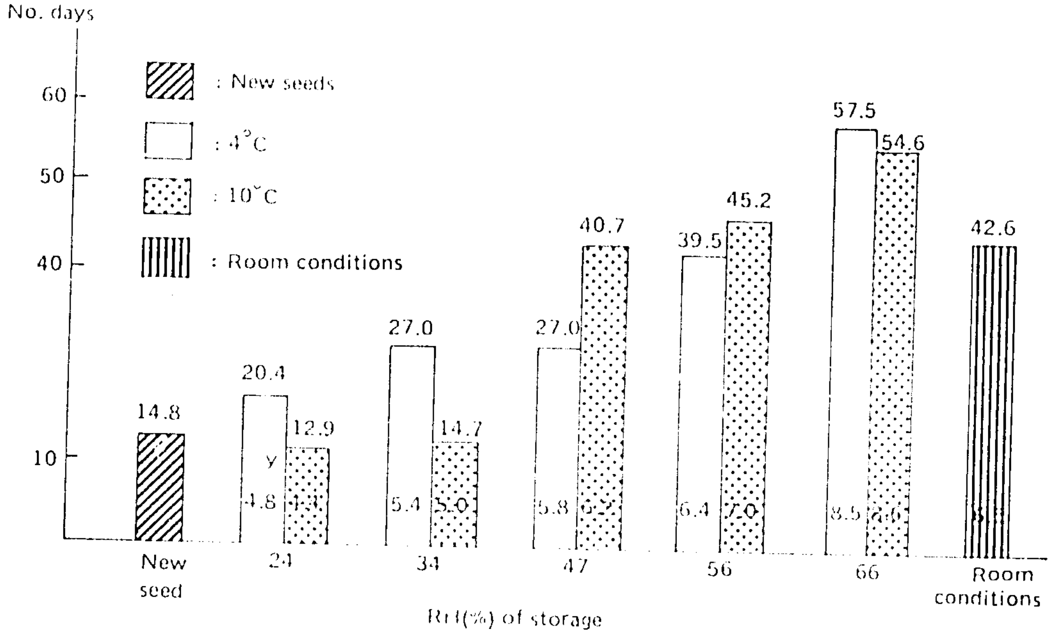

Fig. 4 Percentage of the bolted plants of radish as influenced by temperature and humidity of seed storage^{z}

z: Cultivar: Jinju-daepyeung
Storage period: 1 year
Sowing Date: July 3
Observation: 30 th day from sowing

y: Moisture content(%) of the seed after storage

Table 3 Estimated value of linear regression and its significance between storage humidity (RH), seed moisture content (SM) and bolting rate (BR) in radish^{z}

Variable		Storage temp. (°C)	$\hat{Y}$	t-value
Independent	Dependent			
RH	SM	4	2.60 + 0.078X	4.11*
		10	1.79 + 0.098X	11.81**
RH	BR	4	−2.04 + 0.80X	3.88*
		10	−15.87 + 1.09X	7.47**
SM	BR	4	−28.82 + 10.21X	10.75**
		10	−33.49 + 10.92X	5.97**

z: Cultivar: Jinju-daepyeung
Storage period: 2 years
Date of Sowing: July 3
Observation: 30th day from sowing

SOWING TIME AND BOLTING

Reports on the bolting characteristics of old radish seeds sown in August for the fall crop had concluded that seed age had little effect on the tendency of the plants to bolt. To clarify this, radish seeds stored for long periods under the various conditions of the previous experiment were planted at 10 to 15 day intervals between June 25th and August 5th. Results showed that the seeds stored for a long period and sown around July 6th had the greatest tendency to bolt, while those sown around June 25th, July 20th and August 5 showed a lower, and very similar, tendency to bolt (Table 4). Unfortunately, it is not yet clear why the bolting rate is so much affected by the time at which the seeds are sown. It may be because of the length of the annual endogenous rhythm, and/or the amount of irradiation and the temperature during growth.

Table 4 Percentage of the bolted plants of radish as influenced by sowing time[z]

Storage condition	Sowing time				
	June 25	July 6	July 20	Aug. 5	Mean
4°C, 24% RH	2.0	30.5	3.4	0.0	9.0
4°C, 66% RH	18.5	62.4	13.4	14.0	27.1
Room condition	8.1	37.4	3.9	15.5	16.2
New seeds	0.0	4.5	0.0	0.0	1.1
Mean	7.2	33.7	5.3	7.4	
LSD .05	11.4	11.9	6.6	7.0	

z: Cultivar: Jinju-daepyeung
Storage: 1 year
Observation: 45th day from sowing

OLD SEED SENSITIVITY TO TEMPERATURE AND LIGHT

Low Temperature Treatment of Old Seed

Research was carried out on the effect of vernalization on the bolting characteristics of radish plants grown from old seeds. Seeds stored one and two years in a dessicator were tested in three low temperature treatments for five days after germination. A further control group had no temperature treatment. All seeds were sown in the field on July 6th. The incidence of bolting in plants grown from nonvernalized seeds was low compared to that found when seeds had been subjected to the low temperature treatments (Table 5). The highest incidence of bolting was in plants grown from seed treated at 10°C. Suprisingly, the old seeds tested were sensitive to vernalization at 15°C, a temperature generally considered ineffective for vernalization of radish seed.

Effect of Long Day Length on Plants Grown from Old Seed

Radish plants grown from old seed stored under three conditions of relative humidity and from new seed, were potted and grown under continuous illumination of 5,500 lux to study the effect of long day length on old seed. Plants from seed stored in conditions of high humidity were more sensitive to long day length, and had a higher bolting rate (Table 6).

Table 5 Percentage of bolted plants of radish as influenced by low temperature treatment for 5 days at the emergence stage of stored seeds^z

Storage period (years)	Temp. (°C) treated					
	4	10	15	None	Mean	LSD .05
0	10.2	57.7	7.8	4.5	30.2	
1	26.7	93.1	39.4	7.1	51.9	
2	74.7	87.0	85.4	8.4	74.9	
Mean	37.2	79.3	44.2	6.7	—	11.46
LSD .05					14.1	

z: Cultivar: Jinju-daepyeung
Storage: in desiccator
Date of Sowing: July 6
Observation: 45th day after sowing

Table 6 Percentage of bolted plants, and coefficient of variation of mean days to bolting (CV), of radish grown under continuous illumination after one year seed storage^z

Conditions	% bolting at 15th day	Mean no. days to bolting	CV (%)
4°C, 24% RH	31	17.3	16.60
4°C, 66% RH	55	16.2	10.97
Room conditions	47	17.3	22.18
New seeds	16	18.1	24.40

z: Cultivar: Jinju-daepyeung
Illumination: 5,500 LUx
Temperature: 25°C

EFFECT OF SUBZERO TEMPERATURE STORAGE

A study was carried out of two radish cultivars, Jinjudaepyeung and Mujinjang, to investigate the effect on bolting of storing radish seed at subzero tempratures. Old seeds stored for two years at -10°C and 30% RH and also under room conditions, were tested. Two treatments were compared, one of seed vernalized upon emergence and the other of nonvernalized seed. Seeds were sown on July 5th, with new seed as a control. The cultivar Jinjudaepyeung had a higher bolting rate than Mujinjang in both the vernalized and nonvernalized plots. The incidence of bolting in the plants grown from seed stored at -10°C and 30% RH and not vernalized at emergence was much the same as the incidence of bolting for the new seed in both cultivars. The incidence of bolting in plants of seed vernalized at emergence was significantly higher in the plants of stored seed than in those of new seed for both cultivars. The results indicate that storage of seed in subzero temperatures does not prevent bolting in radish.

VERNALIZATION DURING SEED RIPENING

Shinohara[3] has reported on the effect of low temperature vernalization during the ripening period of radish seed. In Korea, most radishes used for seed production bloom when the temperature is below 12°C, with the result that all seed is vernalized to some extent during early development and seed-set. Han[1] conducted experiments to clarify this hypothesis.

The radish cultivar Jinju-daepyeung was grown in a plastic house where the minimum temperature was maintained above 20°C. Self-pollination on four different groups was done at ten day intervals, from March 15th until April 14th. Ten days after the final pollination, on April 24th, the four groups of plants then bearing seed were divided into seven groups and treated with night temperatures of 5, 10 and 15°C for five or ten days. One of the seven plots did not receive a low temperature treatment. Seeds of all groups were harvested on maturity and sown in the field on July 19th. The incidence of bolting was recorded on the 60th day after sowing.

The incidence of bolting was 14.8% in the control group (Fig. 5). In the low temperature treatments of 5°C and 15°C, the incidence of bolting was not significantly different to that of the control, regardless of the stage of seed development at treatment. However, in the

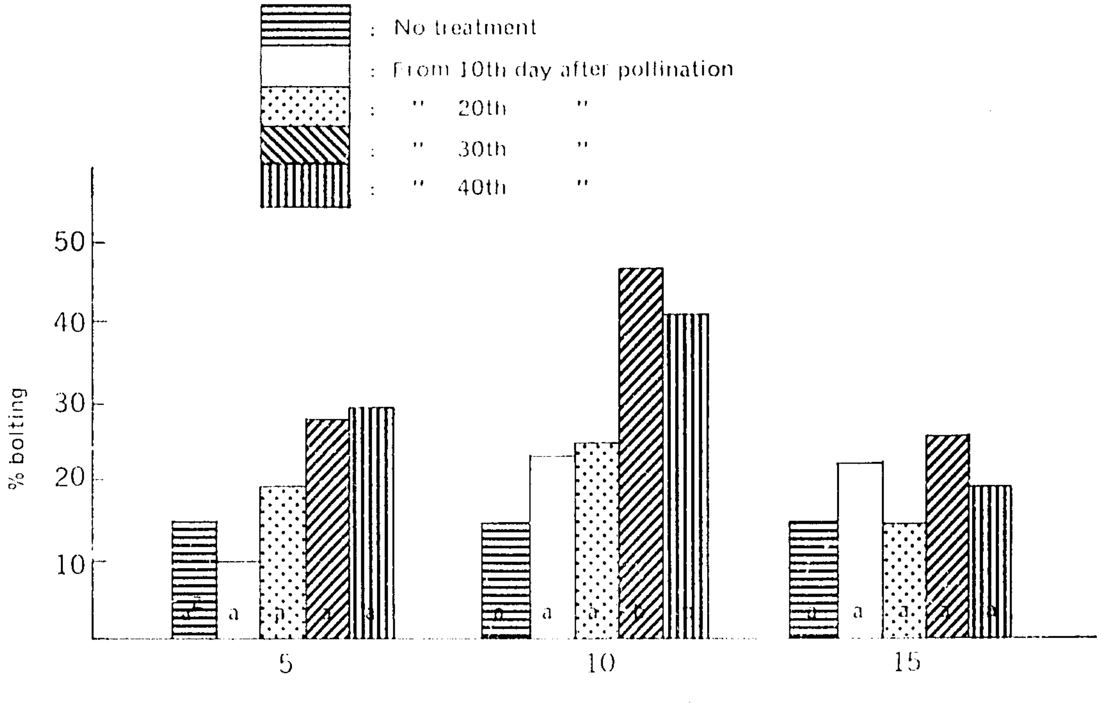

Fig. 5 Percentage of bolted plants grown from seed given low night temperature treatments for 10 days during different ripening periods. (Han, 1986)[1]
Cultivar: Jinju-daepyeung
z: The same letter with each temperature means no significant difference at 5% level of LSD

10°C treatments, the incidence of bolting was significantly higher in plants grown from seeds treated with a 10°C night temperature from the 30th and 40th day after pollination. Thus the effective vernalization temperature for radish during the development of the seed is around 10°C, rather than 5°C, and is effective only when it occurs at least 30 days after pollination.

A further experiment was carried out with two different cultivars, with the aim of confirming this result and to find out the effect of additional low temperature treatment to imbibed seeds which had been exposed to low night temperatures during their ripening period. Low night temperature treatment was given for five days to different groups, at 10, 20, 30, and 40 days after pollination. During seed germination, half the seeds from each group were given an additional low temperature treatment of 5°C for three days. The incidence of bolting was recorded at the 60th day after sowing. Results confirmed that the low temperature treatment was effective for the vernalization of developing radish seeds only when it was applied at least 30 days after pollination. The additional low temperature treatment during germination increased the incidence of bolting equally in every plot (Fig. 6). It would seem that both low temperature treatments were effective and their effect cumulative, provided that treatment took place at least 30 days after pollination.

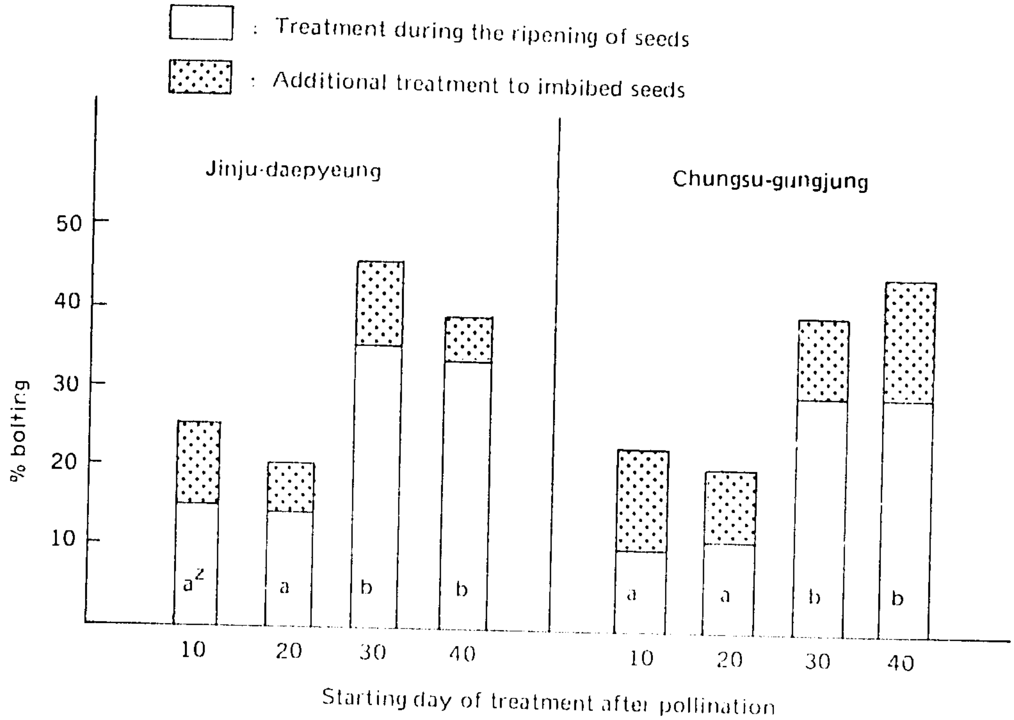

Fig. 6 Percentage of the bolted plants as influenced by low night temperature (10°C, 5 days) during different ripening stage of seeds and additional low temperature treatments (5°C, 3 days) to the imbibed seeds of 2 cultivars of radish (Han, 1986)[1]

z: The same letter in each cultivar means no significant difference at 5% level of LSD

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DISCUSSION

Q. (R.T. Opeña)
Do the three radish varieties used in your experiments on bolting share similar genetic backgrounds? They would need to be fairly diverse to make appropriate generalizations using your results.

A. All of them were fall cropping cultivars. We did also try the spring cropping varieties, which are quite different to the fall cropping varieties in the sense that they are late bolting varieties. The spring varieties also had some potential for changing their bolting property during the storage period, but the change was slight.

Q. (R.L. Villareal)
You have clearly demonstrated the role of seed moisture content on the tendency of radish to bolt. Have you conducted experiments to demonstrate the respective bolting tendencies of old and new seeds with the same moisture content?

A. We did not measure the moisture content of the new seeds, but would assume it to be about 7 – 8%.

Q. (W.N. Chang)
You mention three varieties, Comet, Josaeng-sasibil and Baeksu-gungjung. The variety Comet is not very sensitive to vernalization – it behaves the same whether given cold treatment or not – but is quite sensitive to photoperiod. Is this variety, Comet, of the same genetic background as the other two varieties?

A. The experiments on photosensitivity and vernalization sensitivity were carried out by Dr. Yoo of the University of Korea. Only the experiments on old and new seeds were carried out at the Horticultural Experiment Station. I think the Comet variety is sensitive to vernalization but not to light intensity. We did not use the Comet variety in our own research.

Q. (B. Khatikarn)
What is the receptive period for vernalization in treating radish seed to postpone bolting?

A. Usually radish seeds are given a low temperature treatment after germination, that is after imbitition, to induce flowering. However, radish is a crop which is vernalized by low temperatures at any stage of seed development.

VERTICULTURE IN VEGETABLE PRODUCTION

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ABSTRACT

Verticulture research has identified strawberry as the most successful crop for this type of cultivation. Chinese cabbage, pak choi, lettuce, spinach and rape greens are also suitable crops for verticulture, while soybean and similar large canopy crops are less suitable. For summer crops, net or mesh type pollulators were better than plastic pipe pollulators, while the insulative effect of the plastic pipe pollulator was an advantage for some winter crops. Chinese cabbage yield was better with basal application of slow release fertilizer mixed in the growth medium and hand irrigation, but for most crops fertilizer application via drip irrigation was best. A growth medium mixture (by weight) of sandy loam, rice hull and vermiculite in the ratio 10:1:2 was optimal for growth.

(Chinese Abstract) 摘　要

草莓是立體栽培最成功的作物。小白菜、白菜、萵苣、菠菜及油菜也適合立體栽培，然而毛豆及其他冠蓋較大作物較不適合。夏季生產以網狀的栽培筒(pollulator)較塑膠栽培筒為優，由於隔熱效應塑膠栽培筒較有利於一些冬季作物。白菜以緩效性肥料為基肥混合於培養土與澆灌方法生長良好，大多數作物仍以營養液滴灌最好。培養土採用砂壤土、稻殼及蛭石以10：1：2的重量比最適合作物生長

(Japanese Abstract) 摘　要

夏作物に対しては網又は網目の栽培筒がプラスチック管の栽培筒より勝れており、プラスチック管により隔離されることは冬作物の或種のものには都合が良い。緩効性肥料を培養土と混ぜて基部に施肥するとハクサイの収量は上がったが、その他の多くの作物で滴下法による施肥が良かった。

一番生育の良い培養土は砂壌土10：モミガラ1：バーミュ キライト2(重量比)である。

(Korean Abstract) 적　요

입체재배에 가장 성공적인 작물은 딸기라는 것이 연구에 의하여 입증되었다. 작은 배추, 배추, 상치, 시금치 및 유채도 입체재배에 적합한 작물이다. 그러나 대두 및 이와 유사한 작물 (large canopy crops) 은 적합하지 않다. 망으로 된 원통에서 재배하는 하계작물은 플라스틱 원통에서 재배하는 것 보다 더욱 양호 하였으나, 플라스틱 원통이 지니는 격열효과는 몇종의 동계작물에 유익하였다. 배추는 혼합배양토에의 기초비료와 hand irrigation 이 양호하였으나 대부분의 다른 작물은 시비와 drip irrigation 이 가장좋았다. 혼합배양토는 사질양토, 동겨 및 질석을 10 : 1 : 2 의 중량비율로 섞은 것이었다.

VERTICULTURE IN VEGETABLE PRODUCTION

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INTRODUCTION

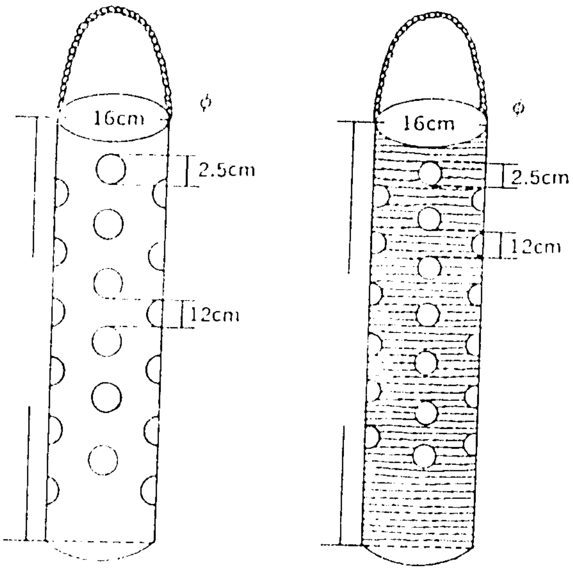
A feasibility study on verticulture, conducted by the Battle Pacific Northwest Laboratories and the Department of Soil Science, National Chung Hsing University, demonstrated its potential for vegetable cultivation on vertical or sloping surfaces provided proper light, water and nutrients are supplied. The original pollulator system used in verticulture, however was expensive, due to the high initial cost of vermiculite used in the growth media and the high labor requirements. The improvement of verticulture techniques by modifying the type of growth medium, structure of the pollulator, the nutrient supply system and patterns of crop management, may develop an economical verticulture system which could be used by individual families and thus extend the use of Taiwan's limited land resources.

The objective of this study was to investigate verticulture in pollulators, and the yield of various crops as affected by

1. The seasonal temperature variation of the medium when different pollulators are used,
2. The effect of various growth medium,
3. The effect of the nutrient supply system,
4. The effect of the irrigation system,
5. The nutrient status of crops grown by verticulture techniques.

MATERIALS AND METHODS

Vertical pollulators were hung in an open field. The pollulators, made of either PVC pipe, steel mesh or PE nylon net, were cylindrical, 90 cm long and 16 cm diameter. Each had four lines of planting holes spaced 12 cm apart (Figure 1).



PVC pollulator Steel mesh pollulator

Fig. 1 Two types of pollulator used in the experiments

Growth media were mixed by weight as follows:

Media I 10: 1: 1: 0.5
soil, bagasse, rice hull and vermiculite

Media II 10: 1: 1
soil, bagasse, rice hull

Media III 10: 1
soil: rice hull

Media IV 10: 1: 2
soil: rice hull: vermiculite

Bagasse was supplied by the Taichung Sugar Plant, and the soil was sandy loam.

Seven vegetable crops, Chinese cabbage, pak choi, soybean, lettuce, spinach, rape greens and strawberry, were tested. Planting space was 24 cm apart for lettuce and soybean, and 12 cm apart for the other crops.

Two irrigation and nutrient supply systems were tested, an automatic drip irrigation system supplying water one to three times per day, with the nutrient solution added twice a week (Table 1), and a hand irrigated system with slow release fertilizer mixed into the growth medium prior to planting (Table 2).

Table 1 Formula of nutrient solution for drip drip irrigation

Macronutrients		Micronutrients	
Component	Concentration, M	Component	Concentration, ppm
KH_2PO_4	0.01	Mn	0.25
KNO_3	0.005	B	0.25
$Ca(NO_3)_2$	0.005	Zn	0.25
$MgSO_4$	0.002	Cu	0.02
		Mo	0.02
		Fe	0.5

Table 2 Fertilizer used for hand irrigation system

	Amount added g/pollulator	Composition, %			
		N	P_2O_5	K_2O	MgO
'Magic' fertilizer*	33	7	40	6	12
Compound fertilizer	34	11	5.5	22	-
Superphosphate	23		18		
Sulfur-coated urea	23.5	24			

* A commercial slow-release fertilizer for flowers

Plant nutrient status was monitored by sampling at different growth stages. The N, P. and K content were determined by Kjeldahl distillation, spectrophotometer and flame photometer, respectively. Available P and exchangeable K in the growth media were determined by Bray II and the 1N NH_4 OAc extraction methods, respectively.

RESULTS AND DISCUSSION

Temperature Variation in the Pollulator

Tables 3 and 4 indicate seasonal temperature variations in the pollulator media, and show that temperatures reached as high as 35°C at 2-4 p.m. in summer, 5°C above ambient air temperatures

Table 3 Temperature variation in growth medium during summer season

Pollulator	Position	Temperature °C		
		10 a.m.	2 p.m.	4 p.m.
PVC	upper	29.6	35.0	35.7
	lower	28.8	34.0	34.6
Steel mesh	upper	28.9	31.2	31.1
	lower	27.5	29.2	28.6
Nylon net	upper	29.0	30.2	30.2
	lower	27.9	30.1	29.9
Air temperature		29.5	32.6	30.5
Soil temperature		26.8	30.3	30.1
Water temperature		26.5	34.0	31.9

(Table 3). Pollulator media winter temperatures were also higher than ambient temperatures, though to a lesser extent (Table 4).

Plant growth, root development and evapotranspiration rate are affected by growth medium temperature. Particularly in the PVC pollulators, heat accumulated and could reach 36°C in summer; however, the insulative effect of the PVC material could be an advantage in winter. Thus in choosing a suitable pollulator, seasonal temperatures and optimal growth media temperatures for the crop need be considered.

Table 4 Temperature variation in growth medium over the winter season

Pollulator	Position	Temperature °C			
		8 a.m.	10 a.m.	2 p.m.	4 p.m.
PVC	upper	14.0	17.8	25.3	22.7
	lower	15.2	17.2	25.8	25.3
Steel mesh	upper	13.7	16.8	21.4	20.5
	lower	13.7	15.7	19.7	19.1
Nylon net	upper	13.1	17.2	21.2	19.8
	lower	13.8	15.0	19.5	19.1
Air temperature		13.5	19.3	21.4	19.1
Soil temperature		16.5	18.7	19.0	18.1
Water temperature		15.7	17.0	20.3	19.1

Physical and Chemical Properties of Media

Under drip irrigation and fertilizer applications, nutrients tended to accumulate in the upper part of the pollulator. With hand irrigation and basal application of slow release fertilizers in the media on the other hand, nutrient distribution was more even (Table 5). However, nutrient could be supplied more efficiently by regulated drip irrigation applications than by the basal application of slow release fertilizer (Table 6). Drip irrigation applications allowed the timing and quantity of fertilizer applications to be regulated according to crop requirements, and minimized loses due to leaching and volatilization.

Table 6 shows that evaporation was higher

Table 5 Nutrient distribution in growth medium

	Position	NH_4^+-N ppm	NO_3^--N ppm	P ppm	K ppm
Drip irrigation	lower	42.4	262	141.7	37.2
	upper	27.1	125	70.0	28.4
Hand irrigation	upper	246.0	543	138.0	30.0
	lower	278.0	566	168.3	47.3

Table 6 Nutrient consumption and water evaporation rates

	Nutrient consumption g/pollulator			Water evaporation Kg/day/pollulator		
	N	P_2O_5	K_2O	PVC	Steel mesh	Nylon net
Drip irrigation	9.97	2.60	10.39	0.86	1.39	1.09
Hand irrigation	13.56	20.14	13.2			

from net and mesh type pollulators than from the PVC pipe pollulators. The PVC pollulator provided an area of only 500 cm^2 for evaporation and aeration, while in net or mesh type pollulators a total surface area of 5000 cm^2 was exposed to the air.

Preliminary experiments showed that Medium IV (10:1:2 soil, rice hull and vermiculite by weight) was the best for all crops, regardless of the type of irrigation or fertilizer application used.) The mixture was slightly acid, with a relatively low bulk density. Rice hull improves aeration and water infiltration of the medium, while better nutrient absorption and water holding capacity are contributed by the vermiculite. Vermiculite also decreased the bulk density of the medium, thus reducing its compaction in the pollulator and minimizing resistance to root development. Root development was generally better in Medium IV. Media containing bagasse were not succeesful, as the bagasse tended to decompose and ferment. Thus, only Media III and IV were used for final growth and yield tests.

Plant Growth and Yield

Plant growth and yield test results are shown in Tables 7-17. Overall, plant growth was better in the upper part of the pollulator. One possible explaination is that the bulk densities of the media were lower in the upper part, thus benefiting root development. The shading effect may also have limited the growth of plants in the lower pollulator. Where drip irrigation fertilizer applications were used, the accumulation of nutrients in the upper pollulator also favored these plants (Table 5).

Since the PVC pollulator accumulated heat, raising media temperatures 5°C 7°C above ambient temperatures in summer, this may have inhibited root development due to high evaporation and water stress. On the other hand, the insulation effect accelerated root growth in winter, when media temperatures were maintained at 3°C 4°C above ambient temperatures. The net or mesh type pollulators allow dissipation of heat and thus gave better yields in summer than the PVC pollulator, but worse yields in winter.

Individual Crop Results

Soybean

Plant height and weight were higher in the upper part of the pollulator than in the lower, regardless of the irrigation system used (Table 7), but this difference was less significant with net or mesh type pollulators. Plant dry weight (Table 7), pod number, pod weight (Table 8) and seed dry weight (Table 9) in the upper part were 4-8 times higher than those in the lower part. This indicates that large canopy crops are unsuitable for verticulture. Soybean plant growth was significantly higher under the drip

Table 7 Growth of soybean plants under verticulture

Pollulator	Position	Drip irrigation			Hand irrigation		
		g/pollulator	g/plant	Plant height (cm)	g/pollulator	g/plant	Plant height (cm)
PVC	upper	327.5	40.9	79.2	123.3	15.4	47.7
	middle	186.3	15.5	68.1	70.5	5.9	47.1
	lower	42.5	5.3	54.6	17.3	2.2	38.5
	Total	556.3	Ave. 20.6	Ave. 67.3	Total 211.1	Ave. 7.8	Ave. 44.4
Steel mesh	upper	523.3	65.4	69.5	138.0	17.3	48.4
	middle	167.0	13.9	63.4	97.3	8.2	53.9
	lower	51.3	6.4	60.9	73.3	9.2	58.4
	Total	741.6	Ave. 28.6	Ave. 64.6	Total 208.6	Ave. 11.6	Ave. 53.6
Nylon net	upper	423.8	53.0	67.5	83.5	10.5	52.1
	middle	219.5	20.0	46.7	88.0	7.4	52.1
	lower	67.0	8.0	63.5	56.5	7.1	55.6
	Total	710.3	Ave. 23.7	Ave. 59.2	Total 228.0	Ave. 8.3	Ave. 53.3

Table 8 Pod number and pod weight of soybean plants under verticulture

Pollulator	Position	Drip irrigation					
		Pod/pollulator		Pod/plant		Pod weight	
		full	empty	full	empty	g/pollulator	g/plant
PVC	upper	316	63	40	8	102.3	12.8
	middle	203	59	17	5	87.1	7.3
	lower	49	6	6	1	21.1	2.7
	Total	568	128	Ave. 21	4.7	Total 210.5	Ave. 7.6
Steel mesh	upper	388	104	49	13	167.1	20.9
	middle	145	18	12	2	62.4	5.2
	lower	87	4	11	0	25.6	3.2
	Total	620	126	Ave. 24	5	Total 255.1	Ave. 9.8
Nylon net	upper	316	40	40	5	135.8	17.0
	middle	162	10	14	1		
	lower	71	5	9	0	30.6	3.9
	Total	549	55	Ave. 21	2	Total 240.1	Ave. 8.7

Table 8 Pod number and pod weight of soybean plants under verticulture (cont.)

Pollulator	Position		Hand irrigation								
			Pod/pollulator			Pod/plant			Pod weight		
			full	empty		full	empty		g/pollulator		g/plant
PVC	upper		210	36		26	5		90.1		11.3
	middle		121	12		10	1		52.0		4.3
	lower		35	4		5	0		15.0		1.9
		Total	386	52	Ave.	13.7	2	Total	157.1	Ave.	5.8
Steel mesh	upper		196	20		25	3		84.0		10.5
	middle		149	9		13	1		64.1		5.4
	lower		121	6		15	1		52.0		6.5
		Total	466	35	Ave.	17.7	1.7	Total	200.1	Ave.	7.5
Nylon net	upper		143	46		18	6		61.5		7.7
	middle		148	30		12	3		63.6		5.3
	lower		97	5		12	1		41.4		5.2
		Total	388	81	Ave.	14	3.3	Total	166.5	Ave.	6.1

Table 9 Soybean seed dry weight

Pollulator	Position		Drip irrigation			Hand irrigation			
			g/pollulator		g/plant		g/pollulator		g/plant
PVC	upper		80.5		10.5		66.9		8.4
	middle		48.4		4.1		38.9		3.3
	lower		15.0		1.9		8.8		1.1
		Total	143.9	Ave.	5.4	Total	114.6	Ave.	4.2
Steel mesh	upper		119.8		15.0		66.0		8.3
	middle		46.8		3.9		50.1		4.2
	lower		16.8		2.1		43.2		5.4
		Total	183.4	Ave.	7.0	Total	159.2	Ave.	6.0
Nylon net	upper		79.5		9.9		38.8		4.9
	middle		56.6		4.8		33.9		2.8
	lower		21.3		2.7		28.2		3.5
		Total	157.4	Ave.	5.8	Total	100.9	Ave.	3.7

irrigation system (Table 7), indicating that the nutrients supplied were used more efficiently.

Chinese cabbage

Plant height and yield were higher in the upper part of the pollulator under drip irrigation, while there was no such difference with the hand irrigation and basal fertilizer application system (Table 10). Average plant height under hand irrigation was about 3 cm higher, and yield was thus also higher. This was at least partly because the harvesting rate was 50% higher under hand irrigation and the basal fertilizer application system. Generally, the Chinese cabbage yield when net and mesh type pollulators were used was higher than with the PVC pollulator. The highest yield of Chinese cabbage on one pollulator was 1400 g.

Table 10 Plant height and yield of Chinese cabbage under verticulture

		Drip irrigation				Hand irrigation			
Pollulator	Position	g/pollulator	g/plant	Plant height (cm)	Harvesting rate (%)	g/pollulator	g/plant	Plant height (cm)	Harvesting rate (%)
PVC	upper	415.8	55.4	17.7		382.8	52.8	15.5	
	middle	235.5	26.9	11.6	59.8	615.5	58.6	15.5	82.5
	lower	—	—	7.5		316.3	46.9	15.0	
		Total 651.3	Ave. 27.4	12.3		Total 1314.6	Ave. 52.8	15.3	
Steel mesh	upper	370.8	47.8	15.3		290.0	58.0	12.4	
	middle	354.5	39.4	14.0	67.0	676.8	62.9	17.9	79.5
	lower	68.3	27.3	9.9		325.0	50.0	16.6	
		Total 793.6	Ave. 38.2	13.1		Total 1291.8	Ave. 57.0	15.6	
Nylon net	upper	487.5	62.9	14.9		372.0	59.5	14.1	
	middle	320.8	37.8	12.1	76.6	667.8	59.4	16.3	85.7
	lower	148.8	29.8	11.2		358.8	55.2	16.5	
		Total 957.1	Ave. 43.5	12.7		Total 1398.6	Ave. 58.0	15.6	

Pak Choi

This crop was planted after the harvest of the Chinese cabbage. Like the Chinese cabbage, plants in the upper part of the pollulator grew taller (Table 11), and yield was higher under the hand irrigation and basal fertilizer application system. The highest yield of pak choi from one pollulator was 960 g.

Lettuce

Plant height showed no significant difference between irrigation systems and pollulator types (Table 12). The average height of 23 cm was taller than in conventional field cultivation, because of the incomplete heading of lettuces grown in pollulators. Under drip irrigation, lettuce yield was higher in the upper part of the

Table 11 Yield and plant height of pak choi under verticulture

		Drip irrigation				Hand irrigation			
Pollulator	Position	g/pollulator	g/plant	Plant height (cm)	Harvesting rate (%)	g/pollulator	g/plant	Plant height (cm)	Harvesting rate (%)
PVC	upper	302.5	18.9	21.0	100	455	28.4	22.0	100
	middle	112.5	6.8	13.7	68.8	380	16.9	16.0	93.8
	lower	25.0	3.4	9.5	50.0	125	10.4	16.9	75.0
		Total 440.0	Ave. 9.7	14.7	72.9	Total 960	Ave. 18.6	18.3	89.6
Steel mesh	upper	300.0	18.8	22.0	100	300	20.0	19.3	93.8
	middle	220.0	11.3	18.0	81.3	240	12.3	15.2	81.3
	lower	85.0	7.9	13.5	75.0	105	7.5	14.4	87.5
		Total 605.0	Ave. 12.7	18.1	85.4	Total 645	Ave. 13.3	16.3	87.5
Nylon net	upper	395.0	24.7	20.6	100	387.5	25.0	20.4	96.9
	middle	312.5	13.0	18.9	100	350.0	16.7	20.5	87.5
	lower	112.5	8.3	[illegible]	84.4	175.0	13.0	15.8	84.4
		Total 820.0	Ave. 15.3	18.1	94.8	Total 912.5	Ave. 18.2	18.9	89.6

Table 12 Yield and plant height of lettuce under verticulture

		Drip irrigation				Hand irrigation			
Pollulator	Position	g/pollulator	g/plant	Plant height (cm)	Harvesting rate (%)	g/pollulator	g/plant	Plant height (cm)	Harvesting rate (%)
PVC	upper	1015	122.4	27.7		564	70.5	22.0	
	lower	149	41.4	13.5	75.0	425	56.8	24.3	97.0
		Total 1164	Ave. 81.9	20.1		Total 989	Ave. 63.6	23.2	
Steel mesh	upper	957	141.9	27.9		489	61.2	18.0	
	lower	283	46.8	17.4	77.0	458	65.4	26.4	94.0
		Total 1240	Ave. 93.8	22.6		Total 947	Ave. 63.3	22.2	
Nylon net	upper	840	106	26.6		479	64.0	25.2	
	lower	276	45.9	18.2	88.0	383	54.7	28.1	91.0
		Total 1116	Ave. 75.5	22.4		Total 862	Ave. 59.4	26.6	

pollulators, but there was no significant difference between the upper and lower part of the pollulator with hand irrigation and basal fertilizer application. Drip irrigation gave a higher total yield (1100 to 1240 g per pollulator) than hand irrigation (average 940 g per pollulator). Although the harvesting rate was lower under the drip irrigation system (Table 12), average plant weight (84 g) was higher than under hand irrigation (62 g per plant). The highest lettuce yield and average plant weight were obtained using steel mesh pollulators. Using hand irrigation, Medium IV gave better growth than Medium III (Table 13). The better performance of lettuce in this medium can be attributed to the high water and nutrient holding capacity of the vermiculite in this medium. However, any economic benefit may be eliminated by the high initial cost of the vermiculite.

Table 13 Lettuce yield grown in different growth media under verticulture

		Media III			Media IV		
Pollulator	Position	g/pollulator	g/plant	Harvesting rate (%)	g/pollulator	g/plant	Harvesting rate (%)
PVC	upper	250	62.5	50	620	77.5	100
	lower	30	4.3	87.5	124	22.5	68.8
		Total 280	Ave. 33.4	68.7	Total 744	Ave. 50.0	84.4
Steel mesh	upper	435	54.4	100	605	75.6	100
	lower	217	27.1	100	372	46.6	100
		Total 652	Ave. 40.7	100	Total 977	Ave. 61.1	100
Nylon net	upper	413	82.5	62.5	562	70.3	100
	lower	210	26.3	50	400	50	100
		Total 623	Ave. 54.4	56.3	Total 962	Ave. 60.2	100

Rape greens

Yield under drip irrigation, (average 933 g per pollulator) was marginally higher than under the hand irrigation system, (912 g) but the difference was not statistically significant (Table 14). The highest yields were obtained on a PVC pollulator with drip irrigation, and on a steel mesh pollulator with hand irrigation. Under drip irrigation, yields were higher in the under part of the pollulator, mainly because of the uneven distribution of nutrients and the shading effect. There was no significant difference between upper and lower pollulator under the hand irrigation and basal fertilizer application system.

Tale 14 Yield of rape greens under verticulture

Pollulator	Position		Drip irrigation				Hand irrigation		
			g/pollulator		g/plant		g/pollulator		g/plant
PVC	upper		605		75.6		368		46.0
	middle		420		35.0		283		23.3
	lower		145		18.1		300		37.5
		Total	1170	Ave.	42.9	Total	951	Ave.	35.5
Steel mesh	upper		473		59.1		200		25.0
	middle		280		23.3		420		35.0
	lower		145		18.1		398		49.8
		Total	898	Ave.	33.5	Total	1018	Ave.	36.6
Nylon net	upper		393		49.1		660		7.5
	middle		373		31.1		380		31.7
	lower		145		18.1		323		40.4
		Total	911	Ave.	32.8	Total	766	Ave.	26.5

Spinach

Yields under hand irrigation with basal nitrogen application were about 17% higher than under drip irrigation (Table 15). The highest yield per pollulator and individual plant weight were obtained on nylon net type pollulators. Both spinach and rape greens are small-leaf vegetables, and yield and plant weight for both crops were higher in the upper part of the pollulator under drip irrigation. There was no significant difference under hand irrigation and the basal application of nutrients.

Table 15 Yield of spinach under verticulture

Pollulator	Position		Drip irrigation				Hand irrigation		
			g/pollulator		g/plant		g/pollulator		g/plant
PVC	upper		188		23.5		203		25.4
	middle		158		13.2		255		21.3
	lower		113		14.1		132		16.5
		Total	459	Ave.	16.9	Total	590	Ave.	21.1
Steel mesh	upper		180		22.5		155		19.4
	middle		175		14.6		235		19.6
	lower		105		13.1		198		24.8
		Total	460	Ave.	16.7	Total	588	Ave.	21.3
Nylon net	upper		235		29.4		170		21.3
	middle		215		17.9		270		22.5
	lower		115		14.4		170		21.3
		Total	565	Ave.	20.6	Total	610	Ave.	21.7

Strawberry

Of all the crops tested, this was most suited to verticulture and gave the best economic return (Tables 16 and 17). The Miyazaki variety gave higher yield than the Aliso, the difference between them being more pronounced under hand irrigation. When both varieties were grown on PVC and steel mesh pollulators with drip irrigation, the Aliso gave a higher fruit number and thus a better yield than the Miyazaki. The highest yields of both varieties were obtained on PVC pollulators under drip irrigation, and on PE net pollulators under hand irrigation. Strawberry yields on vertical pollulators was ten times higher per unit land area than conventional field cultivation, and economic returns were twice as high in spite of the higher costs. The primary reason for the increased yields is because the nutrient and water supply can be managed more efficiently under verticulture. A lower rate of fruit decay and a longer harvest period provide additional advantages.

Plant nutrient analysis

The results of plant analysis, shown in Tables 18-20, indicated that plant growth was closely related to plant nutrient content, which in turn was affected by the type of irrigation system and pollulator used.

In one month old soybean plants, the N, P_2O_5 and K_2O content were all higher in plants grown under hand irrigation than in those given drip irrigation; the P_2O_5 levels were 2-3 times higher (Table 18). Since under hand irrigation, the total amount of fertilizer was added to the growth medium before planting, while only a small fraction of the total plant nutrients were added at each application under drip irrigation, we might expect a relatively high nutrient content in the plant at the early growth stages under a hand irrigation system.

Table 16 Yield of strawberry (Aliso variety)

		Drip irrigation			Hand irrigation		
Pollulator	Position	g/pollulator	No. fruit/ pollulator	g/fruit	g/pollulator	No. fruit/ pollulator	g/fruit
PVC	upper	920	96	9.6	553	45	12.3
	lower	675	66	10.2	390	28	13.9
	Ave.	798	81	9.9	472	36	13.1
	Total	1595	162		943	73	
Steel mesh	upper	654	63	10.4	795	62	12.8
	lower	530 530	48	11.1	250	46	5.4
	Ave.	592	56	10.6	523	49	10.7
	Total	1184	111		1045	108	
Nylon net	upper	717	60	12.0	636	49	13.0
	lower	484	34	14.3	619	54	11.5
	Ave.	600	47	12.8	628	52	12.1
	Total	1201	94		1255	103	

Table 17 Yield of strawberry (Miyazaki variety)

Pollulator	Position	Drip irrigation			Hand irrigation		
		g/pollulator	No. fruit/ pollulator	g/fruit	g/pollulator	No. fruit/ pollulator	g/fruit
PVC	upper	1035	107	9.7	1273	139	9.2
	lower	601	64	9.4	420	34	12.4
	Ave.	818	86	9.5	847	87	9.7
	Total	1636	171		1693	173	
Steel mesh	upper	914	104	8.8	932	92	10.1
	lower	698	84	8.3	696	80	8.7
	Ave.	806	94	8.6	814	86	9.5
	Total	1612	188		1628	172	
Nylon net	upper	851	106	8.0	1112	130	8.6
	lower	668	84	8.0	894	114	7.8
	Ave.	760	95	8.0	1003	122	8.2
	Total	1519	190		2006	244	

Table 18 Nutrient content of one-month old soybean plants

Pollulator	Position	Drip irrigation			Hand irrigation		
		N, %	P_2O_5, %	K_2O, %	N, %	P_2O_5, %	K_2O, %
PVC	upper	3.08	0.33	0.77	4.19	0.81	1.43
	middle	2.87	0.45	1.27	4.15	1.05	1.23
	lower	3.24	0.30	0.76	3.99	1.27	0.94
	Ave.	3.06	0.36	0.93	4.11	1.04	1.20
Steel mesh	upper	3.57	0.44	1.01	3.04	0.69	1.72
	middle	3.29	0.40	0.89	3.77	0.96	1.52
	lower	3.22	0.32	1.93	3.39	0.69	1.75
	Ave.	3.36	0.39	1.61	3.40	0.78	1.66
Nylon net	upper	3.55	0.53	1.82	3.72	0.82	2.73
	middle	3.75	0.32	0.79	4.42	1.40	1.33
	lower	3.42	0.27	1.44	3.57	0.86	1.17
	Ave.	3.57	0.37	1.35	3.94	1.03	1.74

Table 19 Nutrient content of harvested pak choi

Pollulator	Position	Drip irrigation			Hand irrigation		
		N, %	P_2O_5, %	K_2O, %	N, %	P_2O_5, %	K_2O, %
PVC	upper	3.35	6.72	5.54	2.24	7.84	5.48
	middle	2.61	5.93	6.44	1.95	7.09	5.36
	lower	2.54	6.36	6.99	2.06	7.52	6.56
	Ave.	2.83	6.44	6.32	2.08	7.48	5.80
Steel mesh	upper	2.13	5.41	5.78	2.13	10.78	5.12
	middle	2.09	6.29	6.56	2.06	9.84	5.54
	lower	2.07	5.83	5.90	2.07	8.05	5.18
	Ave.	2.10	6.57	6.08	2.08	9.56	5.28
Nylon net	upper	1.98	6.97	6.56	2.14	8.26	6.75
	middle	2.74	7.03	7.10	2.15	9.90	7.57
	lower	2.15	7.25	7.59	2.26	7.77	6.32
	Ave.	2.29	7.42	7.08	2.18	8.64	6.88

Table 20 Nutrient content of harvested lettuce

Pollulator	Position	Drip irrigation			Hand irrigation		
		N, %	P_2O_5, %	K_2O, %	N, %	P_2O_5, %	K_2O, %
PVC	upper	1.59	5.92	6.44	1.49	5.93	.686
	lower	1.73	6.80	6.56	2.18	8.16	7.22
	Ave.	1.66	6.36	6.50	1.84	7.05	7.04
Steel mesh	upper	1.46	5.27	6.98	1.43	5.92	5.12
	lower	1.63	6.25	7.04	1.86	6.46	5.60
	Ave.	1.55	5.76	7.01	1.65	6.20	5.36
Nylon net	upper	1.25	4.77	6.50	1.73	6.14	5.30
	lower	1.96	5.34	7.65	2.01	6.86	5.18
	Ave.	1.61	5.06	7.08	1.87	6.50	5.24

Conversely, the N and K_2O content of harvested pak choi were higher under drip irrigation than under hand irrigation (Table 19), even though cabbage yields were higher under hand irrigation (Table 10). The lower nutrient content of plants which gave a higher crop yield may have been due to the tissue dilution effect. The same effect was seen with lettuce, which had a higher yield and a lower N and P_2O_5 content under drip irrigation (Table 20).

CONCLUSION

Crops with a short growth period of 2-3 months, such as Chinese cabbage, pak choi, lettuce, and rape greens, had relatively higher yields per unit area when grown in pollulators than under conventional cultivation methods. Soybeans, although the crop grew well in pollulators, are a less economic crop for verticulture because of their large canopy and long growth period. Strawberry was the most suitable of all crops tested.

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DISCUSSION

Q. (H. Imai)
When tomatoes are grown under verticulture, what support is needed for the plants?

A. Support is a problem for bigger and heavier plants such as tomato, and the structures needed can be very costly. They tend to need support from stakes, so that there is no space advantage to be gained from using verticulture, as lower plants are retarded.

Q. (H. Imai)
Is the media used repeatedly? Do you get problems of pathogens in the media with repeated use?

A. We have been using the same media two or three times, and then removing the root material and using the media yet again Certainly no problems have developed over two or three years. We had problems only when we added bagasse to the medium.

Q. (C.Y. Yang)
Have you carried out a crop planting density study, to determine how many pollulators can be used on a given area for each crop type?

A. We have determined for strawberry that on the basis of actual planted area, the yield using pollulators is double that from a conventional cultivation system. However, if allowance is made for the total area used in the conventional system, including the space between rows and for access, then the yield obtained can be ten times higher from a pollulator system.

Vegetables grown by verticulture

Rape greens

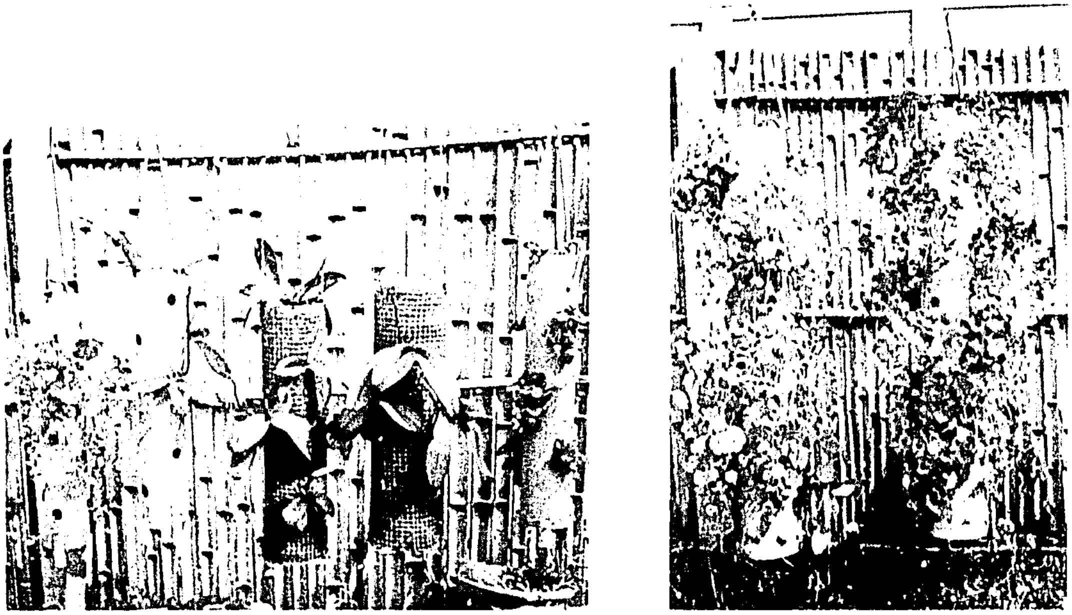
Tomato

Lettuce

Pak choi

Strawberry and ornamental flowers grown by verticulture

Strawberry



Ornamental Plants

Varietal Improvement

BREEDING FOR STRESS TOLERANCE UNDER TROPICAL CONDITIONS IN TOMATO AND HEADING CHINESE CABBAGE

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ABSTRACT

Past research on adapting tomato and Chinese cabbage to hot, humid tropics is reviewed. Particular emphasis is given to defining the constraints of growing these crops in the humid tropics, and the genetic and physiological aspects underlying the major components for tropical adaptation. Finally, breeding strategies to develop improved tropical cultivars are discussed.

(Chinese Abstract) 摘　　要

回顧番茄及結球白菜在熱帶高温多濕環境的適應性研究，並特別著重於界定這些作物在高濕之熱帶的生長限制，及對熱帶適應性在遺傳、生理上的基本要素。最後論及發展改進熱帶栽培品種的育種策略

(Japanese Abstract) 摘　　要

トマトとハクサイを高温多湿の熱帯に適応させる既往の研究を概説した。特に強調してある点は多湿の熱帯において生育を抑制する要因を明確にすること，熱帯への適応のための主な要因についての遺傳的又は生理的観點である。最後に，熱帯に向いた改良品種をいかにして開発するかについて論じている

(Korean Abstract) 적　　요

토마토 및 배추의 고온다습한 열대기후에의 적응성에 관한 과거연구가 검토되었다. 이 연구에서 특별히 고정된 점은 다습한 열대기후에서 이들 작물의 성장에 주는 제한성과 기본적으로 열대기후에 적응할수 있는 유전적 및 생리적 현상이다. 끝으로 열대품종을 개발할 수 있는 육종전략에 관하여 논하였다.

BREEDING FOR STRESS TOLERANCE UNDER TROPICAL CONDITIONS IN TOMATO AND HEADING CHINESE CABBAGE

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INTRODUCTION

The alleviation of nutritional problems in the world's developing regions has often called for the use of the classical 'vegetable' solution, because vegetables offer a cheap and rich source of plant proteins, vitamins, and minerals[19,33,74]. Moreover, many vegetable species are good cash crops, providing a source of livelihood for the world's farming communities.

On the other hand, the expanded production and consumption of many vegetables in the hot, humid tropics are constrained by a variety of environmental, economic, and sociological factors. Vegetable consumption in the tropics is thus often lower than in the more developed regions[74]. A concerted effort to tackle these complex factors is necessary[65].

In 1972, the Asian Vegetable Research and Development Center (AVRDC) launched an intensive research and development program on six principal vegetables. This paper reviews the research activities on two of the six crops, tomato and Chinese cabbage, with particular emphasis on genetically adapting them to the biotic and abiotic stresses limiting their productivity in the hot, humid tropics.

Environmental Vagaries of the Humid Lowland Tropics

The tropical region is defined as the geographical area between the Tropic of Cancer and the Tropic of Capricorn. Within this region, the climate is so widely diverse that to make an unambiguous delineation of lowland tropics is difficult. Several AVRDC researchers have attempted to define the lowland tropics in relation to adapting various crops[62,63,85]. Lowland tropics will be referred to in this paper as the area with a minimum temperature of not less than 20°C, or an average mean temperature of 25°C or above.

High temperature is clearly one of the factors limiting vegetable production in the lowland tropics. Both tomato and heading Chinese cabbage are cool, dry season vegetables. Favorable fruit setting in tomato reportedly occurs at a mean temperature range of 15° to 20°C, night temperature being more critical[73,88,89]. Other workers have argued for the importance of both day and night temperatures[40,44,80]. On the other hand, dense head formation in Chinese cabbage also takes place when mean temperature ranges between 15° and 20°C[30,48,57,58].

Lowland tropics are also synonymous with heavy rainfall. Precipitation as high as 2500 mm or more is not uncommon, with roughly 90% and above of rain falling within a span of three to four months. Although rainfall provides much needed water for crop growth in rainfed areas, excessive amounts are damaging to many vegetable species that are highly sensitive to depletion of soil oxygen. Tomato and heading Chinese cabbage are no exceptions[23,50].

High temperature and high humidity have an indirect but equally devastating effect on plants since they create a favorable environment for rapid multiplication of pests and diseases. The most common diseases and pests of tomato and Chinese cabbage in the tropics are given below.

Tropical lowland soils are surprisingly infertile. Organic matter that promotes good vegetable growth and development is often below 1%. Moreover, soil structure is often substandard.

Fertile Ground for Pests and Diseases

Although tomatoes can be grown fairly well in the cool, dry regions of the tropics, they are often attacked by many pests and diseases during the hot, humid season. Nine or so of 51 tomato diseases caused by bacteria, fungi, viruses and nematodes are major problems in the hot, humid tropics of Asia, Africa, and Latin America[86,90]. These are bacterial wilt (*Pseudomonas solanacearum*), rootknot nematode (*Meloidogyne incognita*), tomato mosaic virus, leafmold (*Cladosporium fulvum*), grey leafspot (*Stemphylium solani*), Septoria leafspot (*Septoria lycopersici*), southern blight (*Sclerotium rolfsii*), early blight (*Alternaria solani*), and powdery mildew (*Erysiphe polygoni*). Bacterial leafspot (*Xanthomonas vesicatoria*) has caused havoc on summer tomato in Taiwan and elsewhere in the tropics, prompting AVRDC breeders to consider it equally important. Field evidence that black leafmold (*Cercospora fuligena*) may be more important than other leafspot diseases is present (Saadaoui, personal communication). Indeed, the large number of diseases attacking tomato in the humid tropics make it a high-risk crop.

Of the major tomato insect pests, fruitworm (*Heliothis armigera*) has received the most attention. It is considered a major problem in India[69] and the Philippines[27]. As vectors for virus diseases, some sap-sucking insects, such as aphids and white fly, are just as important[84]. The green peach aphid (*Myzus persicae*) can transmit virus diseases such as yellow top and tomato aspermy; and the white fly (*Bemisia tabaci*) serves as a vector for tomato leaf curl virus.

Several diseases attack Chinese cabbage, but only three are considered principal problems in the hot, humid tropics[1]. Softrot (*Erwinia carotovora*), is most damaging during the hot wet season. Downy mildew, (*Peronospora parasitica*) can be a serious disease in the early or late summer along the fringes of the tropics or in cool, moist highland areas; however, it is not as important as softrot in the hot season. Although relatively unimportant during the rainy season, turnip mosaic virus can be damaging during the hot, dry season. Apart from those three, clubroot (*Plasmodiophora brassicae*) has become a menace in recent years in the highlands of Indonesia and the Philippines but its incidence is still confined to the cooler areas. Early blight (*Alternaria brassicae*) has been reported to cause severe damage on Chinese cabbage in some tropical countries.

Many pests attack cruciferous vegetables so that chemical control has become an indispensable practice. Their classic pests include diamondback moth (*Plutella xylostella*), cabbage webworm (*Hellula undalis*), cabbage looper (*Trichoplusia ni*), striped flea beetle (*Phyllotreta striolata*), and aphids (*Myzus persicae*, and *Lipaphis erysimi*). In many cases, the diamondback moth and cabbage webworm are considered the two most important insect pests of crucifers[81].

PHYSIOLOGICAL ASPECTS OF TROPICAL ADAPTATION

High Temperature

Fruit-set is one of the key components deciding final yield in tomato[68,79] and is limited to a narrow range of temperatures. Both night and day temperatures are considered important to tomato fruit-set[80]. Maximum temperatures below 30°C favored fruit-set and yield; ranges between 30° - 45°C markedly reduced fruit-set[88]. Poor fruit-set at high temperature might result from the reduction of carbon export from the leaf[21] and the inability of reproductive organs to import assimilates in the early stages of flower development[22].

The process of fruit-setting occurs in the female reproductive part (pistil) which develops seeds within the ovary[68]. Pollen grain germination occurs in the stigma, and the pollen tube must grow through the stylar tissue to reach the ovule. The latter forms the seed after fertilization and then triggers growth of the erstwhile ovary to form the fruit. Finally, the fruit remains attached to the pedicel and grows. High temperatures are known to limit tomato fruit-set because of a simultaneously and/or sequentially impaired series of reproductive processes[25,49,56,72] such as pollen production and development, ovule development, pollination, pollen grain germination, pollen tube growth, fertilization, and fruit initiation (Fig. 1). The effects of high temperature on these processes depend upon the plant's developmental stage when exposure takes place. The greatest effects occur five to nine days before anthesis. Heat treatment one to three days after anthesis greatly reduces fertilization[80]. The difference in fruit-set among varieties at high temperature apparently cannot be attributed to one major physiological factor, but to a combination of responses[49,79]. However, heat tolerance may be potentially enhanced by genetically combining desirable factors[25].

After pollination and fertilization, the developing seed takes the leading role in controlling fruit development. A possible correlation exists between seed number and fruit size[42]. Fruit-set and development are usually associated with endogenous plant hormones produced by the pollen, stylar tissue, or seed during the normal processes of pollination, fertilization, and seed formation. After fruit-set, cell division and enlargement in the fruit are promoted by the endogenous hormones produced by seeds through seed development. Experimental evidence suggests that auxin and gibberellin levels in reproductive organs decrease with increasing temperatures. At the same time, abscissic acid increases, probably enhancing abscission[6,43,53]. Little is known, however, about the varietal differences in the level of endogenous plant hormones or their roles in the reproductive organ during the process of fruit-set and development at high temperatures. It appears that certain plant hormones enable the reproductive organ to mobilize assimilates at high temperatures[22].

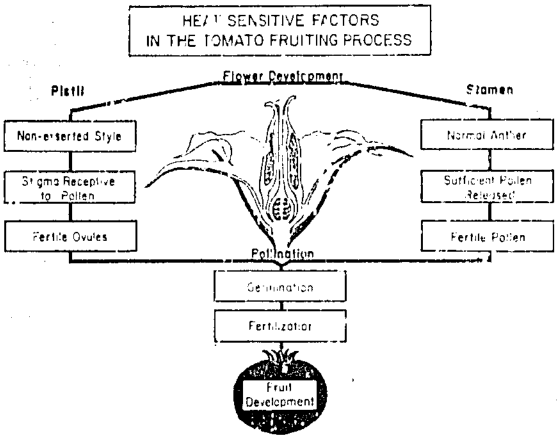

Fig. 1. Components of tomato reproductive process influenced by high temperature.

The heading process in Chinese cabbage plays a major role in deciding yield under high temperatures[64]. Leaf turgidity is a prerequisite for leaf erection, hooking, and eventual head formation to take place[46,51]. Heat tolerant cultivars maintain leaf turgidity under high temperatures[51]. Dry matter production did not differ appreciably between heat-tolerant and heat-sensitive cultivars, implying that head formation at high temperature relies more on the plant's water balance rather than on its photosynthetic source[54]. Heat-tolerant varieties utilize more water than heat-sensitive ones at leaf erection and hooking stages. This difference may be due to the rapid root growth and extensive root system of heat-tolerant genotypes, rather than to the transpiration stream created by an extended leaf area. It is reasonable to surmise that heat tolerance in Chinese cabbage is strongly associated with the water relations in the plant.

In fact, all heat-tolerant varieties have a lower shoot-root ratio than heat-sensitive varieties[51]. The extensive root growth in heat-tolerant varieties may facilitate greater water uptake.

Their initially high water uptake may conceivably be required to maintain high turgor in the leaves so that heading can proceed normally at high temperatures. Furthermore, available data support the importance of thick leaves for head formation of heat tolerant varieties[51,54]. The absence of adequate drought avoidance in the form of a surface barrier of low water permeability due to high stomatal number in the leaves of heat sensitive cultivars may contribute to their rapid dehydration and inability to maintain turgor at high temperatures. A lower leaf surface area per unit shoot weight of the thick-leaved varieties may also decrease transpiration and consequently improve water economy of the plant.

Heat tolerant Chinese cabbage plants contain more electrolytes than heat sensitive ones[54]. Lowering of the osmotic potential is frequently responsible for maintaining turgor when the water content decreases because of high temperature. Thus, high electrical conductivity in the leaf sap of heat tolerant Chinese cabbage plants should lead to the maintenance of higher turgor with a plentiful water supply. If turgidity is well maintained, initial heading processes, such as leaf erection, should proceed normally. High chlorophyll content in the outer leaves of heat tolerant Chinese cabbage plants may also facilitate photosynthetic rate, thereby increasing carbohydrates for use as the source of electrolytes or energy for the heading process.

Measurements of water status and water potential in plants are very important in selecting for heat tolerance. Conventional psychometry is not suitable for Chinese cabbage, so the indirect method might offer a viable alternative. Hence, the relevant morphological traits (Tables 1 and 2)

Table 1 Leaf thickness, trichome number, stomatal number, and chlorophyll content per unit leaf area of Chinese cabbages

Entry	Heat reaction[z]	Thickness (mm)	Adaxial Trichome no. (cm^{-2})	Stomatal no. (mm^{-2})		Chlorophyll (mg/dm^2)
				Adaxial	Abaxial	
B-6	—	0.34de[y]	4.8 ± 0.5[x]	218 ± 36	281 ± 32	2.35ef
B-14	+	0.40b-d	0.7 ± 0.3	262 ± 50	256 ± 50	4.13ab
B-31	+	0.42a-d	0	145 ± 33	224 ± 43	4.02ab
B-40	—	0.30e	1.9 ± 0.8	295 ± 54	386 ± 68	3.08c-e
B-71	—	0.36de	2.2 ± 2.1	208 ± 32	368 ± 59	2.19f
B-126	+	0.42a-d	0	159 ± 39	192 ± 42	4.34a
B-129	+	0.40a-d	0	123 ± 50	182 ± 32	3.77a-c
B-140	+	0.47a	0	183 ± 56	258 ± 40	4.38a
B-152	+	0.44a-c	0	196 ± 59	240 ± 46	3.88a-c
B-171	+	0.46ab	0	193 ± 46	263 ± 39	4.15ab
B-175	+	0.46a-c	0	179 ± 62	316 ± 80	4.20ab
B-189	+	0.39cd	0	151 ± 46	190 ± 50	4.53a
F1-58	+	0.36d	0.4 ± 0.5	232 ± 53	335 ± 75	3.39b-d
F1-62	+	0.42a-d	0.6 ± 0.8	203 ± 46	351 ± 58	2.87a
r[w]		0.802**[v]	−0.849***	−0.730**		0.839***

[z] + = heat tolerant;   = heat sensitive
[y] Mean separation by Duncan's multiple range test, 5% level
[x] Each value represents the average of 3 replications ± SE
[w] Correlation coefficients with heading rate
[v] Correlation coefficients significant at 1% (**), and 0.1% (***)

Table 2 Leaf thickness, trichome number and leaf sap electrical conductivity of Chinese cabbage

Entry	Heat reaction[z]	Thickness (mm)	Trichome no. (cm^{-2})		Electrical conductivity (umhos/cm^{2})
			Adaxial	Abaxial	
B-6	−	0.38c[y]	3.7	11.7	81e
B-14	+	0.43bc	1.7	10.0	84e
B-31	+	0.50ab	0	9.3	106ab
B-40		0.39c	3.0	7.0	89c-e
B-71		0.26d	2.3	0	85de
B-126	+	0.53a	0	0	112ab
B-129	+	0.42bc	0	0	102bc
B-140	+	0.49ab	0	0	118a
B-152	+	0.50ab	0	0	106ab
B-171	+	0.49ab	0	0	112ab
B-175	+	0.39c	0	0	107ab
B-189	+	0.42bc	0	0	90c-e
F1-58	+	0.45a-c	1.3	2.7	99b-d
F1-62	+	0.48ab	0	5.3	99b-d

[z] + = heat tolerant; − = heat sensitive

[y] Mean separation by Duncan's multiple range test at 5% probability level

to aim for in selecting for heat tolerance are 1) thick and dark leaves and 2) vigorous root growth. These are essential in sustaining leaf erection for head formation under high temperature. Other traits (Tables 1 and 2) showing association with heat tolerance may not be generally assumed related, because the heat tolerant materials used in these studies were almost exclusively from Taiwan and had been previously selected for the locally preferred morphology.

Flooding

Heavy rainfall may mechanically damage the aerial parts of plants, but topogenic water accumulation due to poor surface drainage may also lead to damaging flooded conditions. One principal effect of flooding is the rapid depletion of soil oxygen supply to the roots. The effect of oxygen deficiency on plants is complex. It comprises the direct, physiological effects of low oxygen supply, and the indirect, oxygen dependent changes in the soil. It is difficult to separate these two factors. Visual symptoms due to deficient aeration may appear on the roots and shoots. The characteristic symptoms in the shoots of Chinese cabbage and tomato from flooding are:

1. reduced stem growth
2. chlorosis of the lower leaves
3. marked epinastic curvature or wilting of the leaves
4. production of adventitious roots
5. death of the plants.

The primary cause of the above growth disturbances is the inhibition of aerobic respiration in the roots[23]. Other adverse effects on the plant's vital functions such as growth, water uptake, and nutrient uptake, are the consequences of abnormal respiration. The exclusion of oxygen from root metabolism also causes ethanol accumulation and ethylene elevation[15]. Toxic effects of ethanol on plant tissues and the association of ethylene, epinasty, and adventitious root formation are known[50].

The response of the plant to deficient soil aeration also depends on other environmental factors, chiefly temperature. Rapid wilting and/or death of Chinese cabbage and tomato plants after a short period of flooding is usually observed under hot, humid conditions in the tropics. This is probably due to the combined effects of high temperature, flooding and disease infection. High temperatures decrease oxygen solubility in the soil solution, at a time when demand for soil oxygen is high due to a high respiration rate in the root system. Furthermore, high temperature creates a great demand for water, because of the high transpiration rate in the shoot. These effects aggravate the flooding injury to the plant.

The relative tolerance of particular crop species and varieties to flooding is not always predictable as it depends on factors such as the soil physico-chemical properties, temperature, and the plant's development stage. Nevertheless, under controlled experimental conditions some comparisons (Table 3) of different plants and

Table 3 Effect of 96 hr flooding on shoot growth, root growth, chlorophyll content, and root oxygen consumption of eight vegetables

Crops	Relative performance[z]			
	Root growth	Shoot growth	Chlorophyll content	Root oxygen consumption
Amaranthus (Acc. no. 26)	0.35	0.62	0.38	0.78
Chinese cabbage (B-189)	0.90	0.74	0.75	0.80
Mungbean (V-2184)	0.67	0.63	0.77	0.73
Soybean (G-38)	0.82	0.83	0.64	1.18
Sweet potato (AIS 35-2)	1.03	1.29	0.91	1.95
Tomato (L-123)	0.25	0.13	1.03	0.28
Water convolvulus (Green stem)	2.00	0.90	1.04	3.73
Wingbean (UPS 102)	1.00	0.95	0.88	0.76

[z] Expressed as ratio of flooded/control

varieties have been made[3,50,52]. The differences between plants or varieties with respect to survival in oxygen-deprived media are due to their morphological adaptation to an alternative means of oxygen supply to the roots, resistance to toxic metabolites in the soil and plant, and capacity to perform anoxic respiration. Further understanding of genotypic variation for relative tolerance to flooding injury may strengthen the potential of breeding for flood tolerance.

GENETICAL ASPECTS OF TROPICAL ADAPTATION

Successful production of tomato and Chinese cabbage in the hot, humid tropics obviously depends on several components. In broad terms, these crops should possess the following characteristics to improve their productivity under tropical conditions: heat tolerance, tolerance to excess moisture, and resistance to major pests and diseases. Environment also plays a major role in influencing vegetable quality. However, only production-related components will be covered here.

The genetic bases of some of the most important components for tropical adaptation of tomato and Chinese cabbage are given below. Data from literature were combined with some of the AVRDC experimental evidence to arrive at a comprehensive idea of the nature of these components. As the genetics of major disease resistances in Chinese cabbage have not been elucidated, this review covers mainly the resistance to the major diseases of tomato. Emphasis is given to tomato diseases that are currently covered in the AVRDC resistance breeding program, such as bacterial wilt, tomato mosaic virus and root knot nematode.

Heat Tolerance

Heat tolerance in tomato was defined as the ability to set fruits under night temperatures no lower than 21°C[85]. This trait reportedly gives indications of genetic complexity, with variation exhibiting a continuous distribution, and heritability values ranging from 5-19% implying that the major part of the observable variation is environmental in nature[86].

As heat tolerance, defined on the basis of fruit-set, implicates an ultimate product of a complex reproductive process, attempts were made in the past to examine the components of the system to deduce relatively simple genetic situations. For example, stigma exsertion, one of the common responses of heat sensitive cultivars under high temperatures, was found to be controlled by partially dominant genes with high additive component and heritability[25,56,78]. These results corroborated the outcome of an earlier study[71].

Recent studies at AVRDC using a genetically diverse seven-parent diallel analysis indicated the importance of both additive and nonadditive genes in controlling high temperature fruit-set[5]. Differences existed among cultivars in their potential to transmit to their progenies the ability to set fruit at high temperature (Table 4). Some genotypes transmitted high levels of the trait as indicated by a high general combining ability (GCA), as in L 3690. On the other hand, this stock showed high variance for specific effects indicating that this ability was not uniformly expressed in all crosses. In contrast, stocks like L 1076 transmitted the trait more uniformly across crosses, although the intensity was not as high as with L 3690 crosses (Tables 4 and 5).

In the same study, a similar trend was observed in the genetic behavior of antheridial cone splitting (ACS), another common response of tomato flowers under high temperature. L 3690, which showed high GCA effects for fruit-set also imparted the lowest ACS tendency (Table 6). In terms of consistency of transmitting a low ACS tendency to the progenies, L 1076 was again the best stock (Tables 6 and 7). The congruence in results between fruit-set and ACS was supported by their highly significant negative correlation (r = –.67, df = 26).

Table 4 GCA effects and variance of specific effects (S^2_{si}) for fruit-set in a 7-parent diallel experiment

Cultivar	Fruit set (%)	GCA effect[z]	Variance (S^2_{si})
L3690	38.9	5.58	15.9
L229	35.5	2.47	16.6
L232	35.4	–0.19	9.8
L1076	35.0	1.44	0.8
L2991	24.6	–0.04	11.6
L125	16.5	–2.78	16.6
L387	0	–6.48	21.6

[z] Positive effects imply transmission to progenies of high fruit-setting rate

Table 5 Diallel array of SCA effects for fruit-set in a 7-parent diallel experiment

Parents	L229	L232	L1076	L2991	L125	L387
L3690	2.7	4.2	0.4	3.9	4.1	6.7
L229		–3.8	2.8	1.8	1.9	8.3
L232			1.0	2.4	–5.6	1.2
L1076				3.8	1.3	1.2
L2991					6.3	–1.2
L125						3.5

Table 6 GCA effects and variance of specific effects (S^2_{si}) for antheridial cone splitting in a 7-parent diallel experiment

Cultivar	ACS rating	GCA effect[z]	Variance (S^2_{si})
L125	4.4	0.35	0.24
L232	4.2	0.40	0.34
L387	4.0	0.38	0.10
L229	3.6	0.16	0.18
L1076	3.5	–0.06	0.09
L2991	2.8	–0.33	0.15
L3690	2.1	–0.90	0.47

[z] Negative effects imply transmission to progenies of the desirable low ACS trait

Table 7 Diallel array of SCA effects for antheridial cone splitting in a 7-parent diallel experiment

Parents	L232	L387	L229	L1076	L2991	L3690
L125	0.29	0.01	–0.67	–0.74	0.22	–0.60
L232		0.16	0.38	–0.10	–0.33	–1.26
L387			0.40	0.12	–0.41	–0.63
L229				–0.16	–0.59	0.19
L1076					–0.37	–0.09
L2991						0.48

Conventional breeding methods which take advantage of additively acting genes, and hybrid breeding which relies more on genetic interactions, should both be effective in developing heat-tolerant genotypes. In support of the latter, about 1/3 of diallel hybrid progenies from the above study showed significantly better fruit-set than the better parent.

In a follow-up study[6], crosses between stocks carrying varying levels of heat tolerance tended to have higher fruit-set than their crosses with heat sensitive parents (Fig. 2). From the range of F_1 mean values, it was apparent, however, that some of the F_1's from crosses between heat-tolerant and heat sensitive stocks could equal, if not surpass, the performance of heat tolerant x heat tolerant stocks (Table 8). This further supports the results from the previous diallel experiment[5].

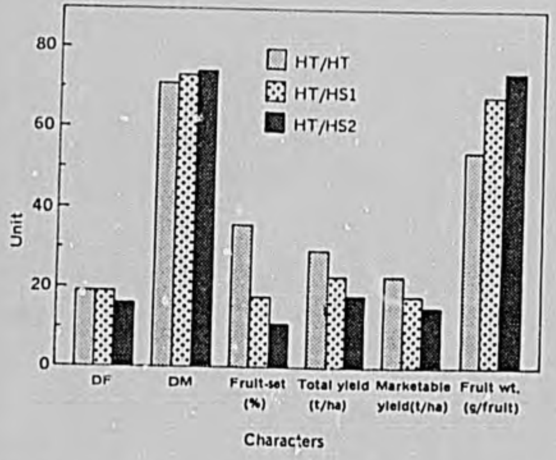

Fig. 2 Average performance of tomato crosses with varying levels of heat tolerance (HT = heat tolerant; HS_1 = heat sensitive with low level of fruit-set; HS_2 = heat sensitive without fruit-set)

Table 8 Range of performance for different horticultural characters among crosses with different levels of heat tolerance

Type of cross[z]	Number of crosses	Fruit-set (%)	Yield (mt/ha)		Fruit size (gm)
			total	marketable	
HT/HT	8	26-52	15.4-37.5	12.3-29.0	41-63
HT/HS1	11	5-30	15.9-28.8	9.8-23.2	57-83
HT/HS2	10	2-32	6.3-33.2	5.9-27.6	59-92

[z] HT = heat tolerant parent
[y] HS1 = heat sensitive parent (low level of fruit set)
[x] HS2 = heat sensitive parent (no fruit set)

Table 9. Segregation for heat tolerance in the F_2 generation of heat tolerant (HT) x heat sensitive (HS) Chinese cabbage crosses[z]

Cross	Total plants	Observed ratio		Chi-square (3:1 ratio)	Probability
		HS	HT		
B41-1xB4-1	346	261	85	0.03	0.80-0.90
B41-2xB4-2	366	272	94	0.09	0.70-0.80
B41-4xB4-4	486	369	117	0.22	0.50-0.70
B173-1xB4-1	431	325	106	0.04	0.80-0.90
Total	1629	1227	402	0.38	0.98-0.99
Heterogeneity test				0.29	0.95-0.93

[z] Adopted from Opeña, R.T. and S.H. Lo. 1979

The genetic basis of heat tolerance in Chinese cabbage, defined as 'the ability to produce compact heads under mean temperatures no lower than 25°C[62]' is surprisingly simple. Genetic analyses of segregation among F_2 populations (Table 9) and backcross progenies indicated that it is controlled by a single recessive gene. AVRDC breeders have not met any difficulty in fixing heat tolerance among breeding lines, further attesting to its simple inheritance. In a parallel genetic study, it was concluded that heat tolerance was under the control of a single dominant gene[91]. The reverse dominance relation could be explained by the fact that in a temperate location, the intermediate type (classified as heat sensitive in the AVRDC genetic experiment) could have been judged as compact headed and therefore, heat tolerant. Korean summer night temperatures and duration of hot days are relatively milder than in subtropical Taiwan.

Bacterial Wilt Resistance

Bacterial wilt (BW), caused by *Pseudomonas solanacearum*, is considered the most important single disease of tomato and other solanaceous crops, as well as a number of other important crop species[47]. In the tropics and subtropics, it is devastating during the warm, wet months and causes incalculable losses to many of its hosts[95].

The underlying genetic basis of BW resistance has been studied in different genetic sources. A type of resistance present in BW tolerant North Carolina germplasm was reported to be polygenic, conditioned largely by recessive genes[76]. In another resistance source (*Lycopersicon pimpinellifolium* PI 127805A) field-selected for nine years in Hawaii, a comparatively small number of genes with major effects were found to be likely to control BW resistance[7]. Partial dominance for resistance up to about seven weeks after planting, followed by a type of resistance conditioned by recessive genes in the more mature plants, was also implied. Several interesting associations of BW resistance with other traits were noted or confirmed, e.g., linkage with indeterminate growth habit (sp+) and small fruit size[7].

In a more recent study using a BW2 line from North Carolina, Louw (1981) as cited by Bosch *et al.*[14] reported that a two-gene model with epistasis was adequate to explain the observed segregation. In Louw's gene designation, gene A^3 was epistatic to gene B^3, both genes exhibiting dominance with incomplete penetrance.

AVRDC breeders have proceeded through the years with the encompassing assumption that BW resistance is polygenic. Both Hawaiian and North Carolina materials have been used in the AVRDC program, thus making this assumption fairly valid. However, the genetics of BW resistance in other important sources, e.g., lines from the Philippines, Malaysia, and other tropical regions, have not been elucidated. According to tomato breeders in India (S. Tickoo, personal communication), there are indications that a fairly simple genetic control may underlie the BW resistance in some of these sources, such as those originating from the Philippines. Although this type of resistance may be useful in certain areas, it may not be stable over the wide range of environments with which AVRDC's advanced tomato breeding lines have to contend.

Different sources of BW resistance may inherently vary in their ability to transmit high levels of resistance to their progenies[4]. In a seven parent diallel experiment, certain stocks, like L 96 (cv. Saturn from North Carolina) and L 285, a local collection from Taiwan, showed a far better average resistance among their hybrid progenies than others (Table 10). These stocks also transmitted high BW resistance more uniformly than others. For example, CL 1351-9-10 tended to show high BW resistance in some crosses but not in others. It appears that nonadditive gene action may also be an important feature of the genetic system conditioning BW resistance.

Table 10 Estimates of general combining ability effects and associated variances for bacterial wilt resistance among parental stocks in a seven parent diallel set

Parental stock	GCA Effect^z (gi)	Variances^y	
		(S^2g)	(S^2s)
L285 (highly resistant)	−7.3	47	6
CL1351-1-9-10	−5.9	28	29
L96	−5.6	24	0
L4670	−2.3	0	13
L366	−0.8	0	6
CL1219-0-12	8.6	68	13
L390 (highly susceptible)	13.3	169	12
Standard error $(\hat{g}i-\hat{g}j)$	3.0	—	—

[z] Negative effects imply transmission of BW resistance to progenies while positive effects imply transmission of susceptibility

[y] Variances that are approximately zero were small negative values

Tomato Mosaic Virus Resistance

Tomato mosaic virus (ToMV) is found worldwide, reportedly causing crop losses ranging from 5% to 50%[8,9,10,16,20,37,87]. ToMV depresses plant vigor, yield and fruit quality; in combination with other viruses, it may totally suppress tomato productivity[83].

Although measures such as cross-protection, seed treatment by chemicals or heat, sterilization of tools and soil sterilization have been proposed, the highly infectious nature and persistence of this virus has made them ineffective[16,17]. Breeding resistance into commercial tomato cultivars is still the most promising approach[11,32,67].

Tolerance to ToMV was first reported in *L. hirsutum* stocks by Holmes[38]. A delayed and mild type of reaction to ToMV was also observed in other species such as *L. peruvianum*, *L. chilense*, and *L. pimpinellifolium*[31]. The true resistance found in *L. chilense*[38] was successfully bred into *L. esculentum* later[66].

A number of ToMV strains exist and they have been classified *vis à vis* the different genes for resistance[18,29,39,60,66,67]. At AVRDC, we use four genetic differentials (Table 11) to identify the major ToMV strains[35]. Two dominant genes are apparently involved in conditioning resistance. Gene Tm-1 imparts resistance to Strains 0, 2 and 2^a. On the other hand, gene Tm-2 controls resistance to all strains except Strain 2. It has an allelic counterpart, gene Tm-2^a, which imparts resistance to all strains except Strain 2^a.

Table 11 Reaction of differential tomato cultivars to ToMV strains

Differential host (*L. esculentum*)	ToMV strain			
	0	1	2	2^a
GCR 26	M[z]	M	M	M
CSTMW-18 (Tm-1/Tm-1)	—	M	—	—
Perou 2 (Tm-2/Tm-2)	—	—	M	—
Delissa (Tm-2^a/Tm-2^a)	—	—	—	M

[z] M = mosaic symptoms, — = no symptoms

As the most common strains in Taiwan and other Southeast Asian countries are Strains 0 and 1, the AVRDC tomato breeding program emphasizes the incorporation only of Gene Tm-2^a into tropical tomato lines[4,35].

Rootknot Nematode Resistance

Among 37 species of rootknot nematodes (*Meloidogyne* spp), seven are known to attack tomato. *Meloidogyne incognita* is the most important species affecting tomato production[75,82]. Losses in productivity due to direct infection[12,55,59] and indirect losses due to predisposition or breakdown in resistance to other root diseases, e.g., bacterial wilt[34], are significant. As with other diseases, breeding for resistance offers the most economical long-term solution.

Bailey[12] reported *L. peruvianum* as a source of resistance to rootknot nematode. The first interspecific hybrid between *L. peruvianum* and cultivated tomato was made in 1944[77] and further backcrosses led to the independent development of cultivars VFN-8 and Anahu in California and Hawaii, respectively. This resistance is controlled by a single dominant gene now known as "Mi".

Rick and Fobes[70], working on cultivar VFN-8 and other nematode resistant cultivars, discovered a variant for locus 1 of acid phophatase isozyme (Aps-1) and concluded that either a tight linkage between the Mi gene and Aps-1, or the pleoitropic effects of a single gene, may be involved. The practical use of electrophoresis as a screening method for nematode resistance complemented or replaced other methods proposed earlier[13,24,28,41]. Medina-Filho and Stevens[61] found that cultivars with pedigree tracing back to Hawaiian materials did not show the Aps-1 band pattern. On the other hand, those derived from resistant California stocks maintained the association between genes Aps-1 and Mi.

Other Tomato Diseases

The genetics of resistance to other major tomato diseases have also been adequately studied (Table 12). Many are common only in temperate countries or in the cool, highland areas of the tropics. Some, like early blight, *Septoria* leafspot, and leafmold, are also considered major diseases in the humid tropics[90], but are currently not yet principal targets for the AVRDC disease resistance breeding.

Table 12 Other major tomato diseases, their causes, and sources of resistance[z]

Disease	Cause	Source of resistance	Gene action
Fusarium wilt	*Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder & Hansen	Pan American	Dominant
Verticillium wilt	*Verticillium albo-atrum* Reinke & Berth.	VR Moscow	Dominant
Bacterial canker	*Corynebacterium michiganense* (E. F. Sm.) H. L. Jens.	Bulgarian 12	Multigenic
Late blight	*Phytophthora infestans* (Mont.) DBy.	West Virginia 63	Dominant or Multigenic
Early blight	*Alternaria solani* (Ell. & G. Martin) Sor.	(on foliage) 68B134 (collar rot) Southland	Dominant or partially dominant
Septoria leaf spot	*Septoria lycopersici* Speg.	Targinnie Red	Dominant
Leaf mold	*Cladosporium fulvum* Cke.	Waltham Mold Proof Forcing	Dominant

[z] Adopted from Webb, R.E., Barksdale, T.H. and Stoner, A.K. 1973. Tomatoes. "*Breeding Plants for Disease Resistance.*" (ed. R.R. Nelson) The Pennsylvania State University, USA. xi + 399 p.

BREEDING STRATEGIES TO DEVELOP IMPROVED TROPICAL CULTIVARS

Evaluation of available tomato and Chinese cabbage germplasm on major traits required for the hot, humid areas enabled the selection of elite genetic stocks for breeding[64,65,85]. Genetic manipulation to combine these traits followed, and the resulting products were widely tested in Taiwan and many tropical countries to identify the appropriate cultivars. These new varieties demonstrated improved tropical adaptation by virtue of their tolerance to stress, especially to heat, moisture and major tropical diseases.

The enormity of factors affecting tomato production in the humid tropics called for a stepwise approach to genetic improvement[65]. During the early years, recombination of heat tolerance and bacterial wilt (BW) resistance was emphasized[1] because these are the bottlenecks in the successful cultivation of tomato in an environment that departs considerably from its normal growing conditions.

The genetic resources used in breeding for heat and BW resistance were purposely derived from diverse germplasm sources (Tables 13 and 14). Hybridization schemes in the early years involved single, three-way, and double crosses aimed at combining these different resources. Segregating progenies were handled mainly by traditional methods, like the bulk and pedigree systems, and occasionally by the single-seed-descent (SSD) method on a few elite crosses. Selection for BW resistance in these early crosses involved screening of young seedlings of early bulked populations, e.g., F2 or F3 bulk, by leaf clipping with a pair of scissors dipped in a mixture of highly infective BW inoculum. Surviving seedlings were grown thereafter in a BW infested field nursery. Whenever appropriate, the survivors were also selected for heat tolerance (based on fruit-set under field conditions) in the nursery. Further selections for BW resistance and heat tolerance were conducted in subsequent generations with similar screening methods.

Table 13 Genetic resources for heat tolerance in tomato and frequency of utilization in AVRDC breeding program

Accession	Varietal name	No. times used in crosses	%	Source	Remarks
L4841	L22 (VC11-3-1-8)	80	12.9	Philippines	
L3958	PI289309	69	11.1	USA (Texas)	
L125	Divisoria-2	56	8.9	Philippines	
L283	Tamu Chico III	47	7.5	USA (Texas)	
L232	Naygarlan	45	7.2	Philippines	
L2972	PI289296	47	7.5	Hungary	
L1488	PI203232	36	5.8	South Africa	Frost resistant
L18	VC11-2-5	34	5.4	Philippines	
L2991	PI190256	29	4.6	USA (Texas)	
L229	Sub Arctic Plenty	27	4.3	Canada	Cold tolerant
L3040	PI294444	16	2.5	Israel	
L3957	BL6807	9	1.4	Canada	Cold tolerant

Table 14 Genetic resources for bacterial wilt resistance in tomato and frequency of utilization in the AVRDC breeding program

Accession	Varietal name	No. times used in crosses	%	Source
L96	Saturn	135	21.8	USA (NC)
L95	Venus	109	17.6	USA (NC)
L366	Unknown	85	13.7	?
L4841	L22	80	12.9	Philippines
L1	VC48-1	34	5.5	Philippines
L15	VC8-1-2-7	34	5.5	Philippines
L8	VC9-1	29	4.7	Philippines
L21	VC11-1	28	4.5	Philippines
L4670	PI406994	28	4.5	Panama

The trend in tropical tomato hybridization from 1981 to the present differs markedly from the first decade of the breeding program (Fig. 3). In recent years AVRDC tomato breeders have emphasized further improvement of the most advanced tropical lines by sequentially incorporating additional resistance to diseases and improved fruit quality. New traits that have been bred into tropical tomato are as follows: resistance to tomato mosaic virus (mainly with gene Tm-2^a), resistance to fruit cracking, fruit firmness, and improved fruit size[5]. At present, breeding for nematode resistance is nearly complete. A few of the new tropical lines with this resistance will be available soon[6].

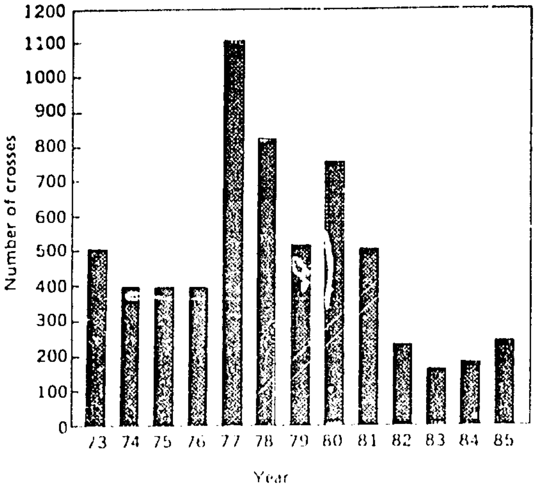

Fig. 3 Trend in the total annual crosses in the AVRDC tomato program

As more desirable genes are added for breeding into tropical tomato, the intensity of the major traits for which they were originally bred may decrease with genetic manipulations. Complex characters, like BW resistance and heat tolerance, are especially vulnerable. AVRDC tomato breeders have therefore increasingly resorted to the backcross (BC) method to recover adequate levels of the recurrent tropical parents while adding new traits. This method is finally combined with either the bulk or SSD method (only for a few elite crosses) in handling the selfed BC progenies. The BC method is a far more involved scheme and, thus, the downward trend in yearly crosses since 1981 is reasonable (Fig 3).

In handling the selfed BC progenies selection for complex traits is now generally delayed until all selections reach family or line stage. Early generation selections are still made but restricted to simple, highly heritable traits, e.g., ToMV and nematode resistance. In so doing, the hybrid progenies can be screened for better horticultural types before selecting for complex traits, like heat tolerance and BW resistance.

The number of backcrosses to the recurrent tropical stocks depends on the nature of the parent but usually varies from one to three. If the donors offer other desirable characters apart from the major gene(s) under transfer, the number of BC's is reduced to two or even one. Experience in the last three years indicates that the minimum number of BC's needed to recover desirable levels of heat tolerance from the tropical parents may not be very high. On several occasions, many segregants with good heat tolerance in the BC2F2 generation were already recoverable. This indirectly suggests that the genetics of heat tolerance may not be overly complex, as previously supposed[56], but perhaps controlled only by a few major genetic factors with minor gene modifiers. We have not evaluated the backcross progenies for BW resistance fully enough to be able to conclude that a minimum of two backcrosses, adopted for heat tolerance, is adequate.

Heat tolerance in heading Chinese cabbage is inherited in a fairly simple fashion[2,62,64,65,91], and thus assures that the genetic transfer of this trait is easy. However, other important characters like head yield and disease resistance still need to be combined with it in the breeding program.

The yield potential of heat tolerant Chinese cabbage was enhanced through two breeding strategies. In the early stages, improvement of one of the major yield components, head weight, was attempted through population breeding[64,65]. Both recurrent selection and mass selection showed that significant gains in selection for head weight could be achieved with suitable cultivars[64,65]. Unfortunately, although the gains were statistically significant, they were small in practical terms (Table 15). Therefore, the dramatic improvement of yield potential was sought through heterosis breeding[64,65].

Genetic diversity enhances hybrid vigor in crop plants, such as maize, where heterosis has been observed[26,36,45]. Certain genetic reasons mitigated the employment of hybrid breeding in improving the yield potential of heat tolerant Chinese cabbage. Heat tolerance

Table 15 Results of two cycles of recurrent selection for yield in Chinese cabbage[z]

Population	Yield (mt/ha)	Mean head weight (g)
B129 C_1	33.1	750
B129 C_2	35.7	787
Gain over C1	2.6*	37*
Predicted gain[y]	—	31

[z] Adopted from Opeña, R.T. and Lo, S.H. 1981. *Chinese Cabbage.* (ed. N.S. Talekar and T.D. Griggs). AVRDC, Shanhua, Taiwan. 489 pp.

[y] Calculated from variance component analysis of population C_1. Predicted gain (g) = KspH, where: K = selection differential = 1.76 (for 10% selection intensity); sp = square root of total phenotypic variance for head weight (19,157); H = heritability of head weight = 0.126

Table 16 Comparative head weight (g) of F_1s among local heat tolerant Chinese cabbage cultivars and among heat tolerant inbreds derived from intercultivar crosses[z]

No. crosses	Material	Head (g) weight	
		mean	range
45	F_1's from 10-parent local cultivar diallel	403	316-494
80	F_1's among inbreds from intercultivar crosses	708	468-972

[z] Adopted from Opeña, R.T. and Lo, S.H. 1981. *Chinese Cabbage.* (eds. N.S. Talekar and T.D. Griggs) AVRDC, Shanhua, Taiwan. 489 pp.

is inherited in a recessive fashion which means that both parents must be heat tolerant to achieve a good level of the trait in a hybrid. Finding two diverse parents with enhanced heterotic interaction was difficult, however, since the heat tolerant gene pool is extremely narrow[64,65]. The key to maximizing heterosis for yield was therefore achieved through the diversification of the heat tolerant gene pool. This was done by crossing the local heat tolerant populations with unrelated temperate cultivars carrying other desired traits, e.g., disease resistance, and mass selecting the resulting populations for two to three cycles for traits like heat tolerance and disease resistance. New inbred lines were consequently derived from these diverse gene pools with greater heterotic interactions than was previously possible among crosses of local cultivars (Table 16). Improved open pollinated populations were also synthesized from intercrosses among the new inbred lines[64].

Although resistance to diseases was not improved to the best possible degree, some of the new hybrids and open pollinated populations offered better, more durable field levels of resistance than the local varieties, e.g., downy mildew resistance[5,6].

Full-scale testing of improved tropical tomato and Chinese cabbage cultivars started five years after the initiation of the crop improvement programs on these crops. This activity became possible mostly through informal scientist-to-scientist cooperation. AVRDC has also entered into official collaborative agreements with several countries (Philippines, Thailand, Indonesia, Malaysia, Korea and West Indies) to establish outreach or bilateral programs. These programs have provided a steady conduit for the transfer of new AVRDC technology, e.g., improved cultivars. As a result, national programs in 37 countries have released improved cultivars from AVRDC on 91 occasions as of 1985. For tomato alone, a total of about 30 different lines have been released to farmers in 20 countries.

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DISCUSSION

Q. (H. Imai)

What is your definition of heat tolerance? Is it based on fruit-set? Does it also include fruit growth (sink-source balance) which is limited under high temperature conditions, and are there also aspects of respiration loss?

A. Our definition of heat tolerance has so far necessarily been made practical and simplistic; i.e. it is based only on ability to set fruit at temperatures typical of the hot humid tropics. This is the phenotype that breeders have been able to recognise easily and incorporate in functional selection programs. However, I agree with you that heat tolerance is more complex and ultimately as a breeding target should not be based on fruit-set alone. Our plant physiologists at AVRDC have indicated this in previous studies. Unfortunately, efficient means of incorporating the complex physiological factors are not yet available to breeders.

Comment: (R.L. Villareal)

The current definition of heat tolerance is too limited. However, with the participation of other disciplines like physiologists, biochemists, soil scientists, etc., the definition will have to be modified. Plant breeders recognise that the full expression of genotype can only be realised with appropriate environmental conditions, i.e. cultural practices, fertilizer and pesticide management.

Q. (W.N. Chang)

Why is the quality of the indeterminate type of tomato better than the determinate type?

A. It is a question of source and sink. In the determinate type, a great majority of the flower clusters bloom at the same time, whereas with the indeterminate type, they are spread over a period of time, and more nutrients are available for each fruit. Thus, in the indeterminate type, the acid balance, solid content, etc., are usually better.

Q. (W. Kongpolprom)

Venus and Saturn varieties have been used as the parent stocks for bacterial wilt disease resistance in tomatoes for at least ten years. Have you found any better breeding line for bacterial wilt resistance?

A. I have shown a table of all the crosses AVRDC researchers have made for bacterial wilt resistance in the past.

Yes, we have developed tropically adapted tomato lines with higher resistance to bacterial wilt than Venus or Saturn, but none have higher wilt resistance than L285 (a primitive and small-fruited type tomato). We have an advanced line, CLN65-349, which is very close to it in resistance level and has good fruit size. We are now concentrating on improving this advanced tropical line for other economic traits.

Q. (W. Kongpolprom)

Do you have advanced lines for root knot nematode resistance?

A. In the past we used Hawaiian cultivars such as Kewalo and Healani as sources of nematode resistance gene, 'Mi', but recently these have been replaced with stocks from California which carry more desirable characteristics such as better fruit size and fruit firmness. Our nematode resistance program was started two years ago; by early 1987, we should have advanced tropical lines which combine heat tolerance, resistance to bacterial wilt, tomato mosaic virus and nematode, and with good horticultural traits like fruit firmness, improved fruit size and cracking resistance. It is a characteristic of the 'Mi' gene that it tends to break down under high temperatures, and better sources of resistance are now being sought.

Q. (W. Kongpolprom)
Is the field test method of screening for bacterial wilt much better than the greenhouse method of inoculating seedling trays?

A. Our bacterial wilt specialists have decided that seedling screening for wilt resistance was too drastic, and that useful genetic materials could be lost in the process. In addition, several seedling screening techniques have shown high coefficients of variability in relation to the amount of inoculum delivered to each test plant. Thus, our bacterial wilt resistance test in tomato has been shifted to field tests, although the handling of a wide range of genotypes is severely restricted, compared to the seedling procedure. This is not too much of a limitation though, since wilt screening is done after selection for other horticultural and disease resistance traits which are, genetically speaking, less complex than bacterial wilt resistance. At this stage, the number of lines being tested for bacterial wilt resistance has already been reduced to manageable proportions.

Comment: (C.Y. Yang)
Earlier at AVRDC pathologists tried several different methods, using greenhouse and field tests, and attempted to verify the results. We settled then for an accelerated high temperature test in the greenhouse, followed by transplanting all survivors in the field nursery for wilt.

Q. (S. de Hoop)
Isn't it risky to use just one tomato mosaic virus (ToMV) resistance gene, the Tm-2^a? If varieties with this gene are widely used, then the strain prevalence might shift from strain 0 and 1 to strain 2^a and resistance is lost.

A. Theoretically, it is risky to rely on a single gene for resistance to ToMV. In practice, however, there has not been any major shift in strain during the last decade. This is evident in some of the major tomato growing areas in the U.S. where the gene Tm-2^a has been widely used. At AVRDC, we have tried to combine Tm-1 gene and Tm-2^a gene into standard open-pollinated lines, but absence of ToMV strain 2^a restricts the efficiency of selecting for gene Tm-2^a alone vs. combined Tm-1 and Tm-2^a genes.

Q. (S. de Hoop)
Can't two genes be used?

A. The problem is that in this part of the world, we do not have the strain 2^a of ToMV which is available in Holland to detect differences between Tm-2^a alone, versus Tm-1 and Tm-2^a together. That is a limitation for breeders in this part of the world.

Q. (R.L. Villareal)

What is the latest AVRDC policy with respect to distribution of its improved germplasm? Who has access to the seeds developed by AVRDC? Do seed companies, farmers and government organizations have direct access by request to AVRDC seed stocks?

A. AVRDC remains a non-profit organization and any new technology developed through our projects, be it cultural practices or improved varieties, is available to all interested parties. Thus, any of our technology can be used by national programs, private enterprise, or individuals. As we do not sell our technology, our survival depends on public recognition of our work. Accreditation to AVRDC is only fair, and private seed companies should recognise this obligation. This is the only way that AVRDC can work in a mutually beneficial cooperation with private seed companies. Should seed companies break this trust, as has occured in a few instances in the past, then AVRDC has no ideal recourse but to consider those seed companies as competitors rather than ideal partners in promotion of a successful vegetable industry in the tropics.

EVALUATING HEAT TOLERANCE IN POTATO

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ABSTRACT

Studies at Cornell University under contract with the International Potato Center (CIP) have concentrated on developing heat tolerant populations of Andigena and of Andigena X Tuberosum to be utilized by CIP plant breeders and their cooperators. For this purpose, we have developed heat screening tests, and we are studying the physiological basis of heat tolerance. Aspects of plant response to high temperature included in our own research or in studies with which we are collaborating are: ability of seed tubers to sprout and give good emergence when planted in hot soils; rates of dark respiration at high temperatures; growth responses to temperature; relative importance of soil and air temperatures; effects of temperature on induction to tuberize; partitioning of dry matter as affected by temperature, including growth analyses of the same set of cultivars grown in various climatic zones; and the use of computer simulation models to study the relative contributions of various possible components of heat tolerance. Other aspects of heat tolerance that deserve consideration are differences among cultivars in the response curve of photosynthesis to temperature; degree of tissue damage from sudden exposure to hot, dry winds; and tolerance to drought induced by high temperature.

There is no reason to expect that cultivars possessing tolerance to one aspect of heat stress will be tolerant in other respects. For example, a clone might excel in the ability to produce biomass at high average temperatures, but most of the dry matter produced might be partitioned to haulms rather than to tubers. Good crop emergence in hot soils might be independent of degree of foliage damage from hot, dry winds. A clone with superior ability to withstand high air temperatures might not fare especially well at high soil temperatures. In some cases apparent heat tolerance may be mainly associated with resistance to diseases or nematodes that are particularly severe in tropical soils, or with such factors as tolerance to high levels of aluminum. Screening tests that select for only one aspect of heat tolerance are unlikely to be beneficial in selecting for 'general' heat tolerance.

(Chinese Abstract)

摘　　要

由康乃爾大學與國際馬鈴薯中心的育種家們合作，集中力量從事 Andigena 和 Andigena × Tuberosum 的族群對耐熱性的發展研究。為達此目標，進行耐熱篩選試驗及耐熱生理的基礎研究。在植物對高溫反應這方面的自行研究與合作研究項目有：生長在熱土壤下薯球的萌芽能力與好的抽長表現；高溫下的暗呼吸率；生長對溫度的反應；土壤及氣溫的相對重要性；溫度對誘導薯球形成的影響；溫度對乾物質分配的影響，其中包括同一組的許多栽培品種分別種在不同的氣候帶下其生長狀況的分析；和利用模擬的電腦模式以研究各種可能的組成所提供的耐熱相關性研究；不同品種其耐熱性與溫度處理對光合作用曲線之關係；突然暴露在高溫、乾風下對組織損害的程度；和高溫誘導的耐旱性。

品種的抗(耐)性選拔如耐熱逆境未必就能兼得其他的耐性之特色。例如，有一營養系在高溫下產生很高的生物量，但它的乾物量分配可能是莖桿比薯球來的多。在熱土壤下雖有好的萌芽抽長，然其所能與熱及乾風對葉的損害程度沒相關。一營養系能抗忍高氣溫未必就能適合高土溫。在某些狀況耐熱性有成特別是在熱帶區土壤之抗病性與抗線蟲要密切配合。另外有時候也要具備耐高鋁含量的條件。對於廣義的耐熱性，單進行一種耐熱篩選是不能夠滿足一般的耐熱條件。

(Japanese Abstract)

摘　要

國際ジヤガイモセンター(CIP)と結んでコーネル大學で行われている研究はCIPの植物育種家とその協力者が利用するAndigena 及び Andigena × Tuberosumの高温耐性集團の開發に集中してきた。この目的のため高温耐性選抜試驗法を開發し，高温耐性の生理學的基礎について研究している。植物の高温に對する反應を，我々自身及び他と協力して次の諸點につき研究している。種茎の萌芽能力と高温土壤に植えたときの良好な出芽，高温時の暗呼吸率，温度による生長反應，土壤温度及び氣温の相對的な重要性，塊茎化の發現に及ぼす温度の影響，同一セツトの品種群が種々の氣候地帯で行う生長の分析を含む温度に影響を受ける乾物の分別，高温耐性の種々の可能性のある要因の相對的貢獻を研究するためのコンピユーターシミユレーシヨンモデル。その他高温耐性につき考えねばならない諸點は、温度による光合成曲線における品種間差異，高温で乾燥した風に急にさらされた時の組織の被害の程度，高温によつて誘導される耐旱性である。

ある種の高温ストレスを持つ品種群が，他のストレスに對しても耐性であるとは期待できない。例えば，あるクローンは高温でバイオマスを作る能力が勝つていても、その生產する乾物は塊茎というよりも茎葉であらう。高温土壤で出芽の良いことは高温，乾燥風による茎葉の損害程度とは無關係であらう。高温に高い耐性を持つクローンは高地温にも耐性であるとは限らない。ある場合には顯著な高温耐性は熱帶土壤で特に被害のひどい病害，線蟲抵抗性，又は高度のアルミニユウム耐性の樣な要因と主に關連しているかも知れない。たゞ1種だけの高温耐性についての選抜試驗は一般的な高温耐性を選抜するのに役に立ちそうもない。

(Korean Abstract)

적　요

국지감자학회(CIP) 와 기약하여 코넬대학이 실시한 연구는 Andigena 및 Andigena X Tuberosum 집단의 내열성 개발에 집중 하였다. 이러한 목적을 위해 열스크린 테스트를 발전 시키고 내열생리의 기초에 관한 연구를 실시하고 있다. 식물의 고온에 대한 국면은 우리의 연구 대상에 포함되고 있으며 우리가 공동으로 연구하고 있는 부문은 다음과 같다. 즉, 발아를 위한 종자괴경능력과 뜨거운 토양에서의 돌출능력, 고온하의 암호흡 비율, 생장과 온도의 반응, 토양과 기온의 상대적 중요성, 발아유도에 대한 온도효과, 온도에 의한 건조물의 분배적 영향, 동일 품종에 대한 각종 기후조건에서의 생장분석, 각종내열가능 요소의 상대적기여에 관한 콤퓨터 시뮬레이션 모델 이용 등이다. 기타 내열성에 대한 국면은 온도에 따른 품종간의 차이, 광합성 커브, 열및 온도로 건조한 상태에 갑자기 노출 되었을 때 조직의 손상, 그리고 고온으로 가문 때의 내성등 이다.

열의 자극에 내성을 지닌품종이 다른 면에서 내성을 지닌다고 기대할 수는 없다. 예를들면, 영양계는 고온에서 생물량을 생산하는 능력이 우월하지만 대부분의 건물량은 괴경보다 줄기에서의 분배력을 나타낸다. 뜨거운 토양에서의 양호한 돌출은 고온 및 건조한 바람으로 생기는 잎의 손상정도와는 관련이 없다. 고온의 공기에 저항성이 좋은 영양계는 고온의 토양에 특히 잘 견딘다고 볼 수없다. 어떤 경우에는 현저한 내열성이, 특히 열대 토양에 심한 병이나 선충류에 대한 저항성과 주로 관련이 있거나, 다량의 알루미늄에 대한 내성요인과도 관련이 있다고 본다. 내열성의 한 국면에 대한 스크린테스트는 일반적인 내열성을 선택하는 데에 만족하다고 볼 수는 없다.

EVALUATING HEAT TOLERANCE IN POTATO

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INTRODUCTION

Several potato (*Solanum tuberosum* L.) breeding programs have been able to demonstrate substantial progress in developing progenies for hot climates[11,15,19]. In this paper we shall consider factors that contribute to heat tolerance in potato, how the physiologist may evaluate their importance, and how the plant breeder might select for them. We also will describe briefly work that we have under way in these areas.

Two excellent articles have been written by personnel at the International Potato Center (CIP) on breeding for heat tolerance: one emphasizing genetic considerations[19], and one from a physiological perspective[28]. Several years ago we extensively reviewed the literature on heat stress in potato[4,8]. We will limit the present literature review to papers that have appeared since that time (1980).

NATURE OF HEAT TOLERANCE

The first and most important point that we would like to make is that there are many aspects of heat tolerance in potato. Varieties might be expected to differ in any of the following traits: plant emergence when seed tubers (or true seeds when this method of propagation is employed) are planted in hot soils[27]; shoot biomass production under prolonged high temperatures; root growth and function at high soil temperatures; reaction to heat induced drought stress[17]; response to sudden, acute heat stress, such as hot, dry winds[16]; relative importance of soil and air temperatures[14,21,27,32,34]; relative importance of day and night temperatures[27]; degree of induction to tuberize at high temperatures[1]; translocation of dry matter from haulms to tubers at high temperatures[12]; effects of temperature on rate of maturation; severity of tuber defects resulting from high temperatures; and keeping quality of tubers harvested from hot soils.

The list seems complex, but is actually an over-simplification. Many of the traits should be sub-divided. For example, the ability to produce good shoot biomass at high temperatures might be related to genetic differences in either photosynthesis[3] or dark respiration[18]; but it could also be the indirect consequence of early sprouting, or of a canopy architecture that provided more shading of the soil[28]. Midmore[27] has shown that under tropical conditions cooler soil temperatures hastened emergence, promoted canopy cover of the soil, and – by thus cooling the soil even further – favored tuber initiation. Midmore and Mendoza[28] emphasize the importance of hastening soil shading through selection for rapid emergence, early and extensive branching, and large leaf size. To maintain good canopy shading over a long portion of the season they advocate selection for increased leaf longevity, high reflectivity (pubescence) of leaves, and strong stems to resist lodging[28].

Another example of the complex relationships involves differences in tuberization. Induction of leaves to tuberize may be greater in one variety than in another[5], but there could also be varietal differences in the expression of induction in stolon tips at high soil temperatures[27,34]. Or consider differences in crop emergence: seed tubers of one variety may sprout better at high soil temperatures than those of another variety because of more rapid sprout growth, or because of a lower susceptibility to bacterial diseases associated with hot soils.

Further adding to the complexity is the importance of diseases and disorders associated with high temperatures. Many humid tropical soils have problems with toxic levels of aluminium or with nutrient deficiencies. In the dry tropics, soluble salts may be a problem. Various nematodes, bacteria, fungi, insects, and other pests may be much more severe at high temperatures than in cooler climates, and direct or indirect resistance to these pests may be essential for good performance of a clone at a given site in the tropics. We have observed that where a soft rot of stems caused by *Erwinia chrysanthemi* is a serious problem, clones with vigorous, thick stems tend to produce better yields. Perhaps this is related to a lower rate of lodging, but thicker stems are presumably also less likely to succumb to the rotting at the soil line caused by the disease.

Consideration of the many aspects of heat tolerance in potato leads us to conclude that no single variety, or even a small group of varieties, will perform well at all tropical locations. The kind of heat tolerance necessary under one set of conditions may be of little or no benefit elsewhere. There is no evidence, for instance, that the ability of tubers to sprout when planted in hot soils is associated with the ability of shoots to withstand sudden hot, dry winds. Moreover, the latter trait may depend upon the degree to which a cultivar is able to undergo heat acclimation before the heat shock is given[2].

The plant breeder is probably well advised to target the particular set of conditions for which heat tolerance is desired, rather than aim for generalized tolerance. Parenthetically, the probable limitations to genetic engineering approaches to heat tolerance might also be noted. Selection of somoclonal variants that can survive in agar at high temperatures might yield a clone that has the ability to produce biomass under hot conditions, but the ability to partition dry matter effectively to tubers at high temperatures could be totally lacking.

SCREENING FOR HEAT TOLERANCE IN WILD SPECIES

If it is necessary to target the particular aspects of heat tolerance that are desired, then it follows that the next step is to develop screening procedures that will help the breeder identify clones with useful levels of these traits. One such procedure is to determine ionic leakage from membranes at high temperatures as an indication of foliage resistance to heat shock[2,29]. The successful utilization of the technique on breeding populations is yet to be demonstrated. Sattelmacher[35] proposed that if seedlings are grown in the greenhouse at high temperatures, the earliness of tuberization can be used to predict field performances in the lowland tropics. He found that very early tuberization was associated with higher yields in the field early in the growing season (less than 50 days after planting), but somewhat later tuberization in the hot greenhouse was associated with better yields in the field at the end of the growing season[35]. However, a complete absence of tubers on seedlings in the hot greenhouse led to very poor yields in the field. The likely explanation is that if a clone is able to become induced to tuberize too easily, it starts to initiate tubers before there is sufficient canopy to support good tuber enlargement. Once tubers have formed, so much assimilate is partitioned to these developing sinks that the rest of the organs are stunted. At the other extreme, if tuber induction is too difficult, most of the biomass will be utilized for shoots, and poor tuber yields will result. It is therefore essential to strike a balance between too much and too little induction to tuberize, which is appropriate for the environment and the desired length of the growing season.

We are screening 'wild' potato species for shoot biomass production at high temperatures by growing them in a plastic greenhouse in the summer. Temperatures in this greenhouse are allowed to reach 40°C during the hot part of the day before ventilation fans are started[1]. On cloudy days, a furnace is turned on to achieve this temperature. Night temperatures are maintained at 30°C. Because we are focusing our attention on the ability of the shoots to grow well at high temperatures, we maintain photoperiods at 18 h to discourage tuberization. Tuber formation would interfere with the assessment of shoot growth, because induction to tuberize causes a drastic shift of dry matter production away from shoots toward tubers.

We also grow the same accessions in a cooler greenhouse, under 18-h photoperiods. Comparison of the growth of each accession under the two temperature regimes gives an idea of the relative tolerance of the shoots to high temperatures. This indicates whether a particular accession is performing well because it has good vigor no matter if grown in warm or cool temperatures, or whether it is less affected by the heat than are other accessions. We not only measure the dry weights of the shoots in both greenhouses, but also make subjective ratings for chlorosis, morphology, necrosis, and general appearance.

Accessions which perform well for shoot biomass production are subjected to a test for ability to become induced to tuberize at high temperatures. Shade cloths are drawn over these plants to give short photoperiods. After two weeks of short daylengths, cuttings taken from the plants are placed in mist chambers under continuous light. If tubers form on the cuttings within two weeks, this is an indication that the leaves are capable of becoming induced to tuberize even under the conditions of the hot greenhouse[33].

SCREENING NEO-TUBEROSUM FOR HEAT TOLERANCE

We use similar procedures to screen a population of Neo-tuberosum clones for heat tolerance. These clones are derived from Andigena accessions, the potatoes that are grown in the highlands of Peru and neighboring countries, where the potato was first brought under cultivation. Our potato breeder, Dr. R.L. Plaisted, subjected the Andigena populations to recurrent selection for ability to tuberize under long photoperiods and, with colleagues in other departments and with financial support from the International Potato Center (CIP) in Peru, is carrying on a program to incorporate resistance to various diseases, nematodes, and insects. After six cycles of recurrent selection, the population no longer had the morphology or photoperiodic reactions typical of the Andigena from which it was derived[31]. On the contrary, the plants looked like typical Tuberosum, the potato grown in North America and Europe. It therefore seemed appropriate to assign the name 'Neo-tuberosum'. Our role in Dr. Plaisted's program has been to select for heat tolerance within the Neo-tuberosum population.

After considerable trial and error, including field testing at CIP's facilities in the lowlands of Peru, we have decided to grow the Neo-tuberosum clones in our hot greenhouse under long photoperiods. We have chosen a long photoperiod (usually 18 h) to magnify the negative effects of high temperatures on induction of leaves to tuberize. The latter trait is examined by taking cuttings from the plants and checking for tuberization on the cuttings. Because only clones with a very high ability to tuberize under unfavorable conditions are able to become induced under the environment of the hot greenhouse, there is a strong probability that clones performing well in this screening test will have good partitioning of dry matter to tubers, even under tropical field conditions.

Equal selection pressure is placed on another trait – the vigor of shoot growth shown by the Neo-tuberosum clones in the hot greenhouse. This second trait gives an indication of the ability of the plants to produce biomass at high temperatures, whereas the tuberization on cuttings indicates the ability of the clones to partition the biomass to tubers. If we selected only for shoot vigor, we might obtain plants with impressive haulm production but very poor tuber yields. Selection only for tuberization on cuttings gives plants with a high harvest index (ratio of tuber weight to total plant weight), but many of them have low yields because of poor overall biomass production. The clones surviving the dual selection show the best performance in the field at San Ramon, Peru[7].

ADDITIONAL CRITERIA FOR SCREENING

We should like to add other criteria to the selection process, and we are in the process of evaluating methods to do so. One question is the ability of tubers to sprout at high soil temperatures.

Current research is aimed at determining whether genetic variability for this characteristic exists and, if so, at finding a method to screen for good emergence.

Another question is whether clones differ in their ability to express at high soil temperatures the signal from the leaves to tuberize. As already indicated, we know that cultivars differ in their ability to produce under high temperatures the stimulus in the leaves that is apparently transported underground and causes tuberization[5]. It would be interesting to know whether there are genetically controlled differences in the expression of this stimulus when soil temperatures are high. If so, it may be desirable to screen at different soil temperatures as well as at different air temperatures, or to warm the soil in which cuttings are inserted during screening[34].

There has been considerable investigation of the hormonal control mechanisms responsible for the suppression of tuberization by high temperatures[6,13,20,22,24,25,26]. Such studies eventually may permit us to use the response to applications of growth substances as an indication of ability to tuberize at high temperatures. Another possibility is that applications of growth substances might ameliorate undesirable effects of heat[23].

DIFFERENCES IN BIOMASS PRODUCTION AT HIGH TEMPERATURES

Eventually we would like to learn more about the differences in biomass production among clones at different temperatures. Here it is necessary to re-emphasize that measurement of biomass production may be very misleading unless several points are borne in mind. First, apparent differences in shoot biomass production may actually reflect differences in partitioning dry matter to tubers. If two clones are equal in potential biomass production under an environment where both produce only shoots and roots, but one is more strongly induced to tuberize under the conditions of the test, then the more highly induced clone will produce smaller shoots but greater total biomass. (Within limits, the total biomass production of a given clone generally is increased when tuberization is increased). Thus comparisons should be made under conditions where tuberization is more or less equal among clones; or, if this is not possible, appropriate allowances should be made.

Also, there is the distinction between overall vigor at all temperatures and the ability to minimize vigor losses as temperatures rise. The CIP clone 'LT-1' typically shows more vigorous growth and higher biomass production than most other cultivars when grown under ideal temperatures[1]. If it maintains this same relationship when grown under heat stress, then even though actual biomass production drops it would still have a comparative advantage. Contrast this with a hypothetical cultivar that is similar to standard cultivars when grown under cool temperatures, but which suffers less loss of production than do the others when the temperature is increased. Both sources of vigor at high temperature may be useful to the breeder, but it is desirable to know which is operating when a given clone performs well in the heat. The distinction between the two cases can only be detected by growing the clones in cool as well as warm temperatures.

With these caveats in mind, let us consider possible reasons for heat tolerance as manifested in higher biomass production at high temperatures. The tolerant clone may be more efficient in production of assimilate, or it may more efficiently use the assimilate in growth. We are engaged in a cooperative research project to examine these possibilities. It is too early to state whether heat tolerant clones differ from other clones in their ability to carry out photosynthesis at high temperatures, in growth or maintenance respiration[18], or in growth rates. However, as more information becomes available on these questions, we want to be in a position to assess the importance of any differences detected. A powerful tool for such assessment is the computer simulation model.

SIMULATION OF POTATO GROWTH

Among several simulation models that have been published, we are examining two in particular.

One is for the 'Russet Burbank' as grown in Idaho[30]; the other is for the cultivar 'Desiree' grown in Israel[9,10]. Of the two models, the former is much more detailed in its attempts to simulate physiological processes. We are studying the models to see whether they can be adapted to heat tolerant clones and to other environments[36]. If so, then we hope to test the effects of any differences observed in photosynthesis, respiration, or maximum possible growth rates by inserting the new values into the code of the model and determining the effects in model simulations.

Growth Analysis

In order to evaluate the simulation models it is necessary to have appropriate data sets from field experiments. We are cooperating with researchers in many parts of the tropics to establish such experiments. The basic experimental design is to grow heat tolerant clones in replicated trials for growth analysis. Plants of each clone are harvested at intervals during the growing season, and the plants are separated into leaves, stems, and tubers. The dry matter present in each part is determined. Phenology of the plants and daily meteorological data are also collected.

Six clones, five of which are considered to possess some degree of heat tolerance, have been selected for the growth analysis experiments[36]. Locations of the trials include Israel, Tunisia, Peru, and Hawaii (three elevations on the island of Maui). For comparison, the clones are also grown in a temperate location (upstate New York). Cooperators in other countries have received the clones and have expressed interest in carrying out similar trials. The work is being coordinated through the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), a project funded by the United States Agency for International Development. The resulting data sets will be essential for adapting simulation models to tropical environments.

Other Uses of Simulation Models

If models can be developed for potatoes in the tropics, they can be put to other uses in addition to assessing the contribution of various physiological factors to heat tolerance[8]. Models should help in predicting whether potatoes can be grown economically at a given location. They should also aid in making management decisions such as when to plant and harvest, what cultivars to select, how and when to irrigate, and even what pest management practices should be followed for optimal returns.

CONCLUSION

Heat tolerance in potatoes may take many forms. Aspects of plant response to high temperature included in our own research or in studies with which we are collaborating are: ability of seed tubers to sprout and give good emergence when planted in hot soils; rates of dark respiration at high temperatures; growth response to temperature; relative importance of soil and air temperatures; effects of temperature on induction to tuberize; partitioning of dry matter as affected by temperature, including growth analyses of the same set of cultivars grown in various climatic zones; and the use of computer simulation models to study the relative contributions of various possible components of heat tolerance. Other aspects of heat tolerance that deserve consideration are differences between cultivars in the response curve of photosynthesis to temperature; degree of tissue damage from sudden exposure to hot, dry winds; and tolerance to drought induced by high temperature. There is no reason to expect that cultivars possessing tolerance to one aspect of heat stress will necessarily be tolerant in other respects.

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DISCUSSION

Q. (R.L. Villareal)
It seems in the complex picture of heat tolerance, both in tomato and potato, that it is practical to concentrate on one specific trait at a time. Has your team done any research to identify which of the different traits contributes most to the expression of heat tolerance?

A. We think that the partitioning to the tubers, that is, the ability of cuttings to form tubers under high temperature conditions, is a very important characteristic. But it is necessary to specify what sort of high temperature conditions we are concerned with, whether it is persistant high temperatures, or intermittent or even a single high temperature stress period.

If what is required is to perform well under continuous high temperature, then the ability to partition dry matter down to the tubers will be very important. This is reflected in the ability of cuttings taken from plants grown at high temperatures to tuberize. However, selection for this trait by itself is not enough, because when plants become highly induced to tuberize, all other organs stop growing. If plants are already growing slowly because of exposure to persistent high temperatures, selection for strong induction to tuberize may lead to stunted plants that have a high harvest index (the ratio of tuber dry weight to total plant dry weight), but a low tuber yield per hectare because of poor overall biomass production. Therefore degree of tuberization on cuttings is not sufficient as a selection criterion. It is necessary to add one more criterion, which is vigorous shoot growth under high temperature. By itself this would not be very helpful, because many of the selections would produce good shoot growth but with poor partitioning of assimilate to tubers. However, when we select simultaneously for both criteria, high tuberization on cuttings and vigorous shoot growth at high temperatures, then these selections are the ones that have done well in tests in the lowlands of Peru. I am sure that other criteria will ultimately be added to these two selection criteria.

In this question of biomass production, we should like to know whether photosynthesis or respiration is more important. In this respect, I think crop simulation with computers will be very helpful. It is very difficult to determine the effect of a 10% increase in photosynthesis, and compare this with a potential increase in respiration. However, with a computer simulation model, estimations could be made and we could use these in deciding the direction for future selection programs.

Q. (H. Imai)
Does the crop simulation model intended for use on potato include a stress evaluation for nitrogen, water and temperature?

A. We are trying to include these. If we want to be able to evaluate all these physiological factors we need to use a very complicated model. We have been working since about 1981 with the Ng and Loomis model, published in 1984, and are trying to perfect it. However, the assumptions in that model include no stress, a well watered soil and an adequate supply of nutrients. We should like eventually to modify that model for the kinds of things you talk about, but first we must make it work for normal conditions. To achieve this we now have a series of cooperators doing growth analysis experiments in cooperation with the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) in various places in the world. There are sites in Hawaii at three elevations on the island of Mauii. In Tunisia there are also a series of experiments, and at each of these locations the same six heat tolerant varieties are being tested. However, it will take many years before we can collate all the information.

Q. (A. Sajjapongse)
There are many factors controlling tuberization of potato – temperature just one of them. I understand that the availability of nitrogen is another important factor, and that interruption of the nitrogen supply, especially just prior to tuber initiation, can increase the tuberization rate. Can you comment on this, please?

A. Another big factor to consider is the photoperiod. The research that you refer to is on intermittent nitrogen effect, carried out by Dr. Adol Krauss and his colleagues in Germany. Their work has shown that if nitrogen is supplied intermittently to the roots of potato plants grown in a nutrient solution, the tubers form like pearls on a string. The potatoes were grown in the greenhouse, with their roots separated from the stolons in separate chambers. Through this unique set-up, a continuous or an intermittent nitrogen supply could be provided to the roots. With the continuous nitrogen, the stolons would grow out normally and tubers would not form.

This experiment was also conducted under low light intensity, and I do not know whether anyone has attempted it in the field where there is higher irradiance. We also know that irradiance level has an effect on tuberization, with high irradiance favoring tuberization, and low irradiation favoring partitioning to the tops.

It is, however, very clear from field experiments that a good supply of nitrogen favors partitioning to the tops in potato. Eventually, there may be a high yield in terms of tons per hectare from a very high nitrogen rate: so much biomass is produced, that even though the portion partitioned to the tubers is relatively low, yields may still be better than with a controlled nitrogen supply.

Q. (A. Sajjapongse)
With sweet potato in field trials comparing the effects of a split nitrogen supply with a basal nitrogen application, we found that a split application improved the rate of tuberization. This was particularly marked when two applications were given 30 days apart, the second applied just prior to tuberization. This may be a related phenomenon to that observed in white potato.

A. To compare the two, it would be necessary to know not only the result in the tuberous roots, but also how much dry matter was in the tops of the sweet potato. Then we could look at the change in the percentage and the harvest index. There is an important distinction.

Q. (M. Thongjiem)
At the Department of Agriculture, Chiang Mai University, we have been testing many heat tolerant potato cultivars from CIP and other sources. We have found that most of the heat tolerant cultivars have small tubers. Is there any correlation between heat tolerance and tuber size?

A. Not as such, but in terms of the selection process you encounter a problem. As a survival strategy, the wild potato tends to set as many tubers as possible, rather than producing one big tuber. The basic genes in the potato are therefore for as many tubers as possible, and it takes a conscious effort in selection by the plant breeder to change this. Consequently, the plant breeder who is concentrating on the question of high yields in terms of tons per hectare will tend to achieve these high yields through a heavy set and a small average tuber size. The breeding material you are testing is not yet at the final stage, and tuber size would not probably have been adequately emphasized in selection. The smaller size is therefore unlikely to be related to heat tolerance, and more likely to be related to the stage of the process of selection you are at when testing the unfinished material.

PERFORMANCE OF SOME HEAT TOLERANT TOMATOES IN ST. LUCIA, EAST CARIBBEAN

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ABSTRACT

Three field experiments were conducted to identify tomato varieties which could be grown successfully under the tropical lowland conditions of St. Lucia. A total of thirty-five varieties were evaluated. From the information on yield and yield attributes, it appears that Caraibe is somewhat heat sensitive and not suitable for growing during the hot season. The most heat tolerant varieties which were suitable for the hot season were CL 5915-222D_4-0-4-0, CL 5915-229D_4-1-5-0 and CL 5915-229D_4-1-1-0.

(Chinese Abstract) 摘　要

三次田間試驗確認番茄品種能成功的栽培在St. Lucia地區的熱帶平地。總計評估35個品種。由產量調查，Caraibe為不耐熱品種，不適合在熱季栽培。耐熱並適合夏季栽培品種有CL 5915−222D_4−0−4−0，CL 5915−229D_4−1−5−0，及CL 5915−229D_4−1−1−0。

(Japanese Abstract) 摘　要

St. Luciaの熱帶の水田で生育の良いトマト品種を特定するための圃場試験を行なつた。全部で35品種の検定を行つたが、caraibe 品種は收量や收獲特性から考えて若干高温に弱く高温期の栽培には向かない。高温期に適した高温耐性の品種はCL 5915−222D_4−0−4−0, CL 5915−229D_4−1−5−0, CL 5915−229D_4−1−1−0 であつた。

(Korean Abstract) 적　요

열대성 평지의 조건을 가진 St.Lucia 지역에 재배하여 성공을 거둘수 있는 토마토품종의 현지 확인시험이 3차례 실시 되었다. 이 시험에서 모두 35종의 품종을 평가 하였다. 그 결과 Caraibe는 열에 민감하고 더운 기절에의 재배가 좋지 않다는 것이 판명되었다. 이 계절에 재배하기 좋은 내열성이 강한 품종은 CL 5915-222D_4-0-0,CL5915-229D_4-1-5-0 및 CL 5915-229D_4-1-1-0을 들 수 있다.

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INTRODUCTION

Tomato is one of the most important crops in the eastern Caribbean. It is planted all year round in the region and demand for the crop is high. However yields are generally low, particularly during the hot summer season. One of the main reasons is the poor fruit-setting of the crop under high temperatures (over 24°C). To improve the situation, high yielding, heat tolerant varieties were sought.

The Caribbean Agricultural Research and Development Institute (CARDI), in cooperation with the Asian Vegetable Research and Development Center (AVRDC), evaluated some of the heat tolerant varieties bred at AVRDC in comparison with local checks. The objective of this project was to identify tomato varieties that could yield well during the hot, wet season (off-season, May to November) and/or cool season (in-season, December to April). This paper reports three experiments, one conducted in a farmer's field and the others at CARDI's field station.

MATERIALS AND METHODS

Experiment I

This experiment was conducted at the field station at La Resource, about 28 km southeast of Castries. A randomized complete block design with three replications was used. Thirteen processing tomato varieties, i.e., TK 70, TN 2, TM 103, PT 778, PT 858, PT 862, PT 913, PT 1017, PT 1599, PT 3027 and three commonly grown local varieties – Calypso, Caraibe and Indian River, were evaluated.

Seedling preparation

Nursery soil for 13 flats (8.0 x 32.0 x 45.5 cm inside dimension) was prepared by thoroughly mixing 1:2 ratio (by volume) of Irish moss peat to moist soil with 23.4 gm ammonium sulphate, 39.0 gm of triple superphosphate and 23.4 gm of potassium chloride. Flats were then filled with the soil and dibbled to make fifty-four (6 x 9) planting holes per flat. Two seeds per hole of each variety were sown in the flats on 22 October 1984. The flats were kept in the field, covered with nylon net, and watered when necessary. Ten days after emergence, the seedlings were thinned to one plant per hole. They were grown until most of them had five true leaves.

Field planting

About two weeks before transplanting, paraquat was applied to the field to eliminate grasses. Later, raised beds of 0.7 x 11 m and 0.4 m high were constructed manually. The beds were separated by furrows 0.5 m wide. Individual beds were divided into three plots, each 3 m long with two 1 m walkways separating the plots.

Each plot received 80 kg N/ha, 100 kg P_2O/ha and 80 kg K_2O/ha as basal fertilizer mixed into the soil before transplanting. Twenty-eight day old seedlings were transplanted on 19th November 1984, planted in one row per plot and spaced 0.3 m apart within each row. The plants received two additional sidedressings, each of 40 kg N/ha and 40 kg K_2O/ha at two and four weeks after transplanting (WAT). Disease and insect pests were controlled by spraying Maneb and Basudin every ten days. Weeds were controlled manually. The crop was harvested weekly from 11th January to 22nd February 1985.

Experiment II

This experiment was conducted in a farmer's field at Grand Riviere in the northern part of the country. A total of 21 varieties were evaluated. This included the three highest yielders from the first experiment, i.e. PT 858, PT 862, and PT 913; 17 new heat tolerant materials from AVRDC, i.e. CL 1113-0-0-7-2-0-11, CL 5915-371D_4-1-2-0, CL 5915-314D_4-1-1-0, CL 5915-153D_4-3-6-0, CL 5915-206D_4-2-5-0, CL 5915-206D_4-2-1-0, CL 5915-223D_4-2-1-0, CL 5915-229D_4-1-5-0, CL 5915-39D_4-1-4-0, CL 5915-204D_4-1-2-0, CL 5915-229D_4-1-1-0, CL 5915-223D_4-3-2-0, CL 5915-136D_4-1-0, CL 5915-223D_4-3-1-0, CL 5915-223D_4-2-2-0, CL 5915-222D_4-0-4-0, CL 5916-214D_4-1-4-0, and a recommended variety, Caraibe. The experiment was carried out in a randomized complete block design with two replications.

Seedling preparation

Seedling preparation was the same as in Experiment 1, except that Irish moss peat was not used. Seeds were sown in flats on 22nd February 1985.

Field planting

Four raised beds, each of 1.5 x 24.2 m in size, were used. The beds were separated by furrows 34 cm wide and 45 cm deep. One week before transplanting, each bed received 23 kg of dolomitic lime and 900 gm of complete fertilizer 16-8-24 as basal application. Individual beds were then divided into eleven small plots of 1.5 x 1.6 m. The plots were separated by 60 cm wide walkways.

Twenty-four-day-old seedlings were transplanted on 17th March 1985, planted in two rows per plot with 40 cm between plants within each row and 100 cm between rows 8 plants per row. The fungicide Maneb and the insecticides Ambush and Kelthane were applied twice on 29th March and 14th April. On 29th April 1985, each plant received 20 gm of compound fertilizer 16-8-24 as a sidedress application. Weeding was done manually, and sprinkler irrigation was administered when necessary. The crops were harvested four times on May 5th, 11th, 16th, and 21th.

Experiment III

This experiment was conducted at the field station at La Resource during the hot season. A randomized complete block design with three replications was used. Fourteen varieties were evaluated, i.e., PT 870, PT 913, PT 1600, PT 1707, PT 1711, PT 3027, PT 4001, CL 1131-0-0-43-8-1, CL 1131-0-0-13-0-6, CL 5915-136D_4-1-0, CL 5915-229D_4-1-5-0, CL 5915-222D_4-0-4-0, CL 5915-229D_4-1-1-0 and Caraibe. Seeds were sown on 10th June 1985, and the seedlings were transplanted on 3rd July 1985. Plot size and other cultural practices were the same as in Experiment I. Fruits were harvested nine times during the period 26th August – 7th October 1985.

RESULTS AND DISCUSSION

Experiment I

Precipitation during the period of the experiment was minimal. Although irrigation from tap water was administered, this was inadequate and the plants frequently wilted, especially in the afternoon. This resulted in stunted and unhealthy plants. The temperature during the growing period ranged from 23.5° to 30.5°C, with an average mean monthly temperature of 27.1°C.

Yield and yield attributes are shown in Table 1. Varieties which yielded higher than the best local check, Caraibe, were PT 913 and PT 1017. The highest yielder was PT 913, which had the yield of 14.4 mt/ha. The lowest yields of 2.9 and 3.3 mt/ha were from Indian River and Calypso, respectively. The two cultivars popular in Taiwan, TN 2 and TK 70, did not yield better than the local checks. Lack of heat tolerance in these two cultivars contributed to their poor performance. Yield difference was due to differences in fruit size and number of fruits per plant. Although PT 913 and PT 1017 had the smallest fruits, they produced the highest number of fruits per plant. Large fruits were obtained from PT 858, PT 862, Caraibe, Calypso, and Indian River. PT 858 had the largest fruit size of 50.1 g/fruit.

Table 1 Yield and yield attributes of tomatoes of different tomato varieties grown during the dry season at La Resource

Varieties	Yield	Fruit size	Fruit number
	mt/ha	g/fruit	no./plant
TK 70	6.3	39.7	5.3
TN 2	4.3	34.4	4.6
Indian River	2.9	42.2	2.4
Calypso	3.3	42.3	2.8
Caraibe	7.0	43.7	5.7
TM 103	7.3	34.5	8.1
PT 778	8.6	38.5	8.1
PT 858	9.3	50.1	6.8
PT 862	10.4	44.5	8.5
PT 913	14.4	27.0	19.1
PT 1017	13.1	29.9	15.8
PT 1599	8.4	35.1	8.7
PT 3027	10.3	32.0	11.4
L.S.D. (0.05)	4.0	10.4	4.1
(0.01)	5.4	14.2	5.0

The results showed that Caraibe outyielded the other two local checks. This is due mainly to the larger number of fruits per plant. Observation revealed that varieties like PT 1017 and PT 913, which had small fruit size and high yield, showed no apparent wilting under the prevailing dry conditions.

Based on the yield performance, the following varieties were kept for further evaluation: PT 913, PT 1017, PT 858, PT 862 and PT 3027.

Experiment II

The mean monthly maximum temperatures during the growing period ranged from 28.2° to 29.4°C, whereas the mean monthly minimum temperatures ranged from 21.0° to 22.7°C.

Unlike the first experiment, water was not a limiting factor in this trial. Late blight was a serious problem, although the fungicide Maneb was applied. This may have been due to inadequate application of the fungicide (only two applications were made throughout the growing period). The disease incidence was first observed during the first week of May.

The number of fruit from different harvests is presented in Table 2. All varieties, except PT 913, CL 5915-153D_4-3-6-0, CL 5915-223D_4-3-1-0, CL 5915-223D_4-2-2-0, had an earlier harvest than the check, Caraibe. In general, more fruits were obtained from the third and fourth harvests than from the first two harvests. Most of the varieties produced more fruits than Caraibe, except PT 858, PT 862, CL 5915-371D_4-1-2-0, CL 5915-314D_4-1-1-0, CL 5915-206D_4-2-5-0, CL 5915-206D_4-2-1-0, CL 5915-223D_4-2-1-0, and CL 5915-214D_4-1-4-0. The most prolific varieties were CL 5915-222D_4-0-4-0, CL 5915-136D_4-1-0, CL 5915-229D_4-1-5-0, CL 5915-229D_4-1-1-0, and PT 913.

Table 2 Number of fruits from various harvests of different tomato varieties grown at Grand Rivière, St. Lucia

Variety	Harvest				
	1st	2nd	3rd	4th	Total
	no./plot				
PT 858	14.5	18.5	27.5	3.5	64.0
PT 862	20.0	32.0	31.0	22.5	105.5
PT 913	N	12.0	60.5	169.0	241.5
PT 1600	9.5	32.0	38.5	99.5	179.5
CL 1131-0-0-7-2-0-11	12.0	36.5	50.0	110.5	209.0
CL 5915-371D_4-1-2-0	17.0	9.0	22.0	60.0	108.0
CL 5915-314D_4-1-1-0	14.6	58.0	54.0	N	126.6
CL 5915-153D_4-3-6-0	N	21.3	60.6	121.3	203.2
CL 5915-206D_4-2-5-0	1.0	12.5	20.5	62.5	96.5
CL 5915-206D_4-2-1-0	3.5	15.5	28.0	40.0	87.0
CL 5915-223D_4-2-1-0	0.5	19.5	38.0	64.6	122.5
CL 5915-229D_4-1-5-0	3.0	36.0	79.5	121.0	239.5
CL 5915-39D_4-1-4-0	18.5	42.0	60.0	16.0	136.5
CL 5915-204D_4-1-2-0	14.5	23.5	54.5	95.0	187.5
CL 5915-229D_4-1-1-0	8.5	53.5	97.5	75.5	235.0
CL 5915-136D_4-1-0	18.0	56.0	78.0	131.0	283.0
CL 5915-223D_4-3-1-0	N	12.0	54.0	99.0	165.0
CL 5915-223D_4-2-2-0	N	19.4	44.0	85.4	148.8
CL 5915-222D_4-0-4-0	29.0	55.5	96.5	120.5	301.5
CL 5916-214D_4-1-4-0	16.5	22.0	36.0	20.0	94.5
Caraibe	N	3.0	20.0	36.0	59.0
L.S.D. (0.05)	8.0	15.0	30.0	57.1	72.8
(0.01)	11.0	20.4	42.0	77.8	99.2

N = No harvest

Table 3 Fruit sizes from various harvests of different tomato varieties grown at Grand Rivière, St. Lucia

Variety	Harvest			
	1st	2nd	3rd	4th
	g/fruit			
PT 858	122.0	81.6	56.6	78.6
PT 862	72.7	67.8	53.2	45.8
PT 913	N	57.2	48.2	31.2
PT 1600	84.1	81.8	62.0	42.8
CL 1131-0-0-7-2-0-11	52.4	49.1	33.8	25.8
CL 5915-371D_4-1-2-0	42.1	41.6	44.4	42.1
CL 5915-314D_4-1-1-0	46.7	39.2	27.8	N
CL 5915-153D_4-3-6-0	N	27.2	45.2	35.0
CL 5915-206D_4-2-5-0	125.0	108.6	84.2	53.1
CL 5915-206D_4-2-1-0	128.6	94.7	79.8	57.8
CL 5915-223D_4-2-1-0	150.0	67.6	50.4	39.0
CL 5915-229D_4-1-5-0	83.3	73.2	57.9	43.6
CL 5915-39D_4-1-4-0	61.2	54.8	34.8	25.8
CL 5915-204D_4-1-2-0	45.7	46.8	40.0	31.4
CL 5915-229D_4-1-1-0	82.2	64.6	45.0	34.8
CL 5915-136D_4-1-0	62.2	52.8	43.9	33.6
CL 5915-223D_4-3-1-0	N	64.6	53.1	36.2
CL 5915-223D_4-2-2-0	N	71.5	58.0	42.6
CL 5915-222D_4-0-4-0	49.2	44.2	35.8	31.5
CL 5916-214D_4-1-4-0	69.6	72.2	54.4	45.5
Caraibe	N	114.5	125.2	73.8
L.S.D. (0.05)	NS	33.9	17.5	28.9
(0.01)	NS	46.2	23.8	NS

N = No harvest

Fruit size varied considerably between varieties and time of harvest (Table 3). Most of the varieties gave decreasing fruit sizes with succeeding harvests. The largest fruit size came from the first harvest and the smallest from the fourth harvest. From all harvests, Caraibe gave the largest fruit size, i.e. 114.5, 125.2, and 73.8 g/fruit for the second, third and fourth harvests, respectively.

Yield and yield attributes are presented in Table 4. Yield differences between varieties were highly significant. There were five varieties which out-yielded Caraibe. These varieties were PT 1600, CL 5915-229D_4-1-5-0, CL 5915-229D_4-1-1-0, CL 5915-136D_4-1-0, and CL 5915-222D_4-0-4-0, which yielded 34.5, 44.0, 38.7, 40.8 and 38.9 mt/ha, respectively. The yield from Caraibe was 19.2 mt/ha. PT 858 and PT 862, two of the best varieties in Experiment I, did not yield higher than Caraibe. In addition, PT 858 was susceptible to fusarium wilt and PT 862 to blossom end rot. The tomato with small fruit, PT 913, gave a reasonably high yield (30.5 mt/ha), although not significantly better than Caraibe. Yield differences were due to fruit size and number of fruits per plant. All of the five best yielders and PT 913 had more fruits per plant than Caraibe, although their fruits were smaller.

Table 4 Yield and yield attributes of different tomato varieties grown at Grand Rivière, St. Lucia

Variety	Yield	Yield attributes	
		Fruit size	Number of fruit
	mt/ha	g/fruit	no./plant
PT 858	18.3	81.5	8.0
PT 862	21.6	59.1	13.2
PT 913	30.5	36.6	30.2
PT 1600	34.5	57.2	22.4
CL 1131-0-0-7-2-0-11	24.0	33.5	26.1
CL 5915-371D_4-1-2-0	15.7	42.4	13.5
CL 5915-314D_4-1-1-0	15.3	35.1	11.9
CL 5915-153D_4-3-6-0	27.2	38.7	19.1
CL 5915-206D_4-2-5-0	22.2	67.8	12.1
CL 5915-206D_4-2-1-0	22.4	73.3	10.9
CL 5915-223D_4-2-1-0	20.1	42.9	15.3
CL 5915-229D_4-1-5-0	44.0	53.5	29.9
CL 5915-39D_4-1-4-0	20.5	43.6	17.1
CL 5915-204D_4-1-2-0	23.7	37.1	23.4
CL 5915-229D_4-1-1-0	38.7	47.9	29.4
CL 5915-136D_4-1-0	40.8	41.8	35.4
CL 5915-223D_4-3-1-0	25.2	44.2	20.6
CL 5915-223D_4-2-2 0	26.0	50.9	13.9
CL 5915-222D_4-0-4-0	38.9	37.0	37.7
CL 5916-214D_4-1-4-0	19.1	58.8	11.8
Caraibe	19.2	94.9	7.4
L.S.D. (0.05)	13.8	11.4	9.1
(0.01)	18.8	15.5	12.4

Based on yield performance, the following varieties were kept for further evaluation: PT 913, PT 1600, CL 5915-229D_4-1-5-0, CL 5915-229D_4-1-1-0, CL 5915-222D_4-0-4-0 and CL 5915-136D_4-1-0.

Experiment III

The temperature during the growing period ranged from 24.0° to 30°C, with an average mean monthly temperature of 28.3°C.

Table 5 shows the yield and yield attributes of all varieties evaluated. Although the field was badly infested by early blight, differences in performance between varieties were still evident.

Table 5 Yield and yield attributes of different tomato varieties grown at La Resource, 1985[2]

Variety	Yield	Yield component	
		Fruit size	Fruit no.
	mt/ha	g/fruit	no./plant
PT 870	19.2 a-d	45.0 bc	9.1 de
PT 913	19.0 a-d	34.8 cf	17.4 abc
PT 1600	22.7 abc	50.1 b	11.5 cde
PT 1707	7.9 d	36.1 cde	7.0 e
PT 1171	15.7 bcd	37.6 cd	12.6 cde
PT 3027	23.4 abc	33.2 def	17.0 a-d
PT 4001	18.5 a-d	35.5 cde	12.0 cde
CL 1131-0-0-43-8-1	23.7 abc	30.6 def	21.8 ab
CL 1131-0-0-13-0-6	15.4 cd	26.2 ef	15.8 bcd
CL 5915-136D_4-1-0	19.9 a-d	29.1 def	22.7 a
CL 5915-229D_4-1-5-0	27.8 ab	35.6 cde	15.8 bcd
CL 5915-222D_4-0-4-0	28.6 a	24.3 f	24.2 a
CL 5915-229D_4-1-1-0	26.9 abc	36.1 cde	18.6 abc
Caraibe	19.6 a-d	81.7 a	5.3 e

[2] Means within a column followed by the same letter are not significantly different at the 5% level by DMRT

The difference in fruit prolificacy between varieties was very obvious. The most prolific varieties were CL 5915-222D_4-0-4-0, CL 5915-136D_4-1-0, CL 1131-0-0-43-8-1 and CL 5915-229D_4-1-1-0. CL 5915-229D_4-1-5-0 was as prolific as CL 5915-229D_4-1-1-0. The least prolific varieties were Caraibe, PT 1707 and PT 870. Fruit size difference also existed among the varieties tested. Caraibe had the largest fruit of 81.7 g, whereas CL 5915-222D_4-0-4-0 had the smallest of 24.3 g. The sizes of all the other varieties were intermediate. Differences in these characteristics resulted in differences in yield. PT 1707 had the lowest yield (7.0 mt/ha) because it produced the fewest fruits with rather small size. Caraibe, a large-fruited variety, gave a high yield (19.6 mt/ha) but one which was not significantly better than PT 1707. The best varieties were CL 5915-222D_4-0-4-0, CL 5915-229D_4-1-5-C and CL 5915-229D_4-1-1-0, which yielded 28.6, 27.8 and 26.9 mt/ha, respectively.

DISCUSSION

Q. (S. Kosiyachinda)
In your studies of tomato in St. Lucia, did you also look at the quality of the lines, in terms of whether they were suited for table or processing markets?

A. Since our objective was to identify a variety that can be grown during the hot wet season, emphasizing yield performance, we did not make any special assessment of quality. Generally, however, there is a problem of incorporating good quality into heat tolerant lines.

ASPARAGUS BREEDING IN SUBTROPICAL TAIWAN

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ABSTRACT

The asparagus mother stalk cultural method practiced in Taiwan is adaptable to tropical and subtropical climates. There are many differences from conventional temperate climate cultivation, and tropical cultivars need to be selected for early yield, brush vigor and tightness of tip attachment under hot humid conditions. In Taiwan, breeding asparagus by mass selection has proved successful over the years, and has produced the lines Tainan Selection No. 1, T.S. No. 2 and T.S. No. 3. Hybridization programs and the breeding of all-male cultivars are still at the research stage.

(Chinese Abstract)

摘　要

臺灣現行的蘆筍留母茎栽培方法適用於熱帶和亞熱帶氣候。由於留母茎方法與傳統温帶地區的栽培法有所不同，是故應在炎熱潮濕的環境下選育早生、植株強健和嫩茎尖端緊密的栽培品種。臺灣利用集團選種方法選育出臺南選一號，臺南選二號和臺南選三號，多年來證明非常成功。此外蘆筍的雜交育種和全雄性育種工作尚在研究進行中。

(Japanese Abstract)

摘　要

台湾で行われているアスパラガス母茎の栽培法は熱帯、亞熱帯の氣候に適している。これは温帯で慣行されている栽培法とは多くの點で異なつており、熱帯に適する品種は、高温、高湿下で、早生、叢生の強さ、先端のしつかりした付着について選抜する必要がある。臺湾では集團選抜による育種にここ数年来成功し、台南1號、2號、3號を育成した。交配による育種計畫、および雄株のみの品種の育成はまだ研究段階である。

(Korean Abstract)

적　요

현재 대만에서 실시되는 아스파라가스의 모경재배 방법은 열대 및 아열대기후에 적용되는 것이다. 전통적으로 온대기후에서 재배되는 것과는 차이가 많은데, 열대에서는 더운 습도 조건하에 재배될수 있는 조생종을 요하며 식물의 활력이 강하고 상부의 부착상태가 탄탄해야 한다.

대만에서는 아스파라가스 재배에 품종의 집단선정 방법을 이용한 것이 매우 성공적이 었으며, 타이난 선정 1호, 타이난선정 2호, 타이난 선정 3호를 생산해 왔다. 그외에 아스파라가스의 교잡품종과 전부 수컷 품종으로의 육종연구가 진행되고 있다.

ASPARAGUS BREEDING IN SUBTROPICAL TAIWAN

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INTRODUCTION

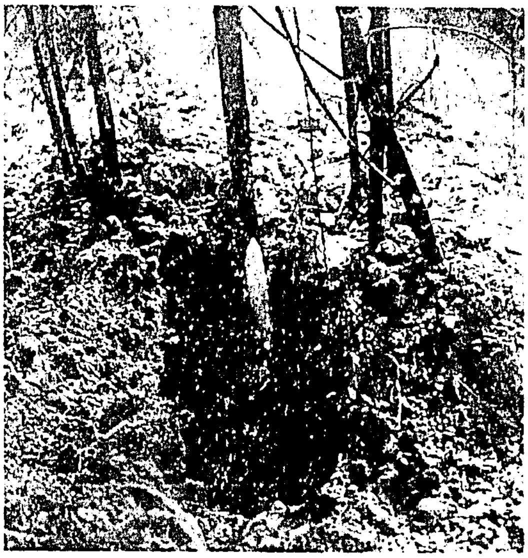
Asparagus has been grown in Taiwan since 1963. It came as a suprise to temperate asparagus producers that Taiwan's asparagus production in subtropical conditions could surpass their own in both total production and average yield. Taiwan soon became the world's leading exporter of canned asparagus (Table 1). An essential part of this success was the mother stalk cultural practice developed for subtropical conditions. As no entirely suitable cultivars are yet available, it is necessary for Taiwan to breed asparagus which will give high, good quality yields under local climatic conditions and cultivation methods.

SPECIAL ASPECTS OF ASPARAGUS CULTIVATION IN TAIWAN

Taiwan asparagus growers follow the mother stalk cultural practice, which varies significantly from the methods used by temperate climate asparagus growers (Table 2)[9]. Experiments comparing the conventional and mother stalk cultivation methods were conducted by Wang (1965)[16] and Lin (1968)[12], and proved the necessity of the latter in the hot humid climate of Taiwan.

The Mother Stalk Method

In the asparagus mother stalk cultural method[16,17,18], a few stalks are left on each plant at the spring harvest. These stalks carry on growth to supply photosynthates for the plant throughout the harvest. In high temperatures, these stalks senesce after two to three months. To allow for this, a staggered turnover of stalks of different ages is maintained, to ensure a high level of photosynthetic efficiency. All above ground ferns need to be cut back 2-3 times each year, to control the severe disease and insect pest problems experienced in the tropics. Fertilizers are applied after harvesting in late autumn, and the plants grow throughout the winter after a very brief rest period.



White asparagus spears grown under the mother-stalk cultivation practice

Seed Supply Problems

The difficulty in obtaining quality seeds from the United States over recent years has been acting as a stimulus to Taiwan's seed production program. In the early stages of Taiwan's asparagus growing and canning industry, supplies of quality seed from the United States were readily available. Over the

Table 1. Production and export of asparagus in Taiwan from 1963 to 1985

Year	Planted area*	Production	Unit yield	Export**	Export value**	Unit price
	(ha)	(mt)	(kg/ha)	(std. case)	(US$)	(US$/std. case)
1963	105	441	4,200	335	4,355	13.00
1964	270	616	2,280	33,244	410,952	12.36
1965	9,533	16,776	1,760	801,039	11,047,654	13.79
1966	10,877	44,120	4,056	916,328	14,218,221	15.52
1967	8,002	31,010	3,875	1,744,509	23,956,381	13.73
1968	6,385	51,583	8,075	2,136,386	28,827,137	13.49
1969	8,315	67,679	9,003	3,353,314	38,866,254	11.59
1970	12,588	112,331	9,658	3,723,417	35,573,382	9.55
1971	17,456	127,517	7,305	4,017,814	35,043,829	8.72
1972	15,918	106,602	6,697	3,376,303	39,680,331	11.75
1973	16,146	112,477	7,173	3,741,974	55,207,178	14.75
1974	17,353	111,146	6,419	3,493,318	84,826,979	24.28
1975	17,636	80,113	4,607	3,659,566	78,893,259	21.56
1976	13,005	93,986	7,265	3,899,399	97,020,879	24.88
1977	13,839	102,117	7,432	2,835,369	79,103,052	27.90
1978	12,610	97,393	7,750	4,344,340	117,870,770	27.13
1979	13,512	102,837	7,631	3,509,110	110,597,958	31.52
1980	12,429	112,871	9,082	3,937,816	135,658,724	34.45
1981	12,458	81,338	6,576	3,057,606	101,171,746	33.09
1982	11,256	52,808	4,700	2,656,715	88,183,671	33.19
1983	9,505	45,638	4,804	1,758,927	60,878,623	34.61
1984	9,647	54,143	5,760	1,665,485	60,716,515	36.46
1985	10,026	62,068	6,268	1,136,123	35,837,875	31.54

* Source from Taiwan Agricultural Yearbook

** Source from Taiwan Exports of Canned Food

Prepared by Council of Agriculture, Executive Yuan, Taiwan, R.O.C.

Table 2 Comparison of two asparagus cultural methods, the mother stalk and the conventional method

Item	Mother stalk method (e.g. Taiwan)	Conventional method (e.g. U.S.A.)
Seedling period	4-5 months	one year
Setting in field	seedling	crown
No. stalks left during harvesting period	few	nil
Region to which it is adapted	subtropics and tropics	temperate zone
Crown condition after a few years	decay in central part	little or no decay
Pinching top of stalks to limit plant height to 1 m	yes	nil
Growing period in a year	10-12 months	shorter growing season
Time of first harvest	within one year	2nd or 3rd year
Harvesting period	spring and autumn	spring
Average yield per hectare (kg)	7,000-8,000	3,000-4,000
Amount of fertilizer applied	more	less
Resting period	0-1.5 months	much longer
Profitable production period	approx. 8 years	10-12 years

years, as Taiwan became an effective competitor in the European canned asparagus market, the quality of seed supplied to Taiwan by the United States has tended to decline – it is sometimes not true to name, and has a lower germination rate. High seed costs, and also the red tape involved in buying seed from overseas, have combined to result in a shortage of asparagus seeed in Taiwan.

ASPARAGUS BREEDING IN TAIWAN

It is necessary for Taiwan to have a strong asparagus breeding program to select and breed varieties suitable for subtropical and tropical conditions, and for the different cultural practices found in Taiwan[2]. Traditionally, all major asparagus production was carried out under temperate conditions and harvested only in spring, after a long winter dormancy. All the cultivars available were bred for these conditions.

Initial Selection

The breeding program in Taiwan has identified varieties which respond better to Taiwan's conditions[7]. The Taipei District Agricultural Improvement Station (Taipei DAIS) conducted a four cultivar trial in 1957-1961. At that time, Mary Washington was the best known cultivar for Taiwan. The Feng-shan Tropical Horticultural Experiment Station conducted a ten cultivar trial, 1967-1971, in which UC711 proved the best. The Quamoy Agricultural Experiment Station conducted a five cultivar trial in 1968, and identified UC500 as the best. Overall, the trials have shown the Californian UC cultivars to be more suitable for Taiwan's conditions than the New Jersey and European cultivars.

Yield

Agricultural extension workers have reported that farmers collecting open pollinated seeds from commercial asparagus fields in Taiwan get high yields but poor quality spears from the progeny[1], which seriously affects the canning quality. The yield increase was assumed to be due to first generation acclimatization, the genotype adapted to the new environment being increased in the population by the farmers' selection technique. The inferior quality of the spears, on the other hand, could have been the result of gene degeneration in related traits with open pollination. Ellison[2] has pointed out that local adaptation is very important in the performance of asparagus cultivars, and has a great effect on yield. There is a great demand from growers for high yielding asparagus varieties adapted to the local environment, and the selection of better plants in older asparagus fields is a good method of selecting for the ability to adapt.

Quality of Spears

Loose spear tip attachment, which seriously affects canning quality, is a common problem in asparagus grown under high temperatures. Ellison[2] recognized a good correlation between a tight tip attachment at the spring harvest, and the height of branching in the summer stalks. Selection based on this criterion is being attempted in Taiwan in order to improve the quality of the spears.

SELECTION OF SUPERIOR ASPARAGUS PLANTS

Huyskes (1959)[10] has reported that male and female asparagus parent plants have an equivalent effect on the characters expressed in open pollinated female progeny. However, the genetic characteristics of an open pollinated female plant are unreliable in progeny tests, and therefore in breeding for quality seed production it is essential to select both good male and good female plants.

Plant Vigor

Formerly, in temperate climates, selection depended on meticulous investigation during the 4-8 weeks of spring growth. However, researchers are now developing methods to accelerate this selection process, in which plant vigor is used as a criterion. Ellison and Scheer[3] in 1958 stated that the yield potential of male and female plants is highly correlated with stalk growth over the preceding years. A positive correlation exists, both between the number of the stalks and the number of spears, and between the diameter of the stalks and the diameter of the spears. This information is useful to breeders when yield records are inadequate. In Taiwan, the longer harvest period provides a greater opportunity for direct selection based on yield traits, and plant vigor can be investigated as a selection index after harvesting in late autumn.

Early Yield

Ellison and Schermerhorn (1958)[4] discovered that plants with many early spears in spring gave a high yield. When they compared plants with five spears on the first day of spring with the controls, they found that over two successive years the former gave yields which were 42% and 94% higher, respectively, and furthermore that the trend continued over six successive years. Positive correlations were established between early yield in the first two weeks of spring, and total yield. Thus, the number of early season large spears is a criterion for selection, and may be applied as a simpler selection index than total yield under Taiwan's conditions.

Plant Vigor and Early Yield

Ellison, Scheer and Wagner (1960)[5] stated that the most desirable plants, namely those with a high yield of large spears, tend to produce an early yield, and are also characterized by high brush vigor (reflected in the number and diameter of stalks) and early spears with a broad diameter. A plant ranking low in any one of these characteristics was considered undesirable. These characteristics correlated closely with yield and could be used as alternative selection indices. Ellison *et al.*[6] showed that the best estimates of comparative yields of different asparagus strains were based on both early yield in the same season and brush vigor during the previous fall. Both these selection criteria should be applicable under a wide range of ecological conditions.

CURRENT METHODS OF ASPARAGUS BREEDING IN TAIWAN

Mass Selection

Mass selection is a basic means of asparagus improvement which can be carried out with a limited budget and resources. Superior male and female plants are selected from established asparagus fields and isolated for seed production. The Tainan District Agricultural Improvement Station has used this method in selecting for adaptation to local conditions, yield, spear quality, and disease and pest resistance. The three asparagus cultivars Tainan Selection No. 1, T.S. No. 2 and T.S. No. 3 which the Station has released have been well received by growers. These were derived from UC309, Mary Washington and UC711, respectively. Nichols (1985)[13] conducted a variety trial in New Zealand on 41 asparagus cultivars, including Tainan Selection No. 1. His results rated Jersey Giant (56 x 22-8) from Rutgers University as the best, with Tainan Selection No. 1 and Minerve equal second (Table 3). Nichols plans further trials in an International Asparagus Cultivar Trial[14] over a wide range of environments.

Table 3 Yield results from asparagus cultivar trial: 1983 and 1984[13]

	Total yield (mt/ha)			Market yield			1984 only		
Cultivar	1983	1984	1983+1984	1983	1984	1983+1984	Butts (%)	Reject (%)	Cross value ($/ha)
56 x 22-8	2.94	10.27	13.66	1.76	6.25	8.28	30.8	8.0	11,534
Minerve	3.75	8.92	12.62	2.67	4.95	7.62	27.9	16.2	8,302
Tainan No. 1	2.57	9.00	11.57	2.25	4.96	7.21	30.5	15.1	8,668

Hybridization Breeding

Hybridization is more demanding in terms of space, equipment and researchers' time than mass selection. Superior plants from mass selection trials provide the basic genetic material. After further selection, the plants are crossed in various combinations to find the best cross based on evaluation of progeny performance in different locations. The Tainan District Agricultural Improvement Station is carrying out progeny testing in hybridization programs, and if the best resultant cross proves satisfactory it will be released as a new cultivar.

All-male Asparagus

H.S. Tsay[15], of the Taiwan Agricultural Research Institute, and researchers at the Tainan District Agricultural Experiment Station are carrying on work breeding all-male asparagus. Anther culture and chromosome doubling are used to produce the superior male plant. The superior male plant is then crossed to a good female plant to give an all-male asparagus cultivar.

FUTURE PROSPECTS FOR ASPARAGUS BREEDING

All-male and All-female Asparagus

All-male breeding is the current trend in asparagus breeding, for the sake of the more numerous spears produced. Several all-male cultivars have already been released throughout the world. All-male asparagus breeding is now in progress in Taiwan, as described above.

As an interim measure, prior to release of an all-male cultivar adapted to Taiwan's high temperature and humidity, female seedlings derived from other research[8] should be planted in an isolated location where they will not be pollinated by male plants. Such isolated female plants will not set seed, but will produce more spears. This management practice will give some saving in seed costs and result in a harvest of larger spears.

Persistant Green Asparagus

A trait for persistant green color in asparagus was identified by Irizarry *et al.*[11]. Plants which have the persistant green trait maintain dark green stalks and foliage in the autumn, when other plants turn yellow or brown. These persistant green plants extend their period of photosynthesis and accumulate more carbohydrates for production of spears in the following spring. In southern Taiwan, where the dormancy period is brief, the persistent green asparagus cultivars may have great advantages for the production of green asparagus during the winter. The persistent green color character is a single recessive gene, and could be easily transfered to local cultivars as a means of increasing the level of adaptation to Taiwan's climate.

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DISCUSSION

Q. (S. Kosujachinda)
Do you have any information on the relative quality of the spears from female and male asparagus plants? Is there any quality difference between white and green spears?

A. I don't think there is any difference in quality between male and female asparagus spears, except with respect to size: the female is the larger. However, the number of spears on the male plant is greater, giving a greater yield overall. This is why all male asparagus is wanted. The green asparagus is said to be more nutritious than the white, but the white is preferred by European consumers. In fact, because white asparagus has to be dug out, it is more difficult to harvest, but the green asparagus gives about 25% lower yield.

Q. (R.L. Villareal)
What is being done to solve the problem of center rot in asparagus in Taiwan?

A. This is not such a serious problem in Taiwan as in the U.S.A. and other parts of the world. We do not know why it is less of a problem in Taiwan asparagus. In fact, farmers in Taiwan do not recognise rot in the crown as a problem, since as the center rots the growth moves outward with each season.

VEGETABLE IMPROVEMENT IN THE PHILIPPINES: BREEDING AND BIOTECHNOLOGY

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ABSTRACT

Since the establishment of the Institute of Plant Breeding at UPLB in 1976, it has concentrated on the collection of germplasm, a breeding program for disease resistance, stress tolerance and earliness in common vegetable crops, and a special project for the selection of nitrogen fixing vegetable crops. Although the Institute is hampered by limited facilities, it is expanding its biotechnological programs. Current projects include somaclonal variation in potato, and selection through tissue culture of salinity resistant tomatoes and potatoes.

(Chinese Abstract) 摘　要

UPLB大學在1976年成立了作物育種研究所，卽致力於蔬菜種源搜集、抗病育種、抗不良環境及早生的育種外，並特別策劃針對固氮蔬菜作物進行選拔工作。在有限的設備下亦利用生物技術進行試驗研究。最近的工作計畫包括了馬鈴薯體細胞變異研究及利用組織培養進行番茄及馬鈴薯的耐鹽育種選拔。

(Japanese Abstract) 摘　要

1976年UPLBに植物育種研究所が設立されて以来，この研究所は遺傳資源の收集，一般野菜の病蟲害抵抗性，ストレス耐性，早生化や，窒素固定を行なう野菜の選抜についての特別プロジェクトなどを行なつて来た。當研究所の諸設備は限られているが、バイオテクノロジ—に關する計畫を擴大しつゝある。最近のプロジェクトはジヤガイモの體細胞變異，組織培養による耐鹽性のトマト，ジヤガイモの選抜である。

(Korean Abstract) 적　요

1976년 UPLB 대학에 작물육종연구소를 설치한 이래 배종질의 수집, 항병육종, 일반 채소작물의 내성 및 조생 부문에 주력하였고, 특히 질소를 좋아하는 채소작물의 선정사업에 집중하였다. 이 연구소는 한정된 시설의 어려움이 있지만 생물 기술진전을 위한 연구를 계속하고 있다. 현재 감자의 체세포 변이에 관한 연구와 내염성토마토 및 감자의 조직배양을 시험하고 있다.

VEGETABLE IMPROVEMENT IN THE PHILIPPINES: BREEDING AND BIOTECHNOLOGY

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INTRODUCTION

This paper reviews the progress made in developing vegetable cultivars f r the lowland tropics, with an emphasis on the efforts made by the Institute of Plant Breeding (IPB) at the University of the Philippines at Los Baños, and particularly on the current status of biotechnology at IPB.

The most significant events in the organization of vegetable improvement programs in this part of the Asian continent during the past 20 years have been:

1964	International vegetable center proposed
1971	Establishment of the Asian Vegetable Research and Development Center (AVRDC)
1973	AVRDC accepted as associate member of CGIAR
1974	Plan to establish sister institute to AVRDC
1976	FAO vegetable research appraisal mission
1977	Vegetable program proposed for Asia and Africa
1978	Vegetable crops designated priority crops for CGIAR
1979	TAC recommends establishment of second vegetable center
1985	TAC recommends that tropical vegetable research be the objective of the CG system
1986	The Winrock International Institute for Agricultural Development recommended formation of an international network of organizations and individuals concerned with R&D of vegetables in the tropics.

During this period, vegetable breeders have significantly improved the yield and quality of crops through conventional selection techniques. Biotechnology, particularly genetic manipulation including gene splicing and transfer, now offers a vast potential for changing the characteristics and performance of plant phenotypes, but lack of facilities and personnel have limited its exploitation in the Asian tropics.

VEGETABLE IMPROVEMENT IN THE PHILIPPINES

Prior to the Establishment of IPB

Academics working on limited budgets led early vegetable breeding in the Philippines. Professors of the College of Agriculture introduced much germplasm of different vegetables. After World War II, breeding work became more highly programmed, with selected crops being developed at the Vegetable Crops Section of the Department of Agronomy. Vegetable breeding was encouraged through the assistance of visiting professors from Cornell University in the 1950s[1,2]. At that time, the author headed the Research and Extension program in Vegetable Crops, the first comprehensive research and development program in vegetable crops in the Philippines[2]. The program trained research personnel, and established a system of trials in strategically located vegetable production centers throughout the Philippines, forerunners of the national cooperative test and recommendation system for new and improved domestic and commercial vegetable releases.

Breeding Philosophy

The Institute of Plant Breeding was established in 1976 to carry out crop breeding research. It adopted a two pronged breeding philosophy. On the one hand it developed high yielding lines for commercial farms, which demanded hybrid varieties that could give maximum response to optimal inputs. On the other hand, alternative lines were bred for low input farms of low income farmers, who demanded a response to low levels of fertilizer, good pest and disease resistance, and tolerance to adverse environments despite minimal inputs.

Experience in the Philippines has clearly demonstrated the relevance of the latter approach. For any developing country where the rural poor predominate, breeding for low input cultivars is desirable to reduce the production costs of vegetables. The majority of input costs are lost to developing countries in foreign exchange. Rasco[15] showed that 36-73% of the cost of production, depending on the vegetable, went in importation of seed, equipment, fuel, chemicals and fertilizers (Table 1). The only significant local component was labor, and even this on some Filipino farms was imported in the form of foreign consultants. The above costs did not include postharvest transport costs, which are again heavily burdened by the cost of imported vehicles and fuel.

Table 1 Foreign and local components of production inputs in growing vegetables in the Philippines[15]

Crop	Production inputs	
	Foreign	Local
	-- % of total cost --	
Potato (Baguio)	60	40
Cabbage (Los Baños)	73	37
Squash	59	41
Ampalaya (bitter gourd) (Los Baños)		
a. local fiber (abaca) for trellis	36	64
b. synthetic material for trellis	69	31

The Institute has made progress in the collection of germplasm, selection for disease resistant, stress tolerant and early varieties of vegetables, and the improvement of nitrogen fixing vegetable crops. It has a well established program in solanaceous vegetables, cucurbits, sweet and Irish potatoes, bulb crops, green corn and several indigenous vegetable crops. There are special projects on the development of vegetable crop varieties for rice based farming systems, and on the evaluation of postharvest qualities of some vegetable varieties[9]. The results of breeding programs are verified by a series of trials in a cultivar release scheme followed by most plant breeders in the country (Fig. 1).

Collection of Germplasm

The National Plant Genetics Resources Laboratory (NPGRL) of the Institute was opened in 1977, and provides for the preservation of 12,122 accessions of vegetable seeds. These accessions belong to 46 different species (Table 2). NPGRL has been designated by the International Board for Plant Genetic Breeding as a regional repository for tomato, bitter gourd, wax gourd, snake gourd and winged beans. Small quantities of seed are generally available free of charge to plant breeders around the world.

A significant part of the NPGRL collection is devoted to unconventional vegetables. The Institute collects and maintains this type of germplasm to evaluate the suitability of such vegetables to poor environments, with the view that they may stabilize the supply of vegetables and maximize land use by utilizing soils unsuitable for conventional vegetables[4]. These vegetables contribute to the diet of 70% of the rural Philippine population.

Disease Resistance

Disease control contributes at least 50% of the total cost of vegetable production, so IPB's breeding program gives high priority to disease resistance. Mindful of the ecological problems chemical insecticides can create, the Institute's approach is to minimize pesticide use. Disease

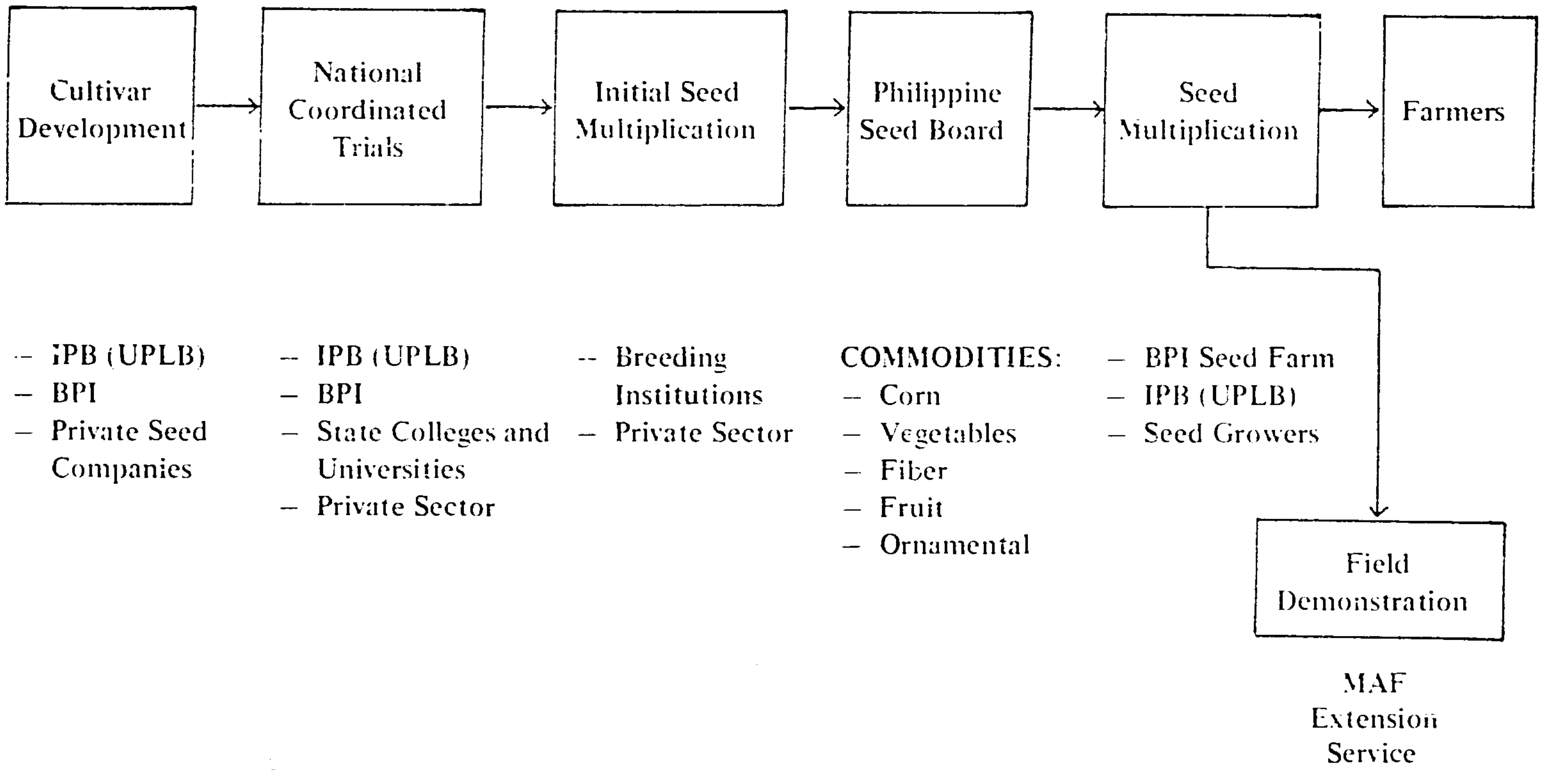

Fig. 1 Cultivar release scheme in the Philippines[14]

Table 2 Vegetable germplasm at the National Plant Genetic Resources Laboratory, IPB, 1986

Group/Common name	Scientific name	No. of accessions
A. Brassicas		
1. Pechay	*Brassica campestris* subsp. *chinensis*	53
2. Chinese cabbage	*Brassica campestris* subsp. *pekinensis*	205
3. Mustard	*Brassica juncea*	7
4. Cabbage	*B. oleracea* var. *capitata*	446
B. Bulbs		
1. Onion	*Allium cepa*	251
2. Radish	*Raphanus sativus*	2
C. Condiments and unconventional vegetables		
1. Okra	*Abelmoschus esculentus*	475
2. Kulitis	*Amaranthus* spp.	5
3. Atylosia	*Atylosia* spp.	20
4. Alugbati	*Basella* spp.	12
5. Kondol	*Benincasa hispida*	16
6. Swordbean	*Canavalia ensiformis*	9
7. Samsamping	*Clitoria ternatea*	4
8. Saluyot	*Corchorus olitorius*	7
9. Lettuce	*Lactuca sativa*	1
10. Malunggay	*Moringa oleifera*	33
11. Sabawel	*Mucuma curranii*	9
12. Yam bean	*Pachyrrhizus erosus*	6
13. Anise	*Pimpinella anisum*	6
14. Sweet pea	*Pisum sativum*	655
15. Aromabean	*Prosopis vidaliana*	1
16. Sesame	*Sesamum indicum*	24
17. Cocoabean	*Stizolobium triangulare*	6
18. Ginger	*Zingiber officinale*	3
D. Cucurbits		
1. Watermelon	*Citrullus lanatus*	42
2. Muskmelon	*Cucumis melo*	93
3. Cucumber	*Cucumis sativus*	11
4. Squash	*Cucurbita maxima*	151
5. Upo	*Lagenaria siceraria*	63
6. Patola	*Luffa* spp.	97
7. Ampalaya (Bitter gourd)	*Momordica charantia*	112
E. Legumes		
1. Pigeon pea	*Cajanus cajan*	543
2. Chickpea	*Cicer arietinum*	406
3. Hyacinth bean	*Dolichos lablab*	56
4. Lima bean	*Phaseolus lunatus*	461
5. Snapbean	*Phaseolus vulgaris*	311
6. Winged bean	*Psophocarpus tetragonolobus*	699
7. Cowpea	*Vigna unguiculata*	1,598
8. Pole sitao	*V. unguiculata* subsp. *sesquipedalis*	111
F. Solanaceous		
1. Bell pepper	*Capsicum annuum*	80
2. Hot pepper	*Capsicum frutescens*	149
3. Tomato	*Lycopersicon esculentum*	4,525
4. Eggplant	*Solanum melongena*	353
5. —	*Solanum mammosum*	1
6. —	*Solanum quitoense*	2
7. —	*Solanum tapiro*	2

Note: Data provided by Altoveroz, N. and J. Fajardo of the Institute of Plant Breeding, 1986 resistant accessions for the major vegetable crops in the Philippines have been identified and incorporated into breeding programs (Table 3) and the improved germplasm included in commercial lines. A significant breakthrough by IPB's pathologists was in clarifying the pathogenicity of the wilt pathogen of tomato. *P. solanacearum* has been classified at IPB by biovars (Tables 4 and 5). Biochemical tests of 106 isolates of *P. solanacearum* obtained from tomato growing areas in various parts of the country identified three important biovars. Biovars I, III & IV, with 3.8%, 85.8% and 10.4% incidence, respectively. Biovar I was isolated only in Luzon, while Biovars III & IV were obtained from Luzon, Visayas and Mindanao. The identification of the different biovars has explained why resistance in different varieties varies with location, and will make possible the development of more location specific solanaceous vegetables.

An innovative cultural practice which is revolutionizing the tomato processing industry in the Philippines is the introduction of wilt resistant tomato varieties from California and AVRDC to follow paddy rice on the lowlands of Pangasinan and Ilocos Norte. In the past, bacterial wilt has precluded the successful production of processing tomatoes.

Stress Tolerance

The majority of Filipino vegetable growers contend with limited moisture in the dry season and waterlogging in the wet. IPB has selected varieties of mungbean, tomato and corn that have tolerance to these extremes (Table 5). The mungbean and corn material is now undergoing tests in the Asian Rice Farming System Network of the International Rice Research Institute[17].

Earliness

Early maturing cultivars provide more flexibility in cropping sequences, and make possible more intensive cropping systems. With the development of early rice varieties, it is now possible to grow two rice crops and one upland crop on the same field in one year. Mungbean, which matures in 60 days, is ideal in this rotation, as is any vegetable with a similar maturation period. Some outstanding early accessions of upo (*Lagenaria siceraria*), batao (*Dolichos lablab*) and snap beans (*Phaseolus vulgaris*) have been selected for inclusion in such cropping systems (Table 6). These early snap beans are a bushy variety which requires no trellising. This reduces production costs by 30%, compared with varieties that need trellis support.

Nitrogen Fixing Vegetables

Pole sitao and batao, grown as green leaf vegetables, both have the attribute of fixing nitrogen (Table 7). They are therefore being developed in a breeding program for incorporation into farming systems.

BIOTECHNOLOGY

Biotechnology is now being applied, with the aim of industrializing agriculture in the Philippines. The National Institutes of Biotechnology and Applied Microbiology, University of the Philippines at Los Baños, is carrying out research programs into biofuels, food fermentation, nitrogen fixation, mycorrhiza, antibiotics, microbial insecticides and genetic engineering[13].

IPB has a program for the production of pure lines of tobacco varieties tolerant to high salinity using anther culture and *in vitro* selection of the lines. Another program just initiated is on the somaclonal variation of potato. This has developed from studies of callus induction, plant regeneration and field evaluation in white potato. A promising result of this research has been the identification of a wilt resistant regenerate of the potato variety Arka, for which 25 other characters remained unchanged during the evaluation[3]. This research and similar work on tomato is expected to develop further in a cooperative project between scientists of IPB and the Ben Gurion University Negev, Israel. An extension of this work is on somaclonal variation in garlic, to identify a flowering variety. As garlic does not naturally

Table 3 Summary of screening for disease resistance, Plant Pathology Laboratory, IPB, 1986

Crop/Disease	No. breeding lines		% of total	Resistant accessions
	Screened	Resistant		
1. Tomato				
Bacterial wilt	1,209	50	4	R 3034-3-10-N-UG, F 5-5-6
(*Pseudomonas solanacearum*)		(I, III, IV)		Tm-L114-48-5-N lt. T. spreading
				Tm-L114-42-1-N-4 P. early H.T.
				Tm L46-1-34-6
Cercospora leaf mold	299	6 MR	2	3034-3-4-8-N, 80-461-7
				R 2043-N-1-7-N-3-6-6-7-3043-N-1-7-N-3-N
				R 3030-2-19-N
Gray leaf spot	109	12	11	Tm L46-1-32-N-VP
(*Stemphylium solani*)				Tm-L114-42-1-N-P early
				I 3034-N-8-N-1-N, RV 9
				VC 42-1/Tamu chico III
Bacterial spot	145	9	6	C 30-0-18-1-1-G S, San Marzano
(*Xanthomonas vesicatoria*)				Homestead, Kurihara, River Mum
Leaf mold	227	16	7	L 4, L 88, C 549-1-4-75-N
(*Cladosporium fulvum*)				Kurihara, Homestead
Root-knot caused by:				
a. *M. incognita* Race 1	265	14	5	CIRT III, CIRT 106, CIRT 103, CIRT 110
				CIRT 105
b. *M. incognita* Race 2	23	5	2	CIRT III, CIRT 106, CIRT 103, CIRT 110
				CIRT 105
c. *M. javanica*	137	13	9	CIRT III, CIRT 106, CIRT 103, CIRT 110
				CIRT 105
Root lesion (caused by	56	7	12	CL 122-0-4-1-0-0, CL 32d-0-1-1-0-0
Rotylenchulus reniformis)				CL 8d-0-7-1-0-0, CL 32d-0-1-24-0-0
				CL 9d-0-3-6
Tobacco mosaic virus yellow strain	443	1	<1	Quick Pick
Tobacco mosaic virus green strain	443	1	<1	Quick Pick
2. White Potato	37 var.	15	2	1282-19
Bacterial wilt (*P. solanacearum*)	173 tuber families			1282-19-40, 1282-19-14
	498 clones			AT 110-67, S 726014-6
Root-knot (*M. incognita*)	40	2 MR	5	79-15 (ATIKA), CIP #800938
3. Hot Pepper				
Bacterial wilt (*P. solanacearum*)	45	3	7	BPI Ligao Albay-3, BPI Ligao Albay-5
		(III, IV)		PI 163189-N-1-3
TMV	52	3	6	Kawit Strain 2
		2 MR	4	Kawit Strain 7, PIP VG X 9161
Root-knot (*M. javanica*)	15	8	53	HP-84-4, HP-84-13, HP-84-3
				HP-84-9, HP-84-11
Bell Pepper				
Bacterial wilt (*P. solanacearum*)	34	6	18	22-6-1, 74-61-6-1-5-1, 74-56-3-4-5-2
		(mixture III & IV)		22-4-2, 22-4-1
TMV	16	1 MR	6	Delray Belle
4. Eggplant				
Bacterial wilt (*P. solanacearum*)	415	1 (IV)	<1	PI 362727
		1 (III & IV)	<1	PI 358311
		3 MR (IV)	<1	PI 320507, Acc. #40-N, CA Cluster

(Continued)

(Continued)

Crop/Disease	No. breeding lines		% of total	Resistant accessions
	Screened	Resistant		
Root-knot caused by:				
a. *M. incognita* Race 1	141	1 MR	<1	PI 320507-N
b. *M. incognita* Race 2	57	3 MR	5	Acc. 132, Acc. 6-N Dumaguete Long Purple
c. *M. javanica*	113	2 MR	2	Acc. 132, Acc. 6-N
5. Ampalaya (Bitter gourd)				
Bacterial wilt (*P. solanacearum*)	19	3 (III & IV)	16	83-006, 83-003, 9-32
Cercospora leaf spot	27	none	0	
Root-knot (*M. incognita*) Race 1	22	none	0	
6. Okra				
Cercospora leaf mold	44	none	0	
7. Patola				
Downy mildew	183	7	4	A23 OP S1, ETR #1 S1, A 18 (X) S2 A 34 (S) S2, A 47 a (OP) S2
Root knot caused by:				
a. *M. incognita*	48	2	4	Acc. 40(OP) S
		2 MR	4	Acc. 40(OP) S2, Acc. A 15 S Acc. 38 (OP) S2
b. *M. javanica*	13	none	0	
8. Upo				
Downy mildew	193	none	0	
Root-knot (*M. incognita*)	22	none	0	
9. Cucumber				
Downy mildew	23	none	0	
Root-knot caused by:				
a. *M. incognita* Race 1	37	none	0	
b. *M. incognita* Race 2	23	none	0	
c. *M. javanica*	37	none	0	
Watermelon mosaic virus	4	2 MR	3	UPL Cu-1, UPL Cu-6
10. Muskmelon				
Downy mildew	18	1 MR	6	85-Mu-1
Root-knot	13	none	0	
Watermelon mosaic virus	27	3	11	85 Mu-1, 85 Mu-11 Honey Dew Green Flash
		10 MR	37	85 Mu-2, 85 Mu-4
11. Watermelon				
Root-knot (*M. incognita*)	3	none	0	
Watermelon mosaic virus	15	2	13	Malali (Danish), Peacock Improved (FM)
		3 MR	20	Crimson Sweet, Tender Sweet Tom Watson (FM)
12. Squash				
Downy mildew	27	none	0	
Root-knot caused by:				
a. *M. incognita*	83	none	0	
b. *M. javanica*	27	none	0	

(Continued)

(Continued)

Crop/Disease	No. breeding lines		% of total	Resistant accessions
	Screened	Resistant		
13. Snapbean				
Bacterial wilt (*P. solanacearum*)	15	none	0	
14. Winged Bean				
Bacterial wilt (*P. solanacearum*)	21	5 (III)	24	F-021 Sibuyan, Romblon, PRCTC #13 PRCTC #32, Los Banos, Medium PRCTC No. 2
Root-knot caused by:				
a. *M. incognita*	21	none	0	
b. *M. javanica*	43	1	2	UPS-62
		1 MR	2	UPS-99
Root lesion (Rotylenchulus reniformis)	20	2	10	Acc. 84, Acc. 144
15. Hyacinth Bean				
Root-knot caused by:				
a. *M. incognita* Race 1	24	none	0	
b. *M. incognita* Race 2	9	1 MR	11	Acc. 80-008
c. *M. javanica*	38	1 MR	3	Acc. 288460
16. Sword Bean				
Root-knot caused by:				
a. *M. incognita*	10	4	10	Acc. 6-2, 8-7, 6-3, 6-1
		1 MR	10	Acc. 8-6
b. *M. javanica*	4	4	100	Acc. 6-2, 6-3, 8-6, 8-2
17. Pole Sitao				
Cowpea mosaic virus	113	3	3	WIR 872, C 83-18-0-4-1, C 83-18-0-4-2
		4 MR	4	WIR 873, WIR 291
Pole Sitao mosaic virus	113	2	2	WIR 873, Acc. 91
		2 MR	2	WIR 291, WIR 1107
18. Bush Sitao				
Cowpea mosaic virus	48	22	46	C 83-10-0-2, C 83-12-0-2-1, C 83-12-0-4-0 C 83-12-0-8-1, C 83-18-0-4-1
Pole Sitao mosaic virus	48	1 MR	2	C 83-09-0-7-1
19. Cowpea				
Cowpea mosaic virus	177	73	41	83 F 611-4, 83 F 742-4, Acc. 207 All season, Vita 8
Pole Sitao mosaic virus	45	3	7	83 F 611-4, 83 F 742-4, Acc. 207
20. Alugbati				
Root-knot (*M. incognita*)	5	none	0	

Note: 1. Data provided by Dr. R.B. Valdez *et al.* of the Institute of Plant Breeding

2. Roman numerals (I, II, III and IV) following a number indicate resistance against biovars of *Pseudomonas solanacearum*; MR indicates moderately resistant

Table 4 Germplasm developed/identified at IPB, and its reaction to pests, diseases and physiological disorders[8]

Crop/Variety	Reaction to diseases, pests, physiological disorders
Tomato	
Mayumi (UPL Tm-4)	Resistant to BW (Biovar 111) SLS; moderately resistant to BW (IV) and GLS; and resistant to cracking; semi-determinate; intermediate drought resistance; poor heat tolerance; intermediate to serious susceptibility to water logging.
Marikit (UPL Tm-1)	Moderately resistant to mosaic, Cladosporium leaf mold, grayleaf spot, bacterial leaf spot and bacterial wilt. Susceptible to Cercospora leaf mold, tobacco mosaic virus (yellow strain) and root-knot nematode. Resistant to blossom-end rot and cracking. Moderately resistant to drought and waterlogging.
Marilag (UPL Tm-2)	Resistant to bacterial wilt and blossom-end rot. Moderately resistant to drought and waterlogging. Susceptible to concentric cracking.
Eggplant	
Tilandoy (UPL-Eg-1)	Highly resistant to bacterial wilt.
Dumaguete Long Purple	Moderately resistant to bacterial wilt and root-knot nematode.
Dingras Long Purple	Moderately resistant to bacterial wilt and root-knot nematode.
Potato	
Arka	Moderately resistant to late blight
Conchita	Moderately resistant to late blight and wind damage. Susceptible to bacterial wilt.
Kennebec	Moderately resistant to late blight. Moderately susceptible to root knot nematode, tuber moth and bacterial wilt.
Hot Pepper	
Red Santaka	Moderately resistant to mosaic virus.
Mitikas	Moderately susceptible to powdery mildew, leaf mold, aphids, mites.
Cucumber	
Pilipina (UPL-Cu-1)	Highly tolerant to watermelon mosaic virus and downy and powdery mildews. Resistant to fruit rot and drought.
Pilmaria (UPL Cu-6)	Resistant to watermelon mosaic virus, downy mildew, fusarium wilt, moderately resistant to leafworm, aphids, beetles.
Watermelon	
Sugar Baby	Resistant to downy mildew. Susceptible to watermelon mosaic virus.
Squash (Kalabasa)	
Sampuso	Tolerant to squash mosaic.
Garden Peas	
Sugar Snap	Resistant to fusarium wilt and moderately resistant to powdery mildew.
05005	Resistant to fusarium wilt and moderately resistant to powdery mildew.
Sweet Snap	Resistant to fusarium wilt and powdery mildew.
Bush Sitao	
Luntian (UP BS$_4$)	Highly resistant to beanrust. Moderately resistant to Fusarium stem and root rot and mosaic virus.
Pole Sitao	
Sandigan	Moderately resistant to fusarium stem and root rot, bean rust and mosaic virus. Highly resistant to shade, drought and waterlogged conditions.
Cowpea	
Sagana	Resistant to bean fly and to fusarium stem and root rot. Susceptible to bean rust and bean anthracnose.

Table 5 Summary of screening for stress condition in mungbean, tomato and corn, IPB [a/]

Crop/Stress	No. accessions		% of total	Tolerant accessions
	Screened	Tolerant		
Mungbean				
Drought[b/]	832	153	18	IPB M79-9-82, IPB M79-6-11, IPB M79-13-98 IPB M79-4-79, IPB M79-9-13
Waterlogging[c/]	663	40	6	IPB M79-13-59, IPB M79-13-60, IPB M79-9-82 IPB M79-16-51, IPB M81-4-19
Tomato				
Waterlogging[d/]	55	13	24	CL 143-0-10-3 TmL 167-7 round, TmL 88 R-3034-3-4-N-58-U6, Narcarlan
Corn				
Drought[b/]	410	176	43	UPCA Var 1, XVH-5, XVH-3 Acc 576, Acc 428

a/ Data supplied by Del Rosario *et al.* of the Institute of Plant Breeding, 1986

b/ Data from a 3-year study at several locations

c/ Data from a 2-year study at several locations

d/ Data from a 4-year study at IPB

Table 6 Promising early accessions of upo, batao, and snap bean

Crop/accession no.		Days to flowering
Upo (7)	Tambuli	46
	Acc 3	63
	Acc 5	60
	Acc 6	62
Batao (10)	P.I. 388019	36
	P.I. 345607	38
	Hiyas (ck)	100
	Luningning (ck)	111
Snap beans (11)		
	Peak	34
	Resisto	34
	Spurt	36
	Pirate	36
	Bush Blue Lake 47	36

Table 7 Total and specific nitrogenase activity in pole sitao and batao

Entry	Total activity um C_2H_4/plant/hr	Specific activity um C_2H_4/gm module/hr
Pole Sitao		
Maagap	31.2	108.0
Sandigan	14.0	36.7
UPLPS$_2$	20.7	55.8
UPLPS$_3$	16.5	42.2
UPLP$_4$	25.9	58.3
UPPS$_1$	18.5	38.6
Batao		
PI 284801	51.0	96.3
PI 388000	2.9	18.6
PI 388002	2.1	23.5
PI 392369 (field type)	7.2	423.1

Note: Data supplied by Dr. E.S. Paterno, IPB N-Fixation Project flower in the tropical conditions of the Philippines, conventional methods of plant improvement are not available to garlic breeders.

Although the limited resources of IPB hamper biotechnological research, it will be used increasingly in conjunction with traditional means of plant breeding, aiding the identification and location of useful genes and generally providing basic knowledge of genetic and physiological processes, making possible genetic transformation and control of genetic expression. With continued research, new methods of producing and selecting plants resistant to pests, disease and stresses will come to light.

CONCLUSION

Vegetable breeders of the Asian and Pacific region are faced with questions of priorities[16]: whether their efforts are best deployed in breeding for varieties more efficient in their utilization of soil nutrients, whether the emphasis should remain on pest and disease resistance, whether breeding should be done for drought, waterlogging and high salinity, or whether the development of appropriate cultural practices be emphasized as the means of reducing these stresses to crops. In addition, plant breeders should consider reducing farmers' dependency on government agencies for the production and distribution of seed, and encourage greater participation by the private sector in this industry.

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DISCUSSION

Q. (C.Y. Yang)

What is the scientific name of the 'pole sitao'?

A. The scientific name of pole sitao is *Vigna sesquipedalis* Frun, which is an indeterminate type, while that of the cow pea is *Vigna unguiculata* (L) Walt.

Q. (C.Y. Lin)

In the breeding of resistance in tomato to bacterial wilt in Taiwan, the races used for screening are race 1 and race 3. It is important that both are used in screening, as screening with only one will leave the tomato susceptible to the other. We do not have any problem from race 2 in Taiwan.

Dr. Kelman of the University of Wisconsin, U.S.A. divided *Pseudomonas solanacearum* into three races, races 1, 2 and 3, according to their pathogenicity. In your paper, you state that *Pseudomonas solanacearum* in the Philippines is divided into three biovars, B_I, B_{III} and B_{IV}, on the basis of a biochemical test. Are these three biovars equivalent to any of the races 1, 2 or 3?

A. Our plant pathologists in the Philippines are using 'biovars' of *Pseudomonas solanacearum* instead of 'races'. Their system helps explain why some tomato varieties that are resistant in some areas remain susceptible in others.

As mentioned earlier, biovars are identified through the use of biochemical tests, whereas races are identified through the use of differential hosts. Races can be equated with biovars.

For example: Race 3 = biovar II
Race 1 = biovars I, III and IV

Comment: (R.T. Opeña)

In potato and sweet potato, race 1 is more prevalent in cooler areas. In tomato, race 3 is the greatest problem, and this is also the only race to attack banana.

Q. (C.Y. Lin)

Your paper states that you have obtained 50 varieties of tomato resistant to *Pseudomonas solanacearum*. Which of these has the highest resistance?

A. They are not varieties; they are breeding lines developed at the Institute of Plant Breeding. Several of these lines have equivalent degrees of resistance. No single line stands out as having the highest degree of resistance.

Q. (C.Y. Lin)

Are there any commercial varieties of tomato released in the Philippines which are resistant to bacterial wilt?

A. I know of at least three recommended varieties: VC 11-1, Mayumi, and Marilag.

Seed Production

HYBRID TOMATO SEED PRODUCTION

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ABSTRACT

This paper considers seed production in Taiwan, particularly of hybrid tomato seed. It outlines the technology used to raise and transplant the seedlings and the type of fertilizer applications used. Methods of emasculation and pollination are described in detail. The final stage of the process is the harvesting and drying of seed, often in Taiwan carried out with the aid of a small-scale seed extractor to separate pulp from seeds. Finally, a seed separator is used to remove any seeds which are too small or too light.

(Chinese Abstract)

摘　要

本文說明臺湾的種子生產，特別是雜交一代番茄種子。略述種苗培育及移植的技術和不同的施肥類型，除雄及授粉的方法則有較詳細說明；後段是採收後及種子乾燥的加工處理過程。在臺湾常用小型的種子萃取機以分離果肉與種子，最後是利用種子選別器用以剔除太輕、太小的種子。

(Japanese Abstract)

摘　要

この論文は臺湾における種子生產，特に雜種トマト種子について考察している。こゝで苗を栽培し，移植する技術や施肥法について概括している。除雄や授粉の方法について詳述している。最後の過程は收獲と種子の乾燥であるが、臺湾では小規模な種子抽出器を使つて種子をパルプから分離している。最後に，小さすぎたり輕すぎたりする種子を除去するのに或種の種子分離器が使用されている。

(Korean Abstract)

적　요

이 논문은 대만의 종자생산, 특히 교잡토마토 종자에 관한 것이다. 종묘의 배육 및 이식에 관한 가술과 시비유형에 관한 것을 약술하였다. 그리고 emasculation 과 수분에 관해 상술하였다. 후단에는 종자의 채취와 건조에 관한 조작과정인데, 대만에서 자주 사용되는 소형종자채취기에 의해 과육과 종자를 분리하는 내용을 소개하였다. 끝으로 종자 선별기의 역할은 너무 작거나 가벼운 종자를 제거하는 것 임을 설명하고 있다.

HYBRID TOMATO SEED PRODUCTION*

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INTRODUCTION

The term 'vegetable crops' is a very broad one. There are at least one hundred species being used as vegetables in the Asian region. Yamaguchi[1] of the University of California, Davis, in his book on World Vegetables, has stated that several hundred species are used around the world as vegetables. These vegetables are grouped in various ways, for convenience in research and data recording, according to their use, their botany, their growing season, or a combination of these. Thus, they are referred to as cool season crops, warm season crops, cruciferous or solanaceous vegetables, cucurbits, legumes etc. The importance of different species varies in different countries and regions. According to one FAO report, the four most important vegetables in Asia are onion, cabbage, tomato and pepper (Table 1). In Taiwan, the five most important vegetables, in terms of area planted, are bamboo shoot, tomato, cabbage, garlic and vegetable melon. Due to the massive numbers of vegetable species involved and their great diversity of climatic requirements for seed production, no country can be self-sufficient in all its seed requirements. In a subtropical country like Taiwan, most of the seed requirements for carrot, spinach, cabbage and late maturing cruciferous crops have to be met by imports from temperate countries such as Japan (Table 2). Perhaps in the Southeast Asian countries there may be many highland sites with an ideal climate for vegetable seed production. However, it is important to investigate which species are most likely to be produced successfully and economically in such areas. No doubt the so-called warm season crops, such as beans, melons, cucumber, eggplant, tomato, and the early maturing brassicas such as Pak chai, edible rape and mustard, should be the priority candidates for consideration.

The vegetable seed production discussed in this paper will cover only true seed species of solanaceous crops, and hybrid tomato seed production in particular, since at the moment this is of great interest to many people in this part of the world.

Table 1 Major vegetable crops grown in Asia (1969-1981)

Variety	Area harvested (1000 ha)				Production (1000 mt)			
	1969-71	1979	1980	1981	1969-71	1979	1980	1981
Onion	705	843	847	875	6,857	8,782	8,639	8,844
Cabbage	725	782	780	794	10,526	14,948	14,891	15,429
Tomato	566	700	717	720	7,462	11,659	12,215	12,558
Chilli + Green pepper	352	526	556	580	1,899	2,685	2,810	2,883
Cucumber	305	358	374	380	3,985	5,103	5,240	5,351
Various melons	188	230	228	228	2,238	3,086	3,145	3,150
Carrot	116	133	138	141	1,776	2,553	2,656	2,731

Source: FAO Production Year Book

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* Presented *in absentia*

Table 2 Imports of vegetable and other seeds to Taiwan, 1981-1983

Value: US$1,000.-

Crop	1981		1982		1983	
	Quantity (mt)	Value (US$)	Quantity (mt)	Value (US$)	Quantity (mt)	Value (US$)
Seeds of fruit vegetables (e.g. tomato)	3	77.7	2	111.1	5	118.2
Cabbage	4	535.0	6	596.3	7	681.6
Chinese cabbage	50	373.9	45	383.3	75	401.0
Spinach	55	226.5	75	324.0	161	727.7
Onion	3	100.9	5	129.7	2	79.4
Seeds of leafy vegetables	38	381.2	39	444.8	174	445.2
Pea	46	51.6	51	57.8	234	266.6
Garlic	283	186.9	788	646.5	1,444	1,545.5
Corn	41	323.2	145	1,103.6	144	1,545.5

Source: 1984 Agricultural Trade Statistics of Taiwan, R.O.C. Council of Agriculture, Executive Yuan, Taipei

TOMATO SEED PRODUCTION

The optimum growing temperature for tomato is 22-26°C in the day time and 14-16°C at night. It is difficult to locate production sites with this temperature range in the lowland tropics, which have a shorter cool season than subtropical areas. In addition, the higher temperatures of the tropics cause more pest and disease problems, and hence often produce lesser quality seed. The fall and winter seasons in southern Taiwan are generally cool and dry, and there is a good irrigation system. Climatically, this is therefore an ideal tomato seed production area.

Tomato grown under optimum temperatures are best for both flowering and fruit setting. Growth is not inhibited even if the night temperature drops to 13°C. However, the day temperature should be above 15°C for anther dehiscence. Too high a temperature causes the flowers to drop, and there is poor fruit-set. Too low a temperature inhibits pollen tube growth and leads to poor fertilization, also resulting in poor seed-set. Occasionally we find that pathenocarpic fruit are produced which have only a few seeds per fruit or no seed at all, when pollination is done during a cold spell.

Tomato have a vigorous root system, and can be grown successfully in either sandy or clay soils. However, to obtain good fruit and a high seed yield, it is best to select a field with deep fertile topsoil which has good drainage and good water holding capacity.

Tomato can be grown in slightly acidic to slightly alkaline soils, but near neutral acidic soil is best for this crop.

Raising of Seedlings and Transplanting

There is not much difference between raising seedlings for fresh market production and raising them for seed. In Taiwan, seeds are normally broadcast direct onto a well prepared seed bed. To raise enough seedlings to plant 0.1 ha in tomato, about 20-30 gm seed and a 100 m^2 seed bed are required. Seeds after sowing are covered with fine compost or fine soil, over which is spread a chopped straw mulch. Raising good seedlings is essential to obtain good seed yield, since up to 50% of the seed yield is controlled by the first three clusters, and the flower initiation of these first three clusters is normally completed at the seedling stage. When the seed bed is prepared, sufficient well-decomposed compost with added phosphorus fertilizer should be used. Compost is normally prepared a few months in advance and incorporated into the seed bed before preparation of the seed bed or potting the plants in plastic pots. Occasionally compost is sterilized with methyl bromide or heat before use, in order to control soilborne diseases, pests and weeds.

In order to regulate labor supply and demand, the sowing date should be determined by adding the number of days required for seedling growth and the number of days the plants are grown in the field before pollination, and relating this figure to the availability of pollinators and the proposed pollination date. Pollination begins about 65-75 days after sowing.

Male parents are normally sown one week in advance of females. The male/female seedling ratio is 1:6. The optimum germination temperature is 26-28°C. Seedling emergence should be complete after 4-5 days. The best seedling growth temperature is 25°C in the day time and 15°C at night. In order to raise strong seedlings, proper thinning to about 5-8 cm between plants is essential, to allow abundant sunshine to reach them.

Transplanting

Seedlings will be ready for transplanting at the 4-5 true leaf stage, or at 25-30 days after sowing. About one week before transplanting the water supply should be withheld, in order to harden the seedlings. Three days before transplanting the seedlings should be sprayed with a solution of 3-5% sugar mixed with 0.5% urea, to improve the survival rate in the field after transplanting. The seed bed should be thoroughly watered just before the seedlings are taken up from the seed bed. Plant spacing should be 90-100 cm between rows and 40-45 cm between plants. Transplanting should be carried out in the late afternoon or on cloudy days, to minimize transplanting shock.

All compost, lime and P_2O_5, and one third of the N and K_2O, should be applied as a basal fertilizer. The remaining two-thirds of the N and K_2O should be split into two equal parts, the first to be applied as a top dressing 25-30 days after transplanting, and the second to be applied 10-15 days later.

Table 3 Recommended fertilizer applications for tomato seedlings

Fertilizer	Recommendation (kg/ha)
Compost	25,000
Lime	1,000
N	500
P_2O_5	700
K_2O	360

Indeterminate types of tomato are normally staked. All side shoots should be removed early, to allow only one stem per stake. With a determinate type, extra care should be taken in pruning side shoots, to ensure that the plant does not become shootless and unable to grow more branches, to the detriment of flowering and seed yield.

Pollination and Emasculation

Emasculation is one of the most important operations in tomato seed production, and is a good half of the total work of pollination. The entire plant should be cleaned before emasculation takes place by removing all fruit already set, blooming flowers and any abnormal flower buds. The indeterminate type of tomato normally bears the first flower cluster on the 8th-9th node, and succeeding clusters every third node. However, the bearing position of the flower clusters not only varies according to the variety, but is also affected by the environment. The number of flowers per cluster also varies, from 4-6 to 10-15 flowers. In general, varieties with small fruit tend to bear more flowers. Emasculation and pollination are normally carried out from the first to the sixth cluster.

Each 0.1 ha (2,400-2,800 plants) requires 2-3 pollinators carrying out pollination continuously for 4-5 weeks. The determinate type, with a more concentrated flowering period, will have a lot more flowers for pollination and will require 3-4 pollinators to pollinate the same area; however, pollination will be completed within a shorter period.

Pollinators normally select the best flowers for pollination and remove small or deformed flowers, since seed yield is positively correlated with fruit size. Flower buds should be emasculated one or two days before they bloom. Emasculating buds too early will damage the ovary, causing pollinated flowers to drop. If they are emasculated too late, there is a danger of selfing, and production of seed with a low level of hybridity. It is also very important to check the plants carefully, and remove any suspected of being off type. Male parent plants in particular should be closely inspected for leaf color and shape, etc., and all off type plants uprooted before any pollen is collected.

Pollen Collection

Male plants are normally planted in the corners of the field in which female plants are growing. Pollen collection may use a pollen vibrator to collect directly from male plants, or the pollen may be collected from the anthers of picked and dried flowers. In the latter method, the flower anthers are picked and desiccated with quicklime in an airtight container overnight, then shaken to remove the pollen for collection.

In pollination, the little finger of the right hand should be used to apply pollen lightly two or three times onto the stigma of a fully open emasculated flower.

After each flower is pollinated, a small pair of scissors should be used to cut the flower sepals as a marker. Emasculation may be carried out in cloudy or rainy weather, but pollen collection and pollination should take place only on sunny days; if pollination takes place on rainy days, fruit set and seed yield will be much lower. Fortunately, the period during which the tomato stigma is receptive to pollen is rather long, two or three days after blooming. Hence, it is better to wait for a fine day for pollination than conduct pollination in rainy weather. Extra pollen may be stored in paraffin bags in a desiccated can or jar for the next day's use. However, it is best to use fresh pollen collected the same day for good fertilization, and for better fruit-set and higher seed yield.

Normally, pollen collection and pollination is conducted in the morning, and the worker then switches to emasculation for the rest of the day. This work will continue for 4-5 weeks, to complete the pollination of 5-6 clusters per plant. In each cluster, small fruited varieties will have 8-10 fruit, while a large fruited variety will have only 3-4 fruit. Total fruit number per plant for small fruited varieties is about 40-50, while large fruited varities have 16-20 fruit.

Care of Plants after Pollination

After pollination is completed, the stem should be pinched off at a point one leaf above the top pollinated cluster. Several times after pollination all side shoots should be removed from the plant, to prevent it from bearing open-pollinated fruit on new shoots, or producing new flowers on the tips of pollinated clusters.

Harvesting, Processing and Drying of Seed

All fruit on the plant should be allowed to turn fully red. Before picking, each fruit should be carefully checked to make sure it has the marker of cut sepals. Tomato fruit take 50-55 days to mature after pollination, but maturity could be delayed by 5-7 days if temperatures are low during the maturing stage. Tomatoes after harvest are stored for one week for full ripening. For small-scale production, the fruit are then cut open and the seeds and juice squeezed out into a container. In recent years, small machine seed extractors have been available, and are commonly used to crush the whole fruit and separate the pulp from the seeds and juice automatically. Seeds are stored with the juice in a plastic tub, for one or two days' fermention. They are then placed in a sieve and washed with tap water to remove all the flesh, skin and gelatin from the surface of the seeds. After washing, the seeds are put in nylon bags and dried in a centrifuge machine. They are then spread out to dry in the sun on a nylon net. The seeds should be stirred once when they are half dry, so they will not form a hard clump. They dry in one day in fine sunny weather. At night, the seeds should be put in a plastic bag, so they do not absorb moisture again from the air. The seeds should be dried for a few more days, to bring the moisture content below 7%. The dry seeds are then cleaned by running them through a seed separator, to remove any that are too light or too small.

Control of Diseases and Insect Pests

Canker

To control canker disease, seeds should be disinfected by soaking them in warm water (55°C) for 25 minutes, or seedlings should be soaked in 1/800 Nobopionin solution for 10-12 hours before transplanting. Plants should be carefully examined for canker at an early stage, and any infected plants destroyed to prevent the spread of the disease.

Blight

This disease is likely to occur after abnormal and marked changes in temperature. Prevention by properly timed spraying with Maneb Dithene, Daconil, Bordeau 4-2 mixture or copper hydrate solution, at 500 liters per 0.1 ha, can control this disease.

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VEGETABLE SEED PRODUCTION IN THAILAND

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ABSTRACT

Though Thailand exports vegetable seeds, a greater volume is imported as local production of seed does not meet demand. Both open pollinated and F_1 hybrid seeds are produced for various vegetable crops. F_1 hybrid tomato seed production in Northeast Thailand has been particularly successful. Chiang Mai University shares the responsibility with other government and private agencies of developing vegetable varieties and of vegetable seed production.

(Chinese Abstract)

摘　　要

泰國雖出口種子，但局限於部分種子，進口還是佔大宗。在泰國各種自然授粉或雜交一代的蔬菜種子均有生產，尤其在東北地區番茄雜交一代種子的生產特別成功。清邁大學和政府機構及私人公司均擔負起蔬菜的品種開發與蔬菜種子的生產。

(Japanese Abstract)

摘　　要

タイ國は若干の種子の輸出を行つてはいるが，種子の國内生産が需要に追いつかない為大量の種子を輸入している。自然交雑種子やF_1種子が種々の野菜について生産されている。

タイ北東部におけるトマトのF_1種子生産は特に成功した。チエンマイ大學は他の政府機關，私立機關と共に野菜品種の開發，野菜種子の生産に貢献して来た。

(Korean Abstract)

적　　요

태국은 채소종자를 수출 하지만 국내생산종자의 공급미달로 다량의 종자를 수입하고 있다. 자연수분 및 교잡 1 대 종자는 각종 채소작물에 의하여 생산된다. 태국 동북지역에는 토마토의 교잡1 대 종자가 특히 성공리에 생산되었다.

이지역의 칭마이대학은 정부 및 민간기관과의 협력으로 채소품종을 개발하고 채소종자를 생산하는 일을 분담하고 있다.

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INTRODUCTION

Vegetables are produced by Thai growers both for domestic consumption and for export to neighboring countries. There are about 30 major vegetable crops, and the young shoots of many indigenous trees and shrubs are used as vegetables. Seeds come from various sources: farmers may set aside seed from their own crops or exchange seed among themselves, while seed is also supplied by commercial seed companies and the extension services of the Department of Agriculture. Commercial suppliers distribute both locally produced and imported seed, the latter accounting for about 30% of the total supply. Thailand exports vegetable seed to Malaysia, Singapore and Taiwan[3] (Table 1).

SEED PRODUCTION OF OPEN POLLINATED VEGETABLES

No exact statistics are available for Thailand, but based on a personal communication from the Chia Tai Seed company, an estimate of vegetable seed production by district has been compiled in Table 2. Seed production of the open pollinated crops, convolvulus, watermelon, cucumber and pumpkin, is long established in Thailand, but farmers still generally grow vegetables only for the fresh market and ignore the potential of seed production. Thailand is able to produce many kinds of open pollinated vegetables, yet vegetable seeds for these are still imported[1] (Table 3). Seed exports are mainly convolvulus and watermelon. With technological input, there is the potential to produce most kinds of vegetable seed in Thailand. Private seed companies act as seed promoters and distributers, with 127 companies sharing the local market, 53 being involved in importing seed, and 33 involved in seed export[1].

F_1 HYBRID SEED PRODUCTION

In 1979, the Adams International Company introduced F_1 hybrid seed production of tomato

Table 1 Import and export of vegetable seeds in Thailand from 1981 to 1985

Year	Import		Export	
	Quantity (mt)	Value (US$1,000)	Quantity (mt)	Value (US$1,000)
1981	970	2,377	531	379
1982	1,248	2,301	297	374
1983	415	2,466	477	1,092
1984	976	2,988	584	1,156

Table 2 Approximate amount of open pollinated vegetable seeds produced per year in Thailand and the production sites

Crop	Total seed production (mt/year)	Production site
Cucumber	80	Chumporn (South) Prachinburi (Middle)
Pea	—	Loam Sak (Northeast)
Pumpkin	3 – 4	Chiang Rai (upper North) Kamphaeng Phet (lower North) Nakhon Sawan (lower North) Nakhon Sithammarat (South)
Sweet corn	300	Ratchaburi (Middle) Kanchanaburi (Middle)
Tomato (porter)	—	Ratchaburi (Middle)
Watermelon	80	(Northeast and lower North)
Water convolvulus	200 – 250	Suphanburi (Middle) Nakhon Pathom (Middle)
Yard long bean	80	Phetchabun (lower North) Nakhon Sawan (lower North)

Table 3 Import of particular kinds of vegetable seeds of Thailand 1983 – 1984

	1983		1984	
	Quantity (mt)	Value (US$1,000)	Quantity (mt)	Value (US$1,000)
a. Cucurbitaceae				
Cucumber	0.01	0.11	33.18	0.37
Watermelon	—*	—	20.70	176.37
b. Cruciferae				
Broccoli	—	—	0.40	28.85
Cabbage	—	—	7.82	381.98
Cauliflower	—	—	8.91	173.67
Chinese cabbage	14.14	261.35	69.58	354.56
Chinese kale	34.29	75.98	149.93	259.80
Chinese radish	11.06	141.93	69.41	213.30
Leaf mustard	9.81	28.26	32.67	88.36
Pak choi	—	—	69.95	92.48
c. Solanaceae				
Pepper	0.63	14.46	0.91	17.92
Tomato	1.20	37.12	2.53	71.49
d. Other families				
Chinese convolvulus	10.00	164.99	127.32	152.36
Lettuce	—	—	3.22	28.75
Onion	—	—	3.43	129.61
Pea	60.93	32.12	104.12	66.94
Sweet corn	0.14	0.26	0.24	2.14

* No data available

into Northeast Thailand. Since the climate in the Northeast was suitable, the farmers reliable, and the company invested heavily, this business was successful within a few years. At the moment there are at least six seed companies in the Northeast and three seed companies in the North. These companies either have contracts with foreign seed companies or are direct subsidiaries of foreign seed companies. Peto Seed Company and Asgrow Seed Company in the United States have contracts with local seed companies to produce F_1 hybrid tomato seeds. There are other investors, such as the Known You Seed Company from Taiwan, the Jin Jong Agricultural Company from Taiwan and East West Farm. These seed companies are involved in F_1 hybrid seed production of tomato, cantaloupe, sweet pepper, open pollinated flowers and cruciferous crops. Most of the seed produced is exported.

Climatic conditions in the Northeast are dry, which offers the advantage of little fungal disease and good conditions for seed development and harvest. However, the high temperatures are a disadvantage for some vegetable crops. North Thailand is cool, but high humidity creates conditions in which seed crops are subject to fungal disease. Seed production of F_1 hybrid tomato seed in the Northeast has been particularly successful, with yields of 1.6-2.8 mt/ha and a gross farm income of U.S.$ 6,000 – 10,900/ha[4], from an investment into farm inputs and labor of U.S.$ 300/ha.

VARIETAL IMPROVEMENT

The component most lacking in Thailand's vegetable improvement is varietal improvement, both for local and imported varieties. Government institutions, the Department of Agriculture, universities and agricultural colleges are responsible for most of what work has been done. Kasetsart University, Khon Khan University and the Department of Agriculture have improved some open pollinated varieties of vegetables[5]. The International Research and Development Center (IDRC) is supporting Chiang Mai University in a project on 'Vegetable seed production in opium- and rice-based agriculture', which aims at developing suitable varieties of vegetables and their seed production in Thailand. The Food and Agriculture Organization (FAO), realizing the specific need to improve technology for the small farmers, is supporting Chiang Mai University in a short-term project on 'Preliminary activities for increased tomato production'.

Location Site Studies

The IDRC funded project will determine the suitability of various locations for certain kinds of vegetable seed production, and has sponsored the establishment of varietal improvement stations at altitudes of 300m, 600m and 1,200 m above sea level. The effects of planting date and altitude are clearly reflected in the seed yield of Chinese radish (Fig. 1) and lettuce[12]. Seedlings of Chinese cabbage to be raised in paddy fields are grown in nurseries and transplanted into the fields (Fig. 2). Seed production for Chinese radish has been very successful, both in hilly areas (Fig. 3) and in paddy fields. Seed yield of Chinese radish increased at higher altitudes, whereas for lettuce it was higher at low altitudes, as high temperatures in the lowlands induced bolting in lettuce while cool temperatures in the uplands tended to induce heading. Thus, uplands and highlands are recommended for production of radish seeds and lowlands for lettuce seed in Thailand. However, a common problem in lettuce production in the lowlands is stem rot, caused by *Sclerotinia sclerotiorum.* For reasons of pest control, planting time is critical in seed production in the lowlands of Thailand. September and October plantings are associated with a lower incidence of fungal diseases on the leaves, inflorescence and pods than either earlier or later plantings, which have higher rainfall at the maturing stage.

In pot experiments, iron and magnesium deficiencies were shown to drastically reduce

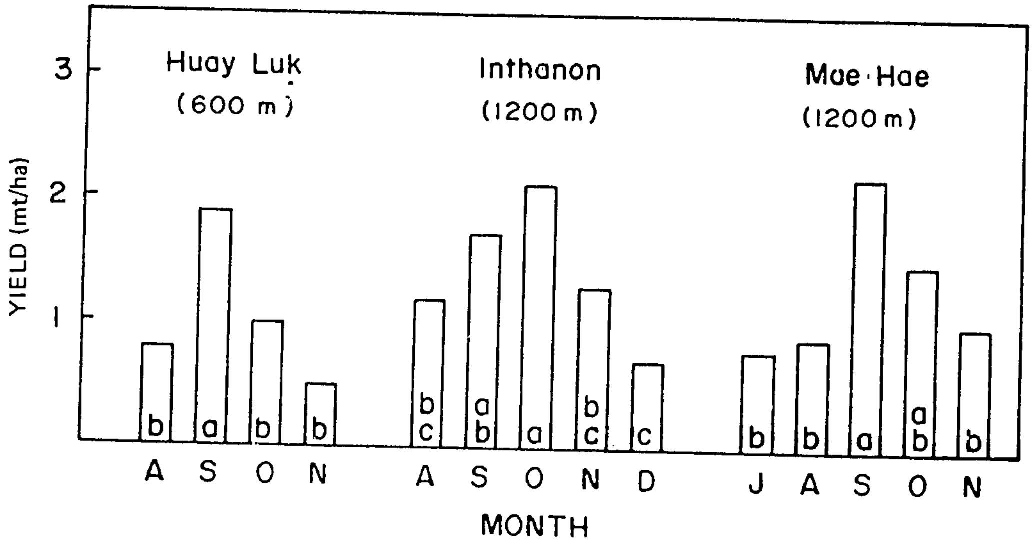

Fig. 1 Seed yield of Chinese radish at different locations and planting dates (figures in parentheses indicate altitude in meters above sea level, names are locations in Chiang Mai, Thailand)

Fig. 2 Chinese cabbage seedlings being transplanted into paddy fields for seed production

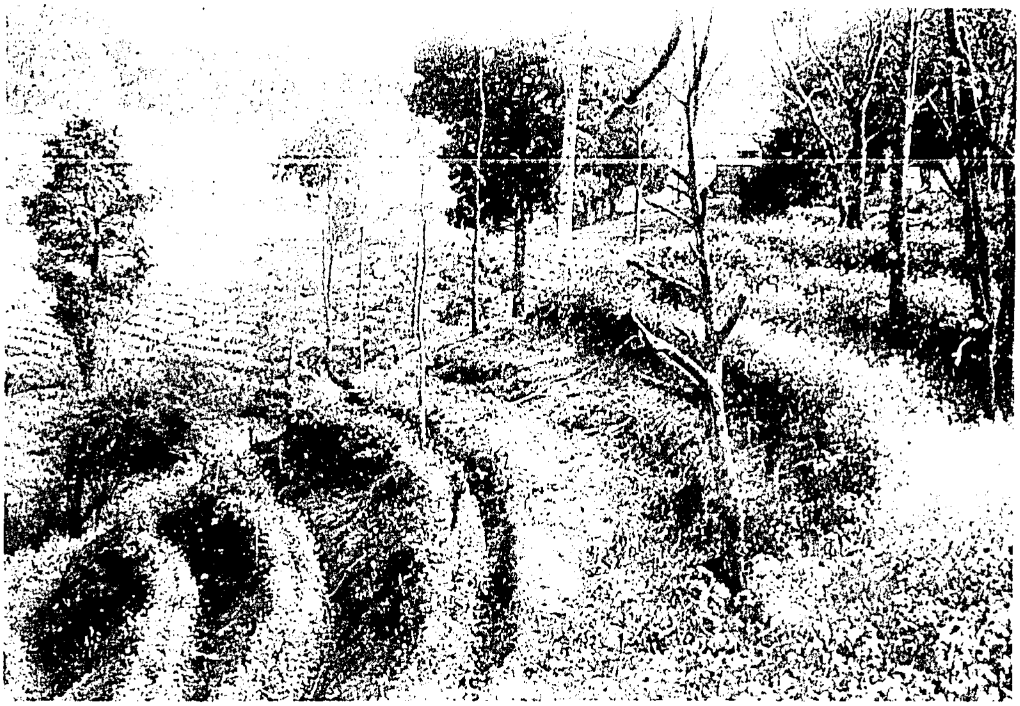

Fig. 3 Seed production of Chinese cabbage is higher in the highlands

seed yields in lettuce (Table 4) and leaf mustard (Table 5)[12]. Using a complete micronutrient supplement applied to the foliage of the plants should benefit seed production.

Table 4 Influence of micronutrients on seed yield of lettuce, tested at Hoay Luk Station (500 meters above sea level)

Treatment	Seed yield (g/pot)
Control	6.7
Check (NPK)	7.7
Complete	13.9
—Mg	5.1
—Fe	4.0
—Mn	14.8
—Zn	14.5
—Cu	12.8
—B	11.9
—Mo	12.8
L.S.D.05	3.3

Table 5 Influence of micronutrients on seed yield of leaf mustard, tested at Hoay Luk, Inthanon and Mae Hae which have altitudes of 600, 1,200, and 1,200 meters above sea level, respectively

Treatment	Seed yield (g/pot)		
	Hoay Luk	Inthanon	Mae Hae
Control	0.9	1.9	0.8
Check (NPK)	1.8	26.2	15.6
Complete	3.0	26.4	16.1
—Mg	1.7	20.1	8.5
—Fe	1.6	27.6	12.1
—Mn	2.6	23.9	12.7
—Zn	2.2	27.6	12.2
—Cu	2.8	22.8	12.5
—B	2.3	20.9	13.9
—Mo	2.2	25.9	14.2
L.S.D.05	1	5.4	4.8

A breeding program, selecting suitable varieties of lettuce, leaf mustard, sweet corn, Chinese radish, Chinese cabbage and tomato has introduced varieties of these vegetables from different countries for screening at experimental sites. After selection, they will be used for varietal improvement.

Two lettuce varieties, King Crown from the Sakata Company and Great Lake 659 from the Royal Sluis Company, were selected as high yielding varieties under Thai conditions[10,11]. However, King Crown was subsequently found to be sensitive to tipburn in the summer and rainy season. Tipburn is the most serious problem of lettuce growers in tropical countries.

F_1 hybrid sweet corn varieties introduced from Japan, the United States, Taiwan and Europe mostly gave good yields but were poor in kernel taste[10,12]. The Sucro variety from the United States was the best[12]. The extraction of inbred lines from commercial hybrid varieties for F_1 hybrid production was carried out[11], and these lines compared with the local sweet variety, Super Sweet DMR (Table 6). Some of the hybrids performed well, and had a better taste than the local variety. The most serious pest problem for Thailand's corn growers is the southern corn blight, caused by *Helminthosporium maydis*, to which imported varieties are always susceptible.

Many inbred lines of Chinese radish and Chinese cabbage have been produced from commercial and noncommercial varieties using bud pollination techniques[9]. F_1 hybrid varieties will be developed from these inbred lines. Chinese cabbage inbred lines have been selected for their vernalization requirement[2], and for their level of self incompatibility using seed set analysis[9] and fluorescence techniques[6]. Two inbred lines of Chinese cabbage, T-1-7-1 and C-2-7-5, from the Asian Vegetable Research and Development Center (AVRDC), had a low temperature requirement of only 12-15 days (Figs. 4 and 5). These two lines are parental material of one hybrid variety which performed well in tests at Chiang Mai University. T-1-7-1 required more vernalization than C-2-7-5, but synchronization studies showed that 20 days of vernalization at 5° - 10°C under continuous light was effective in synchronizing the two inbred lines[7]. The use

Table 6 Yields and horticultural characteristics of 10 hybrids and Super Sweet DMR, tested at Chiang Mai University

Variety	Yield[1] (mt/ha)	Height (cm)	Sweetness[2]	Cob length (cm)	Tip length without kernel (cm)	Kernel row	Row straightness
Hybrid No.3	22.4	140	3.4	20.6	3.6	15	Moderate
Hybrid No.7	16.3	152	3.1	20.0	2.3	14	Moderate
Hybrid No.24	21.3	160	3.2	22.9	1.3	14	Good
Hybrid No.25	20.3	160	3.5	23.1	1.7	14	Good
Hybrid No.30	19.5	165	3.0	20.1	4.3	14	Moderate
Hybrid No.37	25.5	150	3.2	20.2	1.0	15	Good
Hybrid No.61	20.0	170	3.1	20.8	2.1	13	Moderate
Hybrid No.63	16.5	157	3.2	21.6	2.2	14	Moderate
Hybrid No.68	21.0	162	3.1	20.5	2.7	14	Moderate
Hybrid No.90	18.7	155	4.0	18.3	4.1	14	Moderate
Super Sweet DMR	15.2	175	2.6	21.1	2.6	14	Good

[1] Fresh weight including husks

[2] Sweetness rating: 1 = not sweet; 4 = very sweet

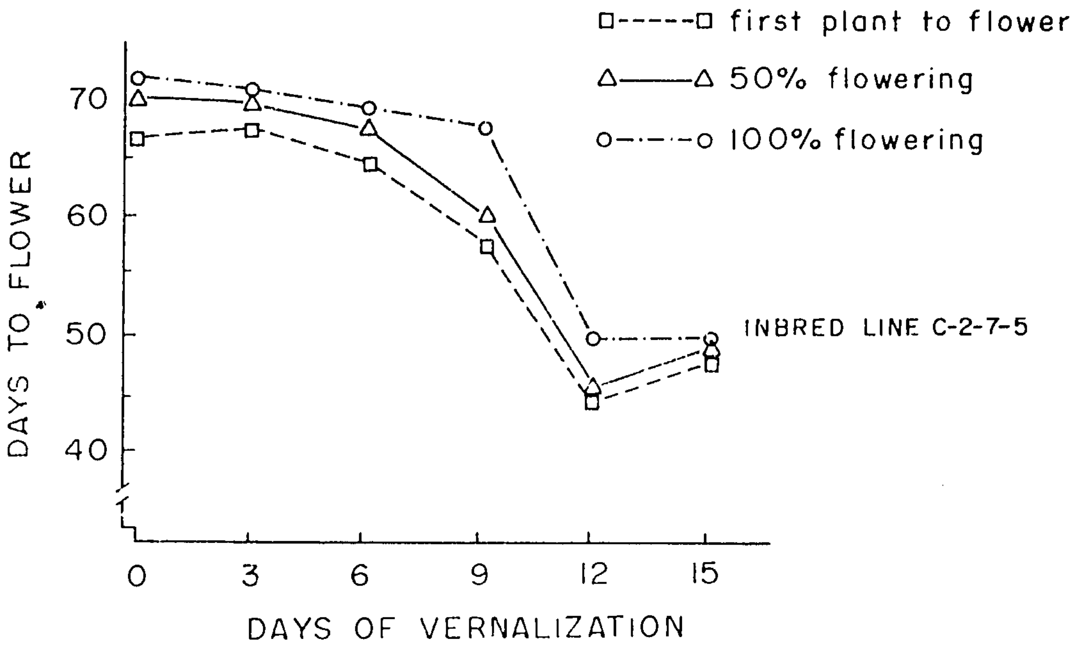

Fig. 4 Influence of vernalization on days to flower of inbred line C-2-7-5

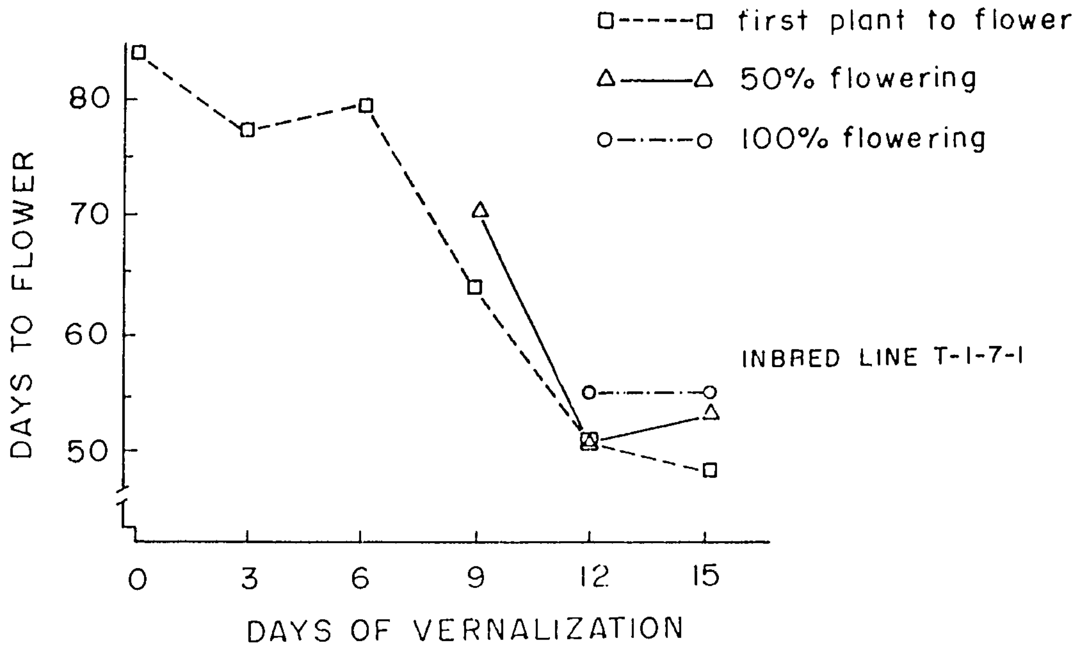

Fig. 5 Influence of vernalization on days to flower of inbred line T-1-7-1

of gibberellic acid and Alar to stimulate or delay flowering without low temperature vernalization was not effective for these inbred lines.

Chiang Mai University is conducting a breeding program in consultation with Dr. M. Allen Stevens of FAO, for varietal improvement of processing tomatoes. High yield, good fruit quality and disease resistance are the breeding targets. Tomato yield in Thailand is low compared to other tropical countries. Bacterial wilt, yellow leaf curl and late blight are major disease pests, and also varieties in current use lack heat tolerance. Development of the tomato industry is hindered by a poor crop production and extension program.

POSTHARVEST HANDLING

Postharvest handling of some open pollinated seed produced in Thailand is not standardized. A large proportion of this seed is traded locally, and packaging does not control moisture content. Often genetic purity and germination percentage are unreliable. Only the seed purchased by seed companies is properly packaged for distribution. In Thailand, the infrastructure for control and improvement of vegetable seed production and distribution is lacking at both a farm and a government level. The Department of Agricultural Extension Seed Division, under a program of vegetable seed production and postharvest handling of seed, has established a well-equipped seed processing plant. However, its scope does not extend to improve already existing seed production. An effective infrastructure to organize seed production and postharvest handling is essential.

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DISCUSSION

Q. (D.J. Murphy)
What potato varieties are recommended for planting in Sanupancpam in Northwest Thailand?

A. A variety from the Netherlands is being used. It is not ideal for processing, but is good for eating fresh. We tried introducing varieties such as *S. burbank* from the United States, but have difficulty in producing these varieties here. Dr. Tongchai Tonguthaisri is the head of the potato project for the Royal King's Project.

Q. (B. Rowell)
Much of the work you presented on sweet corn, peppers, tomato and Chinese cabbage seems to be concerned with the development of F_1 hybrids. Is this emphasis because the hybrid seed is more profitable to the farmers who produce seed, or because it has been determined that the hybrids provide a better return, a yield advantage that justifies the extra cost for the vegetable growers?

A. This is not my work, but rather a report on the work carried out by the seed companies, who are working on both open pollinated and F_1 hybrid varieties. Growers can get benefit from the F_1 varieties, but so far these are not widely distributed here in Thailand.

In F_1 tomato hybrid seed production in Thailand there is a problem of a low germination rate of less than 85%.

PROSPECTS OF ONION SEED PRODUCTION IN TAIWAN

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ABSTRACT

Vernalization of onion bulbs is required for flower induction in onion seed production. In Taiwan, the poor storage quality of bulbs and seed deterioration due to high humidity prior to harvest have constrained seed production. Three varieties have been released by the local District Agricultural Improvement Stations, but the leading variety grown by farmers is Texas Early Grano which was introduced in 1954. Varieties with a high dry matter and pyruvic acid content, and a low nitrogen content, had better storage quality. Bulb storage quality can be improved by increasing the curing time, controlling the temperature and adjusting some cultural practices. Bulbs with good storage quality are necessary for profitable seed production.

(Chinese Abstract)

摘　要

洋葱種子生產之鱗莖必須經過低溫處理誘導花芽之分化。由於鱗莖的不耐貯藏與種子採收前之高濕環境限制了臺灣洋葱種子的生產。改良場雖已育成三個地方品種，但栽培最多之品種仍是1954年引進之早玉品種。鱗莖乾物量與丙酮酸含量高，氮素含量低之品種具有較佳之貯藏力。經由延長鱗莖乾燥時間，貯藏溫度之控制與栽培技術之改進等可以增進其貯藏能力。如要提高種子生產之利益則鱗莖必需要能貯藏良好。

(Japanese Abstract)

摘　要

タマネギの種子を生産するにあたつて、花芽を分化させる爲の鱗茎の低温處理が必要である。台湾では、鱗茎の貯蔵性が悪いこと及び種子採取前の高濕度による種子の品質劣化がタマネギ種子生産を制限している。3品種が各地區農業改良所によつて育成されたが現在最も多く栽培されているのは1954年に輸入されたTexas Early Grano種である。乾物重及びピルビン酸含量が多く窒素含量の低い鱗茎が貯蔵性が高い。乾燥時間を長くし、貯蔵温度を調節し、また或種の栽培技術を改善することによつて鱗茎の貯蔵能力は増進する。種子生産の利益を高めるには貯蔵性の良い鱗茎が必要である。

(Korean Abstract)

적　요

양파종자의 생산에 있어서 개화를 촉진하려면 양파구경에 대한 전온처리를 요한다. 대만에서는 양파구경의 저장성이 약하고 수확전 고습도에 의한 종자질이 저하되어 종자의 생산이 한정되어 있다. 지역농업개량장에 의하여 3 가지의 양파품종이 보급되었으나 가장 많이 재배되는 것은 1954년에 소개된 Texas Early Grano 이다.

구경의 건조성이 높고 피류빈산의 함량이 많으면서 질소성분이 낮은 품종은 저장하기에 좋다. 구경의 저장성은 건조시간을 늘리고 온도조절 및 재배기술에 의하여 개량될 수있다. 유리한 종자생산을 위해서는 저장성이 좋은 구경이 필요하다.

PROSPECTS OF ONION SEED PRODUCTION IN TAIWAN

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INTRODUCTION

In Taiwan, the cultivation of many onion cultivars is constrained by limits of temperature and day length; bulbing types require specific day lengths to initiate bulbing[2,9]. Although Taiwan's subtropic location is not ideal, the onion cultivars Early Grano and Excel Bermuda have now been grown successfully for more than thirty years. These cultivars were introduced to Taiwan by the Joint Commission on Rural Reconstruction (now Council of Agriculture) and the Taiwan Provincial Department of Agriculture and Forestry in 1952.

After thirty years, improved onion production in Taiwan is still being hindered by the lack of cultivars adapted to the subtropic climate in terms of both horticultural and bulb storage characteristics. Onion losses cannot be prevented entirely, but it should be possible to select better adapted cultivars and improve cultivation techniques, to reduce losses in both seed and bulb production.

ONION CULTIVATION AND BREEDING

Records of early onion cultivation in Taiwan at the Taipei District Agricultural Improvement Station in 1933 show that the plants failed to form bulbs. However, the introduction of Early Grano and Excel Bermuda cultivars in 1952 changed Taiwan from an importer to an exporter of onions. Onions for consumption as mature bulbs are grown mainly in the southern prefectures of the island, on an average area of 1000 ha each year[12] (Table 1).

Table 1 Onion production in Taiwan 1978 — 1985[12]

Year	Planted area (ha)	Production (mt)	Yield per ha (kg)	Value (1000 US$)
1978	1044	38,120	36,515	4,069
79	810	25,659	31,684	3,201
80	1173	42,032	35,840	5,243
81	835	30,021	35,970	4,503
82	1102	40,346	36,600	6,909
83	960	22,670	23,615	1,700
84	911	37,788	41,479	6,707
85	980	33,001	33,674	4,950

Source: Year Book of Agriculture, PDAF (1986)

Prior to 1952, there were 7,500 mt of onions imported into Taiwan each year. Export commenced in 1954, and in recent years onions have become one of the most important export vegetables in Taiwan (Table 2).

Taiwan's initial breeding program concentrated on the selection of cultivars. More than one hundred cultivars were introduced

Table 2 Exported volume and value of onions.

Year	Exports (m.t)	Price (US$/20kg)	Value (1000 US$)
1978	1848	4.85	4,481
79	1432	5.80	4,153
80	1426	3.85	2,745
81	2434	7.12	8,665
82	2168	7.00	7,588
83	786	3.18	1,250
84	2496	6.60	8,237
85	1684	5.95	5,010
86 (up to April)	872	3.15	1,373

Source: Taiwan Provincial Farmer Association Data (1986)

and tested for adaptability to the subtropic climate. They included Texas Early Grano, San Joaquin, Yellow Globe, Yellow Granex Hybrid, Excel Bermuda, Yellow Dessex, White Almo, Early Locker Brown, Red Creole, Red Acacia, Red Tropicana, Early Top, Henry's Special, Yellow Creole, Early Supreme, Burgunda, Ring Gold, Granex, Dehydrator 2, Dehydrator 3, Dehydrator 4, Dehydrator 6, Dehydrator 8, and others. At local experimental stations continuous selection has been carried out for cultivars with superior horticultural qualities of uniformity in appearance, early maturity and good bulb keeping quality. However, only a few introduced cultivars, Texas Early Grano, Ring Gold and Granex, have been selected as suitable for release to farmers.

Of the locally developed cultivars, Tainan No. 1, developed by the Tainan District Agricultural Improvement Station, was the first released. Derived by crossing Red Creole and Early Grano in 1959, followed by selection of progeny from seven generations, it was released after testing in 1975. It is a cultivar with a straw colored, flattened bulb which, although it matures two weeks later than Texas Early Grano and Granex, has superior bulb keeping quality in storage to compensate.

The two other local cultivars are Tainan Selection No. 2 and Tainan Selection No. 3. The former was released by Taiwan District Agriculture Improvement Station in 1975, and the latter by the Fengshan Tropical Horticultural Experiment Station in 1985.

ONION SEED PRODUCTION

Two methods, seed-to-seed and bulb-to-seed, can be used in onion seed production[9]. Onion, a biennial plant, produces a bulb in one year and seed in the next. A period of winter chilling, vernalization, is required to initiate flower stalk development. Because of Taiwan's relatively warm winter, onion seed can only be produced by the bulb-to-seed method. For this, mother bulbs are harvested in April and then kept at room (ambient) temperature in shelf storage for 3 4 months. Cold storage at 0 5 C for two months follows, after which the mother bulbs are planted in the field and cultivated in the same way as commercial bulb crops. Tainan No. 1 is the only cultivar used in seed production. Seed production is carried out in commercial bulb production areas.

FACTORS AFFECTING KEEPING QUALITY IN ONION

The keeping quality of onions in storage varies greatly between different cultivars[4,16] (Table 3). In Table 3, the incidence of rotten bulbs is seen to increase over six months storage, with a significant difference in rotting rates between cultivars. After one to six months storage, the average percentage of rotten bulbs increased from 0% to 27.6%, 40.0%, 57.2%, 68.4% and finally 76.0%. The rate of increase was highest during the first three months. The worst of the cultivars tested for storage was Red Creole, with 50% of bulbs rotten at the end of two months, while the cultivars Granex, Texas Early Grano 502 and White Creole reached this proportion of rotten bulbs only after four months, and Tainan No. 1 had only 32% rotten bulbs after six months storage.

Storage temperature can affect the keeping quality of onion. Fig. 1 and Fig. 2 indicate the percentage of rotted and sprouted bulbs

Table 3 Incidence of rotten bulbs in stored onions of different cultivars. Onions were stored at room temperature for six months

Date	Cultivar					
	Tainan no. 1	Granex	Texas early grano 502	Red creole	White creole	Ave.
May 1	0^{a*}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}
Jun. 1	6^{a}	22^{a}	22^{a}	50^{a}	38^{a}	27.6^{b}
Jul. 1	12^{a}	38^{a}	48^{a}	64^{a}	44^{a}	40.0^{c}
Aug. 1	18^{a}	56^{b}	78^{b}	74^{b}	60^{b}	57.2^{d}
Sep. 1	22^{a}	66^{b}	84^{b}	76^{b}	94^{b}	68.4^{de}
Oct. 1	32^{a}	74^{b}	94^{b}	80^{b}	100^{b}	76.0^{e}

* Any mean, within each column, followed by the same letter is not significantly different at the 5% level.

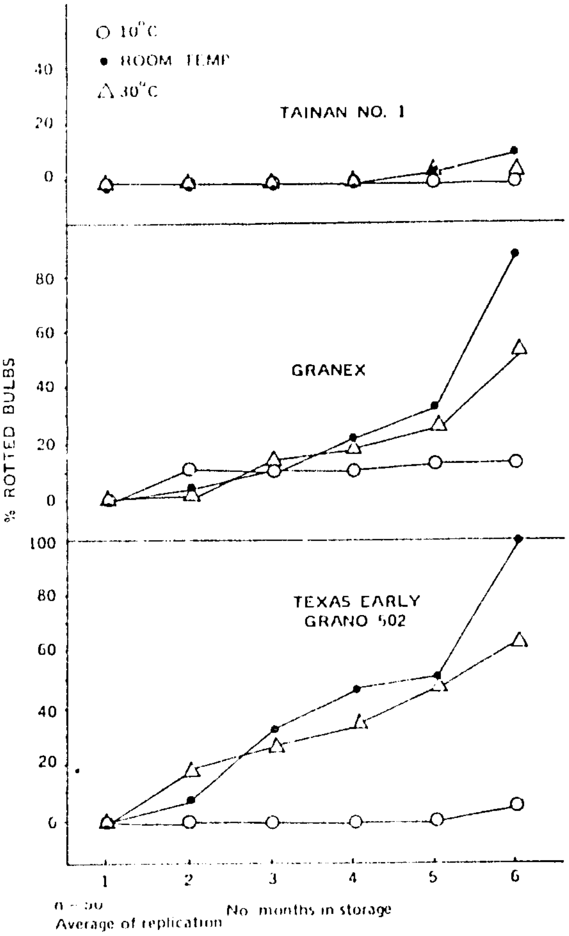


Fig. 1 Effect of temperature on incidence of rotten onions in stored lots over time

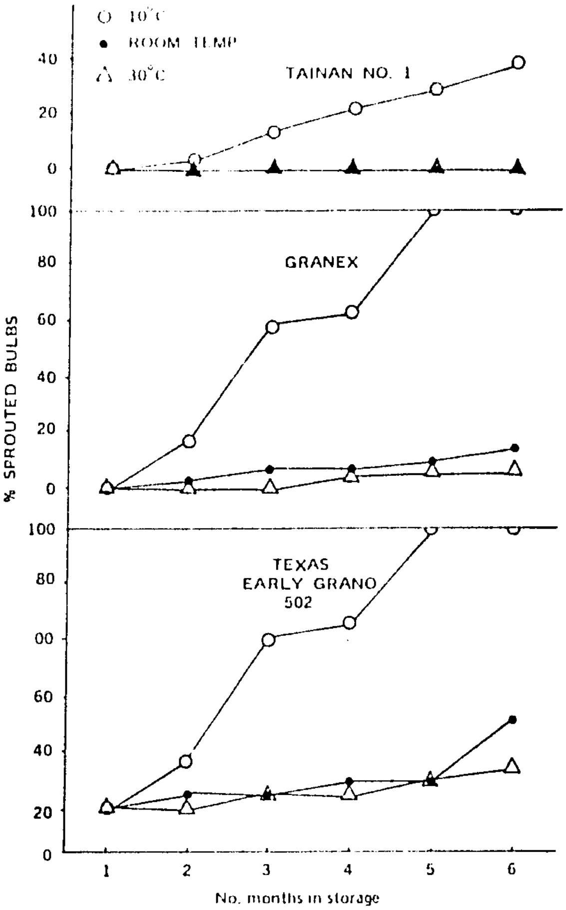
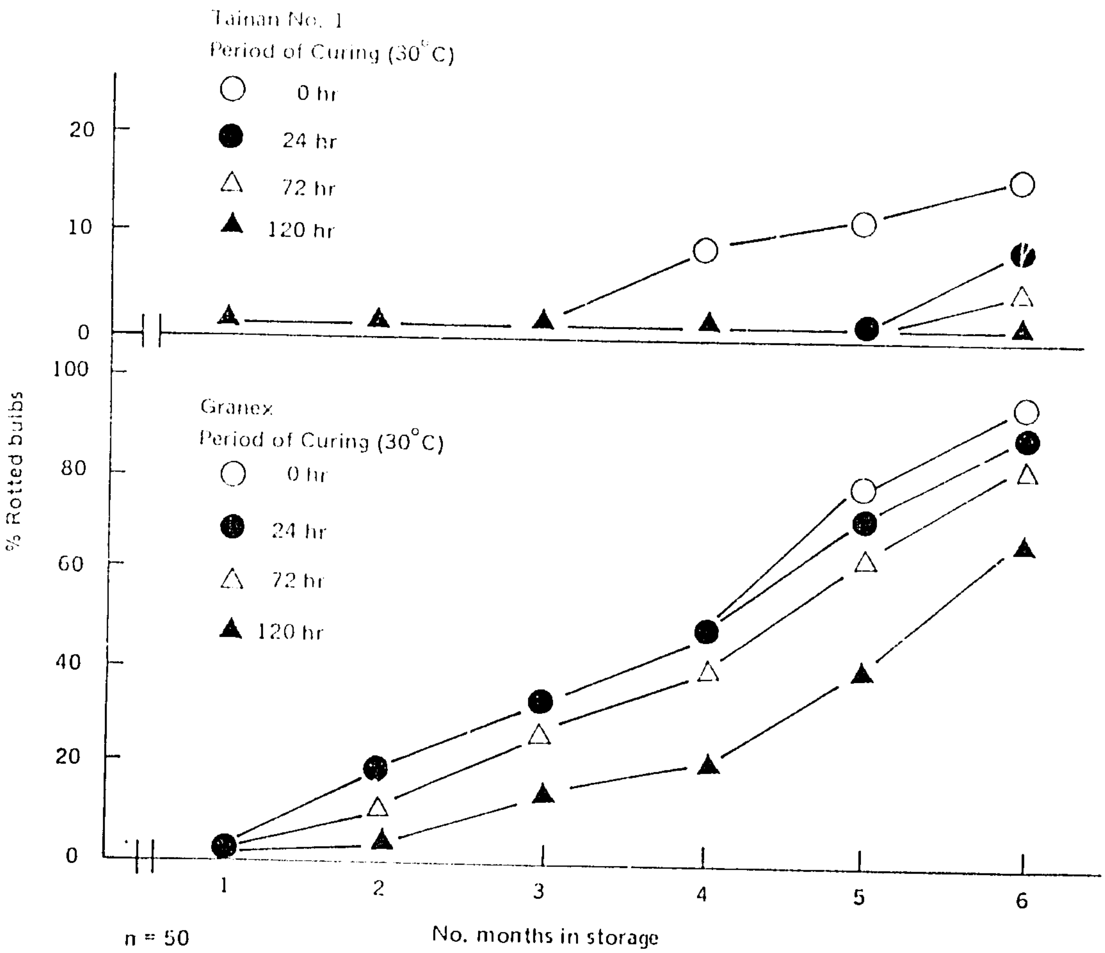


Fig. 2 Effect of temperature on incidence of sprouting in stored onion bulbs of three cultivars

of onion cultivars, Texas Early Grano 502, Granex and Tainan No. 1 kept at 10°C, 30°C and room temperature. Tainan No. 1 had much the best keeping quality, with less rot or tendency to sprout at all temperatures. Within the temperature range tested, Tainan No. 1 recorded less than 10% rotten bulbs in all lots after six months' storage. However, Granex and Texas Grano 502 rotted more readily at room temperature than at either 10°C or 30°C. The percentages of rotten bulbs in lots stored for six months at 10°C, room temperature and 30°C, respectively were 4.4%, 100% and 67% for Early Grano 502, and 13.0%, 89.0% and 40.0% for Granex. Tainan No. 1 also had better keeping quality with respect to sprouting. Almost no loss due to sprouting was recorded in the lot stored at 30°C for six months. All three cultivars had the highest percentage of sprouting in lots stored at 10°C, but was lowest in Tainan No. 1, increasing in Texas Early Grano 502 to the highest incidence of sprouting in stored Granex bulbs.

Curing can remove excess moisture from the outer skin and neck of the onion, and thus reduce losses due to rotting[5] (Figure 3). Artificial curing at 38°C for 72hr and 120hr significantly reduced the percentage of rotted bulbs in Tainan No. 1, but had less effect on Granex even when the bulbs were cured for 120hr.

Changes in the bulb constituents over time for three cultivars are shown in Fig. 4. Tainan



n = 50
4 replications

Fig. 3 Effect of curing on bulb rotting in storage

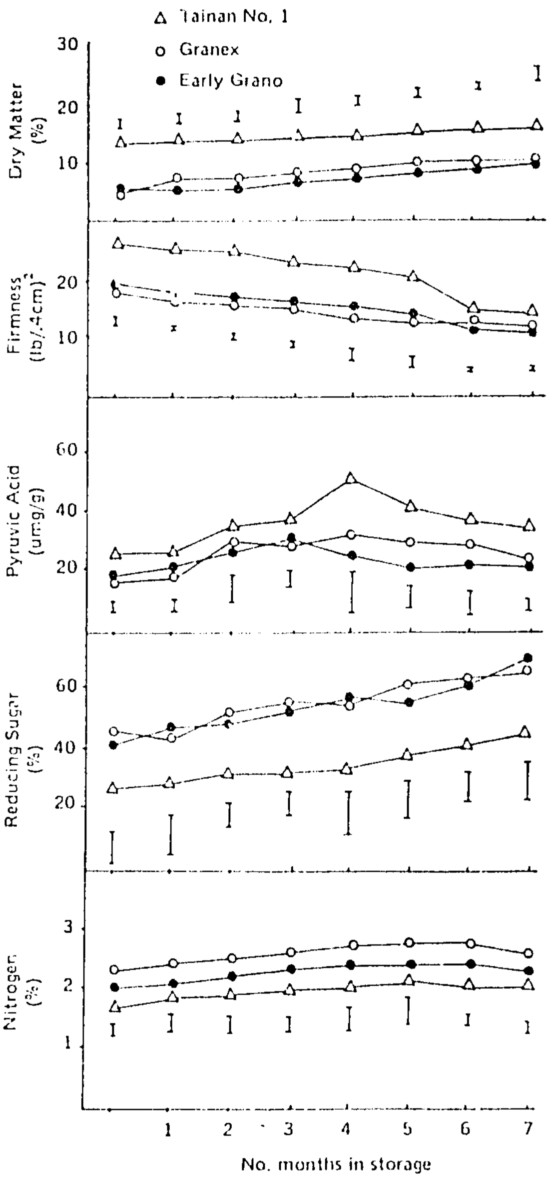


Fig. 4 Changes in bulb constituents during storage at room temperature

No. 1 bulbs had a higher dry matter and pyruvic acid content and were firmer than bulbs of either Texas Early Grano 502 or Granex, but were lower in reducing sugars and nitrogen content. Changes in constituents and physical characteristics in bulbs of the three cultivars showed similar trends during the period of storage. Dry matter content and reducing sugar content increased, while bulb firmness decreased with time. Pyruvic acid and nitrogen content initially increased, then declined after three months of storage.

Many workers[4,9,10,18] have associated poor keeping quality in cultivars with bulbs which have a low dry matter content, a high relative rate of water loss and a high total water loss. This is especially the case if water loss occurs in the period immediately after harvest, when shrivelling, softening and loss of bulb weight may occur. Such cultivars are more susceptible to storage rot and sprouting. It has been noticed that the more pungent varieties, like Tainan No. 1, with a higher pyruvic acid content, generally keep better.

FACTORS AFFECTING SEED PRODUCTION IN ONION

Improving Bulb Keeping Quality

In situations where bulb loss is more than 50% in storage, seed production is not economical. Loss due to sprouting can be reduced by preharvest spraying with MH-30 (active ingredient maleic hydrazine), and this practice has been incorporated into commercial onion production in many parts of the world[7,8,20,21]. MH-30 reduces the respiration of the bulb by suppressing the activity of dehydrogenase, and has been proven effective and safe since it came into use in 1950. MH-30 sprayed on Tainan No. 1 onion plants two weeks prior to harvest significantly reduced the incidence of sprouting in bulbs during storage (Table 4). After six months of storage at room temperature, the incidence of bulb sprouting in Tainan No. 1 onions was 22.1%,

Table 4 Effect of preharvest foliar spray MH-30 on incidence of sprouting (%) in onions

MH-30 (ppm)	No. months in storage						Average
	1	2	3	4	5	6	
0	0^{a*}	0^{a}	12.1^{b}	24.3^{c}	41.8^{d}	54.3^{e}	22.08^{a}
1000	0^{a}	0^{a}	9.5^{b}	17.5^{c}	26.0^{d}	37.5^{e}	15.08^{b}
2500	0^{a}	0^{a}	2.1^{a}	3.4^{ab}	8.4^{bc}	11.5^{c}	4.23^{c}

* Any mean, within each row or column, followed by the same letter is not significantly different at the 5% level
Cultivar: Tainan No. 1, Storage Commenced April 1

15.1% and 4.2% when sprayed with concentrations of 0, 1000 and 2,500 ppm MH-30 solution, respectively.

Though MH is useful in the commercial production of onions for consumption, it cannot be used on bulbs intended for seed production. Other plant growth regulators are now being investigated for this purpose (Tables 5 and 6). Neither GA_3 nor ABA treatments reduced the incidence of sprouting in stored bulbs: on the contrary, bulbs treated with 100 ppm GA_3 showed an increased sprouting rate, with 43% of bulbs sprouted after six months' storage compared with a 17% incidence in the controls.

GA_3 and ABA had no significant effect on the incidence of rotten bulbs in the first five months of storage. Their effect on longer term storage may need further research. MH remains the only plant growth regulator consistently effective in reducing sprouting and rotting in stored onions. Cultivars that do not keep well in storage cannot be improved to the level of Tainan No. 1 cultivars by exogenous growth regulator treatment.

Table 5 Effect of different plant growth regulator treatment on incidence (%) of rotting in onions

Growth regulator	No. months in storage					
	1	2	3	4	5	6
0 (Control)	0	13	23	34	60	93
100 ppm GA_3	0	17	37	53	60	77
100 ppm ABA	0	13	27	40	50	67
200 ppm MH_3	0	3	7	23	37	50
ABA + MH_3	0	13	17	27	33	43

Cultivar: Tainan No. 1. Storage Commenced April 1
N = 30
4 Replications

Table 6 Effect of different plant growth regulator treatments on incidence (%) of rotting in onions

Growth regulator	No. months in storage					
	1	2	3	4	5	6
0 (Control)	0	3	3	10	13	17
100 ppm GA_3	0	7	13	23	37	43
100 ppm ABA	0	0	0	0	10	13
200 ppm MH_3	0	0	0	0	3	7
ABA + MH_3	0	0	0	0	0	7

Cultivar: Tainan No. 1. Storage Commenced April 1
N = 30
4 Replications

Bulb Weight and Number of Flower Stalks

The greater the number of seed flower stalks produced by the onion plant, the more seeds harvested[17]. A correlation exists between mother bulb weight and the number of flower stalks produced per bulb (Table 7). In each given weight group, 100 bulbs were dissected to assess the average number of potential flower buds per bulb at that weight. As bulb weight increased from 100 to 250 g, the average number of potential flower buds increased from 3.11 to 5.18. Not all buds develop into flower stalks in the field. The average flower stalk production per bulb for each of the weight groups 100, 150, 200, and 250 g were 2.2, 2.3, 2.7, and 3.5, respectively.

The effect of bulb weight on seed production is shown in Table 8. Bulb weight does not usually affect the number of days from planting to bolting, which ranged between 28 and 29 days for the whole 100 g to 250 g bulb weight range. Since the number of flower stalks significantly affects the final yield in seed production, lighter bulbs produced less seed yield per plant. Results indicated that seed yield increased from 286 kg per ha from 100 g bulbs to 737 kg per ha from 250 g bulbs.

Table 7 Effect of bulb weight on number of flower buds and stalks

Bulb wt. (g)	No. Flower buds	No. Flower stalks
> 100	3.11	2.2
100 – 150	4.15	2.3
150 – 200	5.05	2.7
200 – 250	5.18	3.5

Cultivar: Tainan No. 1

Table 8 Effect of bulb weight on seed production

Bulb wt. (g)	Days to bolting	No. of flower stalks per bulb	Wt of seed per plant	Yield kg/ha
100	28.0	2.2	2.9	286
150	28.0	2.3	3.8	376
200	29.0	2.7	4.7	471
250	29.0	3.5	7.4	733

Cultivar: Tainan No. 1

Low Temperature Storage of Onion Bulbs

Boswell and others[1,13,11,15] have reported that the temperature at which bulbs are stored significantly affects seed stalk development in onion. In Taiwan, research has been carried out on the effect of the length of the cold storage period on onion flower stalk production, in cultivar Tainan No. 1 (Table 9)[5]. With no period of cold storage, the plants produced insignificant numbers of flower stalks. With a four week period at 9°C, the plants had 80% bolting and produced an average of 1.9 flower stalks per plant. Eight and twelve week periods at 9°C increased bolting to 97% and 100%, respectively, and average flower stalk production to 3.5 per plant overall. Differences between the eight and twelve week storage periods in terms of the number of days to bolting, bolting percentages and numbers of flower stalks per plant were not significant. Eight weeks of low temperature storage were thus considered sufficient to induce flower bud initiation. However, results also showed that average fruit-set was less than 50%, which would be a major factor causing low seed yield.

Table 9 Effect of low temperature storage on seed production

9°C (wks)	Bolting (%)	Days to bolting	No. F1 stalks	Fruit set (%)
0	7	60	0.1*	52
4	80	44	1.4	33
8	97	36	3.5	46
12	100	34	3.5	43

Cultivar: Tainan No. 1
N = 100 (4 plots, 25 plants per plot)

Stimulation of Root Development and Growth

Studies of Tainan No. 1 onion cultivars grown for seed production have shown a reduction of 75% in both foliage and root growth in the late growing stage. Attempts were made to promote root growth by IBA treatment, and study the effect of this on seed production[3]. The first two weeks after IBA treatment proved to be a latent period with respect to root growth promotion. However, treated bulbs showed better development in both roots and foliage one month after treatment (Figure 5), and an overall increase at the end of the growth period. No significant difference in seed yield was observed between treated onions and controls.

PROSPECTS FOR ONION SEED PRODUCTION IN TAIWAN

If every onion flower produces its

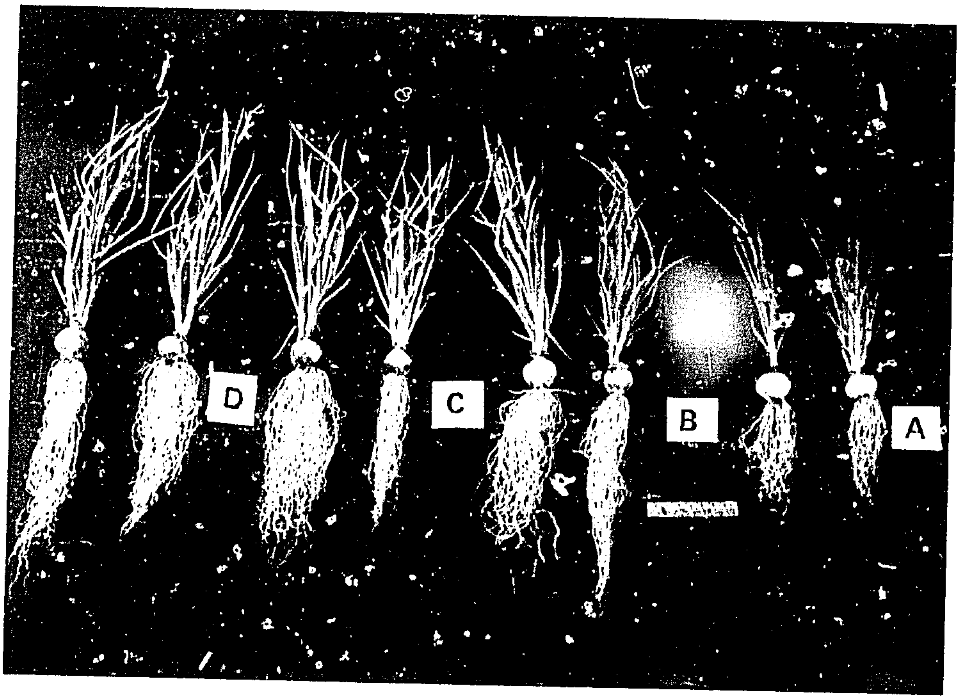


Fig. 5 Effect of IBA treatment on root development and growth
A) Control, B) 2.5mg, C) 5.0 mg D) 7.5 mg
Cultivar: Tainan No. 1

maximum of six seeds and the field is saturated with umbels, the theoretical maximum onion seed yield could reach 4310 kg/ha. In California, the average yield for most open pollinated onion varieties under good management is approximately 1100 kg/ha. However, in Taiwan the average yield obtained from Tainan No. 1 is less than 400 kg/ha, only one third of the United States seed yield and less than one tenth of the theoretical maximum.

Genetic, environmental and cultural factors may be causing the low seed yield in Taiwan. Tainan No. 1 has a low fruit set rate, and the poor keeping qualities of other varieties in the humid subtropics is a major constraint to their use for seed production. On the other hand, Taiwan has a high bulb production of 40 mt/ha, which compensates for some loss of bulbs in storage. Chemical, physical and physiological methods of reducing bulb loss in storage are being studied. Cultural practices of fertilizer and moisture control are also being attempted in Taiwan, to improve postharvest bulb keeping quality, but the most successful means of doing this so far has been cultivar selection and improvement.

With a view to seed production, attempts have been made to increase bolting percentage, number of flowering stalks, number of flowers per umbel and fruit-set over the past ten years. Bulb keeping quality is important in improving seed yield, and thus cultivar selection is also important. The present seed yield is low in Taiwan, but there is great potential for improvement in the near future.

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DISCUSSION

Q. (W. Kongpolprom)

Before harvesting the onion bulbs for onion seed production, it is necessary that they are quite dry. How dry do they need to be?

A. In seed production the farmers are generally using field curing of the mother bulbs and do not actually measure the dry matter percentage, but our tests show it is around 12%.

Q. (W. Kongpolprom)

In the vernalization process, what is the temperature and period of treatment for the onion bulbs?

A. The cold storage facilities are rented by the month to farmers, so they simply treat the mother bulbs for two months, which period is adequate at 2°C.

There are two types of cold storage facilities available to onion growers in Taiwan, one is the ammonium system and the other the freon system. They have found that the freon system produces more flower stalks in the field.

THE ROLE OF IMPROVED VEGETABLE SEEDS IN THE DEVELOPMENT OF THE VEGETABLE INDUSTRY OF SOUTHEAST ASIA

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ABSTRACT

Suitable varieties and reliable seeds are the cornerstone of the vegetable production industry. New developments in the production of fresh and processed vegetables for domestic and export markets require well-adapted cultivars.

This paper gives a brief historical outline of the interaction of the vegetable industry and the seed industry in countries with a highly-developed vegetable production system in East Asia, Europe and North America, and makes extrapolations about similar developments in the near future in Southeast Asia.

(Chinese Abstract)

摘　要

適當的品種及可靠種子為蔬菜產業之基石。發展鮮食或加工蔬菜供應國內外市場之用，必需要有良好適應性之品種。

本文簡要回顧東亞、歐洲及北美地區已高度發展之蔬菜生產制度，其蔬菜產業與種子產業間之互相信賴性，提供東南亞未來類似產業推廣之借鏡。

(Japanese Abstract)

摘　要

野菜栽培には適當な品種を選び，信頼のおける種子を使うことが必要である。國內向けや輸出用の生鮮又は加工用野菜を新しく開發するためにはそれに良く適した品種を使う必要がある。東アジア，ヨーロツパ，北アメリカの高度に發達した野菜生產國における野菜作と種子產業との相互關係について歷史的に概說し，東南アジア諸國にも近い將來同様の發展が見られることを推定している。

(Korean Abstract)

적　요

적절한 품종과 확실한 종자는 채소재배산업의 기본이 된다. 국내 및 수출시장을 위한 신선하고 가공된 채소의 생산개발에는 가장적합한 품종이 요구된다.

이논문은 고도로 발전된 채소생산체제를 갖춘 동아세아, 유럽 및 북미제국에서 채소산업과 종자산업간에 연결되는 상호관계에 대하여 역사적개황을 소개하였다. 그리고 가까운 장래에 동남아세아에서 이와 비슷하게 나타나게될 발전전망을 추정 하였다.

THE ROLE OF IMPROVED VEGETABLE SEEDS IN THE DEVELOPMENT OF THE VEGETABLE INDUSTRY OF SOUTHEAST ASIA

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GENERAL BACKGROUND

The economic history of mankind may be characterized by continuous domestication and adaptation to constraints. The same can be said about the history of agriculture, and more recently horticulture. The boundaries of horticulture are not always distinct. The original meaning of the Latin word is 'farming in an enclosed area'. From an economic point of view, it appears useful to define horticulture as the farming of plant crops with a relatively high added value. This would obviously include vegetables and fruits.

What are the most pressing constraints in agriculture in Southeast Asia for today and tomorrow?

Many discussions at an international level focus on population growth, shortage of food, nutritional deficiencies and poverty, or in the language of economists, lack of buying power. There seems to be a growing consensus that these problems are interrelated and that the only solution is to make more efficient use of the farmland now available. An advertising slogan of an American Seed Company sums it up neatly.

> "Helping farmers to get more from every acre"

We will leave the wide vistas of the macro-economic analysis and also the production of commodity food crops such as rice, corn, soybean and edible oil, since on a worldwide scale these are now in oversupply and farmers are losing money with these crops. This could be a blessing in disguise, since it will focus more attention on the high-value, or horticultural, crops.

VEGETABLE PRODUCTION AND PLANT BREEDING

Vegetable farming in most situations shows the importance of domestication and adaptation to constraints.

Many vegetables came from somewhere else and had to be adapted. This adaptation process is not a single phase affair, but is a continuous development of adaptations to new requirements.

Some of these requirements are:

Seasonal Adaptation

In the temperate countries this usually means adaptation to early and late season production. In the tropics, it may mean adaptation to hot and dry, or rainy season, conditions of the lowlands.

The seed industry in Holland helped to

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* Paper presented by Simon de Hoot, East-West Seed Co., Ltd.

develop year round lettuce production in greenhouses by breeding varieties for months with a very short day length. In Japan, the season for harvesting fresh cabbage was extended from six to ten months by developing suitable varieties.

In the tropics, a good start has been made with hybrid cabbage and Chinese cabbage for heat stress conditions. In cauliflower, the introduction of the heat tolerant short cycle variety Patna from India is now being followed up by the development of improved hybrid and open pollinated varieties from Taiwan and Japan.

Reproduction Adaptation

Since many vegetables are introduced from somewhere else, seed production, especially of biannual seed crops, can give problems When Chinese cabbage was introduced to Japan from China and Korea in the period 1890 1920, it took 10 20 years to develop the right varieties for local reproduction and learn how to produce seed. Dr. Shinohara gives good examples of other crops in his books[2,3]. Japan has always had a strong motivation to grow its own seed, and not depend on other countries for a vital link in its food production.

Disease Adaptation

Plant diseases and insects have always been major constraints in vegetable production, especially in tropical countries. Plant breeding for genetic disease resistance has made great progress in the developed countries during the last 30 years. However fungi, bacteria and viruses may mutate and become tolerant to chemicals, and the struggle for adaptation is continuous. In the tropics, modern agricultural chemicals are helping the farmers (at a substantial cost) but there is a great untapped potential for disease resistance plant breeding in tropical vegetables. The work of AVRDC has shown that it is possible to obtain high levels of genetic tolerance to soil borne bacterial wilt in upland tomatoes. In Chinese cabbage, the releases from AVRDC with tolerance to heat stress, and to diseases such as soft rot and most strains of turnip mosaic virus, should pave the way for plant breeders to develop the right varieties for their own local markets.

It is encouraging that AVRDC will soon start work on peppers. This program, to be carried out in cooperation with other plant-breeders in Asia, should help to solve some of the serious disease problems in this important crop of substantial economic importance, for which the acreage in Thailand and Indonesia alone is estimated at 200,000 hectares.

We may expect interesting releases from public and private breeding programs in the Philippines in the near future of such cultivars as yard long beans with tolerance to rust and virus, and pumpkin (*Cucurbita moschata*) with a high tolerance to virus

Product Quality Adaptation

Market requirements are always changing, and new varieties and production systems are needed to meet these challenges. Examples:

Post harvest quality

Vegetable shippers and dealers require better shipping quality and longer shelf life.

Eye-appeal quality

Supermarkets require more uniformity, including a more uniform color.

Processing quality

Food processors require special characteristics for every crop they handle.

The requirements of the emerging vegetable processing industry in the Asian and Pacific region will put a heavy claim on the skills and imagination of our plant breeders and vegetable farmers.

The field for the ideal variety of tropical, dry season, processing tomato is still wide open. Temperate varieties do not have the right combination of high yield, high brix, good color and disease resistance. F_1 hybrids appear to have the best chance, since their obvious hybrid vigor can overcome some of the adverse natural conditions in the tropics. The recent AVRDC releases in processing tomatoes seem to confirm this concept.

In pickling mustard we need more uniformity. There is no suitable tropical pickling cucumber yet.

In peppers, the large market for dried hot peppers would benefit from improvements in yield, dry matter and capsicine content.

Farming System Adaptation

This covers a wide area of farming technology, and includes the everlasting need of farmers to increase their yield.

Good old yield improvement plant breeding has given excellent results in most countries for many crops, including tropical rice and corn, but there is still a long way to go in tropical vegetables.

Intensive upland farming of Kang Kong (*Ipomoea aquatica*) as practised around Bangkok, instead of the traditional, labor intensive harvesting of aquatic Kang Kong from river and canal banks, is one case which shows that new varieties can affect a farming system.

PUBLIC AND PRIVATE PLANT BREEDING

In the developed countries, with highly developed plantbreeding activities, considerable controversy has existed over the division of work between public and private plant breeding, the latter usually done by seed companies.

As a result, different models have emerged, some of which carry the marks of a political background.

In Western Europe, England has a strong emphasis on public plant breeding and thus new varieties are mostly sold by a national seed corporation. The models of France and Holland are somewhat similar. The public plant breeding institutes handle mostly basic or fundamental research, and the seed companies the applied plant breeding or commercial variety development. The main difference between these two countries is that the Dutch seed industry and other vegetable industry partners have a fair degree of influence on the direction of the government programs. This is not the case in France.

In the U.S.A., the division of work between public and private interests is not formalized, but informal patterns similar to those of France and Holland have emerged.

I am not very familiar with the situation in Japan, Korea and Taiwan, but it appears from the outside that effective interaction between the public and private sectors has developed over the last 30 years.

In India, most of the plant breeding in vegetables is controlled by the government, and private seed companies are mostly engaged in seed production and marketing.

The key issue involved here is how best to develop new varieties that are of interest to the vegetable farmers and the vegetable buyers.

Commercial plantbreeding has a strong market orientation, and has to come up with varieties that will sell in order to survive. During the last five years, I have seen many varieties released from public breeding programs in Southeast Asia that have not found acceptance in the market. The countries of Southeast Asia will have to reach a decision on which of the existing models is the best for the development of the vegetable industry. One criterion might be to compare the rate of development of the vegetable industry and the seed industry in each country with the model used in that country.

FURTHER DEVELOPMENT OF VEGETABLE PRODUCTION AND THE SEED INDUSTRY IN SOUTHEAST ASIA

Historical trends in demographic and consumption patterns make it very likely that the total population and the per capita consumption of vegetables in Southeast Asia will increase during the next 25 years.

My colleague Leonard Ho from Taiwan, at a FAO/DANIDA seminar in Bangkok last

May, presented very interesting figures about the development of vegetable consumption in Taiwan during the 1945–1980 period (Table 1). They show the following increases over this 35 year period:

a) Vegetable acreage	554%
b) Vegetable consumption per capita	242%
c) Population increase	192%
d) Vegetable yield per hectare	64%

We may not expect quite the same pace of development in Southeast Asia during the next few decades. The Chinese appear to have a stronger natural affinity for vegetable consumption than most other peoples in Asia.

The following observations can be made:

1. The vegetable acreage of Thailand is increasing. Every week rice fields near Bangkok are converted to year-round vegetable production. The recent low price for rice has encouraged this trend.
2. The increase in the consumption of vegetables, fruits and animal protein per capita is strongly correlated with increases in spending, and therefore linked to overall economic development. We are entitled to some optimism that economic growth in this part of the world may continue.

   Vegetable consumption patterns also vary from country to country. Thais are fonder of vegetables than the Filipinos, for example. It is interesting to note that in Taiwan and Japan the per capita consumption of vegetables (130 kg per year) is higher than the consumption of rice (100–120 kg).
3. We must leave predictions of population growth to the demography experts.
4. The increase in yield per hectare is the concern of vegetable farmers, plant breeders and seed suppliers, the vegetable crop experts and extension people. Yield increases will improve the farmer's income, provide more vegetable volume to satisfy the increasing demand and therefore keep vegetable prices at a reasonable level.

   Remarkable improvements in yield can be made by developing new varieties with better rainy season adaptation, particularly in the so called fruit vegetables of the solanaceous and cucurbit families.

   Experience in the developed countries shows that the private seed industry, supported by strong basic research programs of the government, is in the best position to supply the high quality seeds that the market needs. This is

Table 1 Vegetable production and per capita consumption in Taiwan

Year	Acreage ha	Yield per ha kg	Production mt	Population (1.000 persons)	Per capita consumption kg
1945	35,319	8,567	302,575	6,090	38
1951	78,601	7,834	615,789	7,869	63
1956	81,859	8,190	670,460	9,390	58
1962	94,247	8,928	841,409	11,512	56
1965	108,808	8,898	968,159	12,628	57
1970	141,540	11,906	1,685,191	14,676	85
1975	187,381	11,881	2,226,308	16,150	110
1980	2[illegible]077	14,038	3,224,849	17,805	130

after all a market economy. I don't like the word capitalism that Marx invented more than 100 years ago. Market economy is much better. We need a few new varieties that will become successful. This will give our plant breeders the confidence to continue the never-ending battle for better varieties. Accomplishment breeds confidence and confidence breeds accomplishment.

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DISCUSSION

Q. (B. Rowell)

Mr. Groot, in discussing the ideal tomato variety for the tropical environment, states in his paper "F_1 hybrids appear to have the best chance, since their obvious hybrid vigor can overcome some of the natural adverse conditions of the tropics."

Does the work with open pollinated and F_1 hybrid vegetable varieties of the breeders present at this meeting support this statement?

A. (R.T. Opeña)

Tomato is a self pollinated crop, and hybridization response is not as good as in other cross pollinated crops. The existence of hybrid vigor in tomato is mostly in the propaganda of seed companies. You do get some, but not to the same extent as in cross pollinated crops. At AVRDC we have not looked at F_1 hybrid tomato varieties for the tropics.

Q. (S. de Hoop)

Hybrids generally are more vigorous than open pollinated varieties. However, in California there is a swing back to the open pollinated varieties, but these conditions are almost optimal for growth, whereas in the tropics conditions are far from optimal and extra vigor is needed to provide disease resistance and heat tolerance. Good processing tomatoes from open pollinated varieties are still a long way from development.

A. (R.L. Villareal)

I agree with Dr. Opena that there is no clear evidence of the advantage of F_1 hybrid tomatoes over open pollinated varieties. If the seed companies can persuade the farmer of the advantage of F_1 hybrids then the growers are dependent on the seed companies for seed, whereas with open pollinated varieties the farmers can use their own seeds.

Q. (K. McKay)
Dr. Groot's paper raised the issue of whether seed development programs are better managed by the public or private sectors in Southeast Asia. He said that some varieties are being released that are not really acceptable in the market. Dr. Villareal has mentioned the breeding philosophy in the Philippines and pointed out that it was necessary to breed with the small farmer in mind who is dependent on growing with low input. Dr. Manee Wivutvongvana has said that in Thailand there has been little work done on the improvement of indigenous vegetables. Do participants feel that private enterprise is now serving, or is able to serve the needs of the small farmers for vegetable seed? Is this an area which must be served by public institutions?

A. (R.L. Villareal)
In the Philippines, the public and private sectors can work together. For example at the Institute of Plant Breeding, the breeding philosophy has two aspects, one being to care for the commercial high yield technology, and the other to care for the low input technology. For the low input technology, varieties must be disease resistant and adaptable to the wide range of conditions found in farmers' fields in the Philippines. For the two different end users we will produce semi-finished breeding lines that the private sector can take over, and develop into their final market product. We have done this in the case of maize, mungbean and some vegetables. The private sector still works on developing their own lines, including hybrid varieties, but they target these seed products to the 30% of the production which is carried out by commercial farms. In the long term the low input group will decrease in size.

Q. (S. de Hoop)
In Thailand the situation is not so advanced. At the East-West Seed company, we are the only private company involved in vegetable seed production. I feel that it is good that both private and public sectors are working on improving vegetable production. However, many of the releases from public institutions have not found any acceptance at all, usually because the workers involved have not gone into the field to find what the farmers want and how their products can be improved. We in the private sector are more market oriented.

A. (M. Wivutvongvana)
For the breeding of indigenous vegetables I think some good work has been done in Thailand in the public sector.

AUTHOR'S COMMENT ON DISCUSSION (S. N. GROOT)

1. *Re* Dr. Opeña's statements, it is interesting to note in the AVRDC 1984 and 1985 Progress Report Summaries that AVRDC is now paying much more attention to the development of hybrid varieties, especially for processing purposes.

2. The use of F_1 hybrids in commercial tomato farming is spreading every year. Western Europe, and that includes the open-field tomato farming in Southern Europe, is now more than 80% hybrids. Also in Turkey the hybrids have taken a substantial share of the market. Japan is 100% F_1 hybrids in all solanaceous fruit vegetable crops.
This cannot be ascribed to propaganda alone. As the saying goes, you can fool some people all the time but never all the people all the time.

3. Thailand and the Philippines each have a market for tomato seed that is estimated at 3000 kg per year. At the prevailing price of US$25 kg for non-hybrid seed, this does not offer much incentive from a business point of view to make substantial investments in commercial plant breeding of non-hybrid varieties.

   On the other hand, it is widely acknowledged that major efforts in improving heat tolerance and disease resistance in tropical tomato are needed.

   In my opinion, the development of superior F_1 hybrid tomatoes with high seed prices can bridge the technical and economic requirements at the same time.

Postharvest Technology

POSTHARVEST PROBLEMS OF VEGETABLES IN THAILAND

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ABSTRACT

In Thailand, postharvest losses of vegetables mainly result from physical injury caused by rough handling at all stages of the marketing channels. At market, losses due to pest and disease infestation reflect poor on-farm cultural practices. Heavy losses also occur in transportation to distant domestic markets. The export trade in vegetables also needs improvement of postharvest handling and quality control.

(Chinese Abstract) 摘 要

泰國蔬菜採收後處理之損失，主要由於在市場產銷過程中，物理性損害及操作不當所致。由市場上病蟲害感染之損失，可反應出田間栽培管理之不當。國內市場長途運輸亦可能造成嚴重損失。蔬菜外銷貿易亟須採收後處理及品質控制之改進。

(Japanese Abstract) 摘 要

タイ國では收獲後の野菜の損害は、流通過程における亂暴な取扱いによる物理的な傷によるものが殆んどである。市場での病蟲による傷害は圃場での貧弱な栽培法のためである。國内でも遠隔地への輸送の場合大きな被害がおきる。野菜の輸出についても收獲後の處理や品質管理を改良する必要がある。

(Korean Abstract) 적 요

태국은 채소수확후 발생되는 손실이 주로 모든 유통단계의 거친조작에 의한 물리적손상에서 초래되고 있다. 시장에서 병충이나 병균으로 의해 오는 손실은 재배관리가 소홀하였음을 나타낸다. 그리고 거리가 먼 국내시장으로의 운송과정에서 대량의 손실을 가져오고 있다. 채소의 수출교역에 있어서는 역시 수확후의 조작 및 품질관리의 개선이 요구되고 있다.

POSTHARVEST PROBLEMS OF VEGETABLES IN THAILAND

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INTRODUCTION

There are 20 kinds of vegetables listed by the Department of Agriculture as consumed by Thai people[2] :

shallot
lettuce
cucumber
pumpkin
yam bean
white gourd
bitter gourd
cabbage
chilli
garlic
taro
tomato
ginger
Chinese mustard greens
Chinese radish
Chinese kale
water spinach
yard long bean
angled luffa
sugar peas

The population of Thailand is 51.8 million and in 1983/84, Thais cultivated 0.31 million ha of vegetables. Of these, 2.7% were lost due to preharvest damage. The total annual production was 2.1 million metric tons, of which 4% was exported, leaving a farm gate vegetable production of 39 kg per annum (107 gm/day) available for market per Thai. Between 30% and 50% by weight of the harvested vegetables is then discarded as inedible outside leaves, twigs and stems. Losses beyond these are considered postharvest losses, which if combined with the discarded portions drastically reduce the 107 gm/day available for consumption. However, other estimates put the average daily vegetable consumption of Thai people at 200 gm/day. Part of this difference is made up by the large volume of indigenous vegetables and those which are not officially listed. Some of these are of significant economic importance, and include:

asparagus
broccoli
mushrooms
carrot
okra
coriander
baby corn
snap bean
bamboo shoot

Indigenous vegetables are grown both for market and for home consumption, in kitchen gardens and on fences, or are collected from the wild. Generally they pose little of a postharvest problem, being consumed soon after harvest. Some indigenous vegetables are high in nutritional value, particularly in provitamin A. Examples include:

Acacia pennata Willd. subsp. *insuavis* Nielson
Cassia siamea Britt.
Piper sarmentosum Roxb.
Leucaena leucocephala de Wit
Morinda citrifolia Linn.
winged bean, *Psophocarpus tetragonolobus* DC.
ivy gourd, *Coccinia indica* Wight & Arn
water mimosa, *Neptunia oleracea* Lour.

PREHARVEST FACTORS INFLUENCING POSTHARVEST LOSS

Perishability

Different vegetable crops have different perishability rates, according to various physiological, climatic and seasonal factors. Vegetables with a marketable life of more than a few weeks are garlic, pumpkin, shallot, sweet potato, taro and white gourd. Vegetables with a high water content, a large surface area to weight ratio or a high level of physiological activity are highly perishable, and have a marketable life of only a few days. These include broccoli, Chinese kale, lettuce, sugar peas, water spinach, and yard long bean.

Pests and Diseases

Fresh produce which is infested by disease or pests at harvest may be unmarketable or have a short shelf life. Infestation may be obvious or latent, and is often the result of poor preharvest management. Attacks of fruit fly in certain fruit vegetables, or heart rot and tipburn in lettuce and cabbage, for example, all cause damage which is revealed when the crop comes to market.

POSTHARVEST FACTORS

A number of other preharvest factors in the food production system contribute to food losses. The causes of postharvest losses are well documented[1,5,6,9,15] and include:

- plant physiology
- season
- temperature
- unsuitable containers
- genetic makeup of crop
- humidity
- poor storage
- poor packaging
- lack of care at harvest, and other cultural practices
- physical properties (morphology) of crop
- other biological and microbiological factors
- management and time of harvest
- mechanical or rough manual handling
- damage during transportation
- distribution and marketing management
- other socio-economic and political factors

Strictly speaking, postharvest activity begins right after harvest. Some of these activities, such as loading, transportation, buying and selling, are repeated at different stages along the channels between harvest and consumption. Losses occur at almost every stage along these channels: the greater the number of stages, the more food losses occur.

A simplified flow diagram of Thailand's vegetable distribution channels is shown in Figure 1[16]. The practices used are conventional, and have remained basically the same over many years. Improvements are slowly occuring, as in the modern treatment and storage of onions.

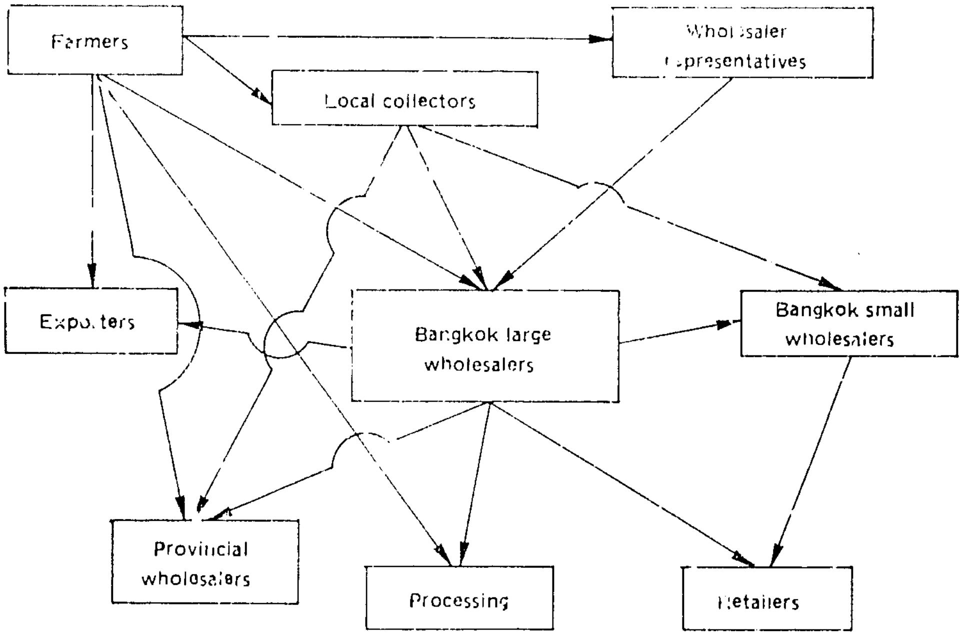

Fig. 1 A simplified diagram of vegetable distribution channels in Thailand. Modified from Reungtawikoon[16]

POSTHARVEST LOSSES IN VEGETABLES

Statistics from Taiwan[11] show the postharvest losses in transport, wholesaling and retailing of 16 vegetables to range from 4% for green beans to 30% for Chinese cabbage. The losses in the ASEAN region as a whole are much higher, ranging from 22% to 80%[4,13]. White onions suffered the greatest losses, followed by cabbage with about 45% postharvest losses.

In Thailand, Pankasemsuk and Kosiyachinda[14] have reported that in a shipment of bell peppers sent from Chiang Mai to Bangkok, 10.20% of the peppers were found to be unmarketable. The loss was caused by micro-organism damage (4.31%), insect damage (1.39%) and sunburn (0.90%), while 3.40% of the peppers were crushed and bruised. Pakrushapun and Lohara[15] reported postharvest losses of vegetables during handling and transportation from production areas near Bangkok to Bangkok Central Market to be 1.7% for bamboo shoot, 15.4% for Chinese cabbage and 16.2% for coriander, with losses for other vegetables falling between 3.5% and 10%. Generally, mechanical injury was the greatest cause of loss, rather than decay or reduced moisture content.

The Royal Project for vegetable production in the highlands of Thailand has recorded the weight loss between harvest and final marketing for 23 types of produce. Some of these showed a very high rate of weight loss in some locations or seasons, and a comparatively low rate in others[3] (see Table 1).

Head lettuce suffered the greatest weight losses. In highland lettuce, 4-6 wrapper leaves accounted for 28.01% of total weight at the production site, while losses (by weight) prior to retailing included 35% in wrapper leaves and 5.54% due to dehydration[7]. No losses were caused by insect damage. In another study of a shipment of head lettuce from the highland production site to a Bangkok buyer in July 1982[8], initial trimming of inedible wrapper leaves accounted for a 40.8% reduction of harvest weight. Subsequent weight loss due to dehydration was low, between 0.3% and 0.6%, while loss due to biological decay was only 2.0%. Some lettuces required one or two leaves to be removed before delivery in Bangkok, which accounted for an average 15.48% weight loss in head lettuce. One farmer had found that 80% of the lettuce heads he had produced were affected with tipburn, but this was a production loss, not a postharvest problem.

Table 1 Weight loss (%) of selected vegetables between production sites and Chiang Mai packing station in different periods of 1981/82 and 1982/83[3]

Season	April–June		July–Oct.		Nov.–March	
Year	81/82	82/83	81/82	82/83	81/82	82/83
Vegetables						
Bell pepper	12	30	13	25	9	20
Cabbage	19	60	4	14	9	10
Cauliflower	6	—	50	50	31	20
Chinese cabbage	—	—	48	17	9	10
Head lettuce	42	50	55	24	18	50
Tomato	11	30	13	40	13	20

One might have expected postharvest losses to decline as farmers gained experience, but more recent reports show that similar levels of loss persist (Tables 2 and 3). Losses were caused by trimming, insect infestation, puffiness, moldiness, decay, small size, cracking, soft and overripe fruit, heart rot, stem-end and blossom-end rot, defects, yellowing and senescence, and poor sales because of lack of market demand. The relative importance of each cause of loss was not recorded.

Table 2 Head lettuce losses (%) between production sites and Chiang Mai packing station during April to August 1984

Location	Month				
	April	May	June	July	August
Samerng	72.2				48.8
Maehair	19.8	20.3	28.0	14.0	24.8
Tungluang	5.8	67.8	29.8	6.0	22.0
Huylirk	36.0	29.4	--		-
Maepoonluang	16.9	7.3	20.5		
Intanon	--	--	20.5	79.0	41.2

* Adapted from monthly vegetable data of Highlands Vegetable Extension, The Royal Project, 1984; unpub. data

Table 3 Weight loss (%) of selected vegetables between Chiang Mai packing station and the Project Office in Bangkok, May and June 1985

Vegetables	Month	
	May	June
Capsicum	10	12
Head lettuce	61	30
Red cabbage	11	15
Spinach	33	42
Tomato	34	11

* Adapted from monthly vegetable data of the Royal Project, Bangkok Office; unpub. data

MARKETING AND POSTHARVEST LOSSES

A certain level of postharvest loss in vegetables is inevitable, because of their perishable nature, but this should be kept to a minimum. In Thailand, the extent and cause of postharvest loss varies greatly according to the type of market where the vegetables are sold.

Local Markets

Vegetable produce bound for local markets generally reaches the retailer within 24 hours of harvest. Supply correlates closely with demand, eliminating storage losses. Losses tend to be due to exposure to the elements, or mechanical injury during handling and transport. Farmers often wash their vegetable produce after harvest. This may cause bruising, which makes vegetables deteriorate rapidly. Leafy vegetables are usually sprinkled with water to reduce wilting. Although this practice may prevent weight loss due to dehydration, it can also initiate deterioration. The final stage of loss occurs where the consumer does not use purchased vegetables within a reasonable period of time.

Distant Domestic Markets

Shipment to these markets may take eighteen hours or more: road freight from Chiang Rie to southern provinces in Thailand takes two nights. Traffic delays are common and produce receives a severe jolting on sections of rough road. Marketing channels are more complex, and very inefficient if local markets are included in the initial stage[16]. Leafy vegetables are shipped with plenty of wrapper leaves which adds to transport cost and creates a garbage disposal problem at markets. It is common for water spinach, water mimosa, asparagus and ivy gourd to be harvested and sold with unnecessarily long stems. Trimming of many vegetables is often not correctly carried out: nor is sorting and grading. Cabbage is generally transported in bulk, stacked with no protection, while more perishable vegetables are stacked in baskets. Heat builds up in the stacks, and this leads to deterioration. Losses due to dehydration, rough handling and high temperatures are greater when vegetables are sold in distant domestic markets than in the local markets: the level of tender loving care declines with distance.

In Thailand's domestic markets, cold storage facilities for vegetables are rare. Traders taking delivery of produce are forced to sell it quickly, before it decays. At all levels of marketing, there is a need for education on appropriate postharvest treatment of vegetables, and better packaging and storage technology.

Export Markets

Thailand's vegetable export trade is still in its infancy, and requires a large input of research and development if it is to be improved and expanded. Commodity selection, packaging and transportation are quite different to those found in domestic markets. The postharvest problems of export markets include low quality produce from farms, particularly fruit and vegetables which are overmature[1,7]. Grading of vegetables is a serious problem. There are frequent complaints from exporters that unsorted produce has been delivered. Packaging is not standardized, and often packages with a high unit cost are used. Incidents have been recorded where worm infested Chinese cabbage and decaying capsicums have been received by importers of Thai produce. There is an urgent need for regional packaging stations for export produce, with facilities for grading, packaging and quality control.

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DISCUSSION

Q. (C.Y. Yang)
Your paper presents a good account of the undesirable aspects of postharvest handling of vegetables in Thailand. Could you tell us whether there are any national programs to counter these problems? How many varieties of baby corn are grown in Thailand?

A. There are a number of research projects, for example the one on color development in off season tomatoes harvested at the mature green stage, and one on the senescence and yellowing of broccoli and Chinese kale, both of which can be stored for up to two weeks in modern controlled atmosphere facilities at 1°C. A report has been published on this work. Because of the conservatism of Thai farmers, implementation of these programs is slow. Even the exporters are slow to accept their value.

Three different varieties of baby corn are grown. They are mainly grown just south of Bangkok, but the processing plants are in the north. The farm gate price is fixed at about 20 Baht/kg.

TOMATO PROCESSING IN THAILAND

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ABSTRACT

Currently, tomato processing in Thailand is a small-scale industry, carried out in small factories using locally made machinery and supplied by small farmers. The paste is used mainly by sardine canneries, but demand for better quality paste by sauce makers is increasing. Large factories are being established in response to this demand. Survival of the smaller factories, and of small-scale farmers as their suppliers, will depend on their ability to adopt improved production techniques.

(Chinese Abstract)

摘　　要

目前泰國番茄的加工業仍屬小規模之產業，由小型工廠利用當地製造的機械及小農户提供之原料。番茄糊主要是用於沙丁魚製罐，由於品質要求日漸提高，為配合此需求，正在興建大型的工廠。小型工廠或小農制是否能生存，端視其是否引用進步的生產技術。

(Japanese Abstract)

摘　　要

タイ國におけるトマト加工業の現狀は、小規模で地方産の機械を使い、小農が作つた原料を使つている。トマトペーストは主にいわしのかんづめに使われているが，ソース生産業者からの良質ペーストへの需要はふえつゝある。大規模な工場はこれらの需要に對應して作られた。小工場やその原料供給者である小農のあるものの將來は改良された生産技術に適應できる能力があるかどうかにかゝつている。

(Korean Abstract)

적　　요

현재 태국의 토마토 가공은 국산기계를 갖춘 적은 공장에서 이루어지는데, 소농으로부터 원료를 공급받는 소규모 산업에 불과하다. 가루반죽은 주로 정어리 통조림공장을 이용하지만 조미료 제조업자들은 보다 나은 품질의 반죽을 요구하고 있다. 이러한 요구에 부응하여 큰 공장들이 세워지고 있다. 작은 공장들과 원료 공급자들인 소농들이 살아 남을수 있는 길은 보다 진보된 생산기술의 채택 여부에 달려있다.

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INTRODUCTION

The tomato processing industry in Thailand has grown over the past decade to serve the sardine canneries. Tomato juice, sauce and whole peeled products remained insignificant in production quantity up until two years ago. Many new sauce factories using processing tomatoes have recently been established. Since sardine production has become static, the response of these new factories to changes in market demand will have an important impact on the development of tomato processing in Thailand. Government incentives for agro-industries have encouraged the growth of the tomato paste industry to a point where it can now meet local demand, and there is potential for export. This paper will concentrate on tomato paste production, which uses 90% of all raw tomatoes entering the processing factories.

THE DEVELOPMENT OF TOMATO PROCESSING

Production Capacity

The tomato paste industry in Thailand has expanded continuously over the past ten years, from minor beginnings to an industry of eleven processing factories in 1981, with a total processing capacity of 470 mt of raw fruit per day, to 16 factories processing a total of 620 mt in 1983, and to 21 factories processing 1120 mt in 1986 (Table 1). Assuming a 60 day season at full capacity, these factories would require approximately 67,200 mt of raw fruit per year. This increased production capacity has almost completely replaced imported tomato paste, which reached a peak in 1982 of 938 mt, equivalent to 6400 mt of raw fruit. (Table 2.).

Table 1 Regional location of tomato paste production plants and their capacity

Location	1981*		1983*		1986**	
	No. plants	Capacity (mt/day)	No. plants	Capacity (mt/day)	No. plants	Capacity (mt/day)***
North	5	210	7	270	9	550
Northeast	3	170	6	260	9	530
Central (Bangkok Metro)	3	90	3	90	3	90
Total	11	470	16	620	21	1120
Estimate Raw Materials	45,000 Ton		62,000 Ton		106,400 Ton	

* Thavorn Govitavakorn[1]
** Estimates of Royal Project/Royally Recommended Project – Food Processing Plants
*** Mt raw fruit per (24 hour) day

Table 2 Tomato paste imports into Thailand

Year	Amount Imported (mt)
1980	200
1981	762
1982	938
1983	460
1984	18

Source: Office of Agricultural Economics

Production Technology

Most factories use cheap, crudely made, local production equipment, since a low capital investment is the prime consideration. The majority have a processing capacity of 50-100 mt of raw fruit per day, normally in a semi-bath processing system with a single effect evaporator. Only one factory has installed a continuous triple effect evaporator. The evaporator is the major unit of production equipment in any processing factory. Generally, the evaporators installed are adaptations of the natural circulation Calendria type, developed originally for the sugar industry. Except for the lower quality paste used by the sardine canning industry, this type of evaporator is unsuitable for tomato paste production; to produce quality paste, concentration should be carried out at relatively low temperatures. Some improvement has been achieved in a few factories by incorporating a circulation pump into the system, which improves evaporation efficiency and capacity. With proper quality control these plants can produce paste of suitable quality for the sauce industry. However, if a high quality product is to be achieved, and particularly if export specifications are to be met, further input from trained engineers is required. Locally available technology has already managed to improve paste quality, dramatically, in terms of color and consistency, over a single production season (Table 3), so it seems unnecessary to depend on imported technology for quality improvement.

Table 3 Improvement of paste quality by the modification of locally built equipment of the Royally Recommended Project plants at Sakolnakorn

Quality tested	Prior to modification (1985) %)	After modification (1986) %
1. Color (a)		
red	60 – 65	65 – 75; 75 – 85
yellow	10 – 12	3 – 10; 8 – 10
black	22 – 25	18 – 22; 12 – 18
2. Consistency (b) (cm)	10 – 13	7 – 10
3. Soluble solids(c) (°B)	24 – 25	28 – 30

a ...... Mebeth Colourimeter
b ...... Bostwick Consistometer at 12 5°B, 3)
c ...... Abbe refractometer

Fig. 1 describes the various production stages in tomato paste manufacture. Tomato paste produced in Thailand is of the cold break type, and is normally packaged in square 20 kg tins, or in cans of 3 kg or less.

Figure 1 Steps in the production of tomato paste

Raw materials
↓
Washing
↓
Trimming, selecting
↓
Macerating
↓
Thermobreak
↓
Pulper, finisher
↓
Evaporation
↓
Sterilization
↓
Packaging

RAW MATERIAL

Most factories buy tomatoes through contractors, who purchase fruit from the farmers and transport it to the factory. The factory gate price fluctuates from a high early season price of 1.5 Baht/kg (U.S. $0.07/kg in 1986), to a low at season's end of 0.80 Baht/kg (U.S. $0.03/kg in 1986). Occasionally, a surplus, of fruit upsets the market. This is due in part to the unpredictable climate of Northern Thailand, and in part due to lack of overall planning and cooperation from the farmers.

The productivity of Thai tomato growers is low (Table 4) compared to that of their counterparts in Taiwan, Australia, the U.S.A. and southern Europe, where yields of 15 mt per rai (90 mt/ha) are common. As the raw material accounts for the major cost factor in tomato processing (Table 5), there is great potential for improvement in product cost through horticultural means. The national average yield for all types of tomatoes in Thailand is 1.8 mt/ra. (11 mt/ha), but the yield from most farms growing processing tomatoes is higher than this, at about 3 mt/rai (19 mt/ha), as seen on the farms associated with the Bureerum and Sakolnakorn Factories of the Royally Recommended Project.

Table 4 Annual production of fresh tomatoes in Thailand, and average productivity

Year	All Thailand			Royally Recommended Project, Bureerum & Sakoknakorn Factories		
	Annual production (mt)	Productivity mt/rai	Productivity mt/ha	Annual production (mt)	Productivity mt/rai	Productivity mt/ha
1979 – 1980	31,575	.65	4.00			
1980 – 1981	49,968	1.54	9.68			
1981 – 1982	68,134	1.18	7.38			
1982 – 1983	70,193	1.39	8.69			
1983 – 1984	96,295	1.82	11.38	2,177	2.00	12.50
1984 – 1985				2,700	2.17	13.50
1985 – 1986				6,091	3.00	18.75

* Source: Department of Agricultural Extension

Table 5 Breakdown of production costs for tomato paste

	%
Raw materials	50 – 55
Labor/Salaries	5.5 – 6.0
Energy	17 – 19
Containers	18 – 22
Other	4

FUTURE OF TOMATO PROCESSING

Predictions made in this paper are based on the author's experience with the development of the four tomato paste production factories run under the King's Project and Royally Recommended Projects. Two of the four are located in Northern Thailand and have a total production capacity of 150 mt of raw fruit per day, and two are in Northeastern Thailand and can process 120 mt per day.

Marketing

Since the production of the local sardine canning industry has now leveled off, expansion of the market for tomato paste over the next five years will depend on whether higher quality products can be made for sauce makers and food processors, for both local consumption and export. The transition from locally consumed products to export quality products, including value added products such as canned sardines of export quality, will boost the market demand for Thailand's tomato paste, provided we can compete in terms of price with products from Taiwan and multi-national manufacturers like Heinz and Hunts.

Production Technology

Production research and development must be initiated by government agencies. As R&D is almost nonexistent now, the effect of this input should be a dramatic improvement in efficiency and product quality in the smaller tomato paste processing plants. A threefold decrease in energy consumption has been predicted. Although larger factories will probably import new technology, small factories will continue to depend on making their own improvements, with the assistance of government agencies. Improvements will concentrate on packaging systems and materials. Plastic in box packaging will become standard in both sterile and more rudimentary packaging systems. The evaporator and equipment for sterilization and macerating can be improved dramatically, simply by applying locally available technology.

Raw Materials

In order to reduce the cost of raw materials, larger factories can be expected to turn to contract farming, or begin hiring farmers to cultivate factory owned and managed land. However, smaller factories will probably continue to buy under the present system. Productivity could be increased from the current 3 mt/rai (19 mt/ha) to at least 8 mt/rai (50 mt/ha) within six years. Such a reduction in the cost of raw materials would ensure Thai tomato paste products keep a competitive place in world markets.

The raw materials are also important in deciding the quality of the paste product. As quality consciousness increases, attention will turn to fruit varieties more suited to both local conditions and the final product. A few companies are currently running trials of different tomato varieties.

The standard of small farm management will be important to the smaller factories, and cooperation in harvest planning will be vital to ensure the survival of both small-scale farmer and factory. The farmers need an adequate income, and the factories need fruit at a low unit cost. Large mechanized factories and farms will tend to draw labor away from smaller production units, unless the smaller units can through greater efficiency offer better earnings to local farmers.

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1. Agricultural Statistics of Thailand Crop Year 1984/1985. Center for Agricultural Statistics, Office of Agricultural Economics, Ministry of Agricultural and Cooperatives, Bangkok, Thailand, 1985. *Agricultural Statistics* No. 293.
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DISCUSSION

Q. (C.Y. Lin)

In Table 4 of your paper, the average tomato production per area is very low, only about 2 mt/ha as compared to 3 mt/ha in Taiwan. Why is it so low?

A. (M. Wivutvongvana)

Commercial producers can achieve yields as high as 6 mt/ha. Table 4 gives the average covering the whole country, and includes both processing and table tomatoes. These figures demonstrate that varieties more suited to the conditions of the poorer farms are needed. The commercial varieties released perform very badly under such conditions.

(N. Patamayothin)

The data does not differentiate between processing and table tomatoes, nor between local and commercial varieties. The production of some of these is extremely low. However, I would think that for yields of processing tomatoes the figure would be more like 25.3 mt/ha.

Q. (R.L. Villareal)

In the Philippines, the majority of farmers growing processing tomatoes do so under contract to the factories. What percentage of Thai tomato farmers grow tomatoes under contract?

A. There is usually a middleman, who finances the inputs for the crop and purchases the crop for sale to the factories.

Q. (R.L. Villareal)

What is the farm gate price for processing tomatoes?

A. (M. Wivutvongvana)

As an average over the whole season, 1.2 Baht/kg.

The contract growing of processing tomatoes has been carried out under the King's Project, but most farmers are not covered by a contract with a factory, and deal direct with a businessman.

(B. Khatikarn)

There has been a rapid advance in the production of processing tomatoes in Thailand. We had a seminar on this topic only a few years ago, and the production level of tomato paste was then about 260 mt per day. Now it is double that. Under the King's project, a guaranteed price is given only in Northeast Thailand, and not in the Northern part. The main centers for processing tomatoes are Lampang in the Northern part of the country, and Nomkai in the Northeast.

BABY CORN PROCESSING IN THAILAND

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ABSTRACT

Projections based on the broad economic influences acting on the processed baby corn market show that Thailand will face difficulty in increasing its share of the international market. The dominant factor in achieving any increase over the next five years will be the improvement of Thailand's farm technology.

(Chinese Abstract)

摘 要

加工玉米筍由於受到國際經濟的影響，泰國面臨到不易打進國際市場的困難，故在未來五年增加市場的最主要因素為改進泰國的生產技術。

(Japanese Abstract)

摘 要

加工ベビーコーン市場に作用している廣い經濟的影響を考慮に入れた見通しによればタイ國は國際的市場でのシエアを伸ばすことは難かしい。今後5カ年間にシエアを伸ばすことが出來るかどうかはタイ國で農業技術改良が出來るかどうかにかゝつている。

(Korean Abstract)

적 요

가공 베이비콘의 시장에 대한 경제적 영향을 기초로하면 태국의 국제시장 점유율 증가는 매우 어렵다는 것을 알 수 있다. 차기 5년간 증가달성에 있어서 가장 중요한 요소는 태국의 영농기술을 진전시키는 데에 있다고 본다.

BABY CORN PROCESSING IN THAILAND

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INTRODUCTION

Ninty nine percent of baby corn processed (canned) in Thailand is exported: the industry is thus important both as a source of farm income and as a foreign currency earner. However, the economic influences which assisted in the establishment of the industry have now taken a turn for the worse, and future expansion will be difficult.

DEVELOPMENT OF THE INDUSTRY

The volume of canned baby corn exported from Thailand increased rapidly from a mere 916 mt in 1980 to 6281 mt in 1986 (Table 1). Unfortunately, this volume increase has been obtained at the expense of the unit price, which has fallen from U.S.$17 FOB in 1984 to U.S. $13.50 FOB in 1986 per (6 x 3 kg can) carton.

Table 1 Thai exports of canned baby corn

Year	Export volome Ton
1980	916
1981	1229
1982	1521
1983	4014
1984	4468
1985	6281

Source: Office of Agricultural Economics

The canneries, of which there are now 24, have passed at least part of this loss back to the farmer, and the farm gate price of baby corn in hull is currently around 2 baht/kg.

Baby corn processing in Thailand is a simple but labor intensive operation (Figure 1.) The corn is graded and packed by size, most being packed in an A-10 can (1.5 kg net). Grading for size and quality is manual, and requires close supervision. Despite the high labor input, raw materials represent the major production cost (Table 2).

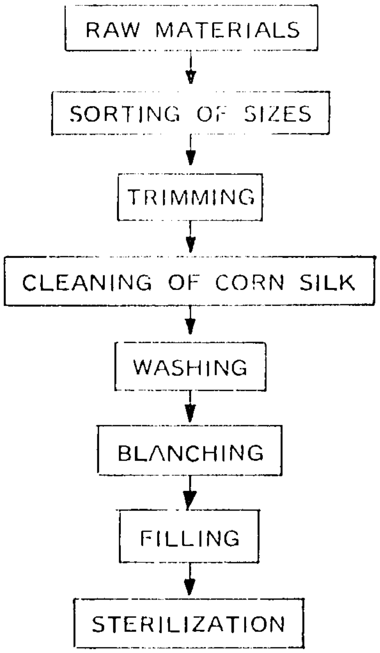

Fig. 1 Canning operation for baby corn

Table 2 Cost breakdown of canned baby corn production

Items	Cost (%)
Raw materials	60
Labor/salary	6
Energy	4
Container	25
Others	6

Government statistics on yield and productivity of baby corn in Thailand are given in Table 3. However, the authors' experience is of lower recorded values: for example, the average productivity for Northern Thailand in 1985 was 600 kg/rai (3750 kg/ha) and for Northeastern Thailand 350 kg/rai (2188 kg/ha).

FUTURE OF THE INDUSTRY

The declining value of processed baby corn on the international market has left only a small profit margin. Small gains may be made by cutting labor and energy costs by improving the processing technology. However, little is understood of the biochemical changes in baby corn during processing, and research will be needed before new procedures are adopted. Since the raw material is the greatest cost factor, it offers the greatest potential for production cost savings. New varieties have been tried, with only marginal yield improvement. The most recently tested variety produces 3-5 cobs at the same time, but gives no improvement in overall productivity. The future of the baby corn processing industry may lie with the development of improved cultural practices, and their adoption by Thai farmers.

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Table 3 Regional annual baby corn production and productivity

Region	1983/1984			1984/1985		
	Annual production	Productivity		Annual production	Productivity	
	mt	kg/rai	mt/ha	mt	kg/rai	mt/ha
North	15,284	1,420	8.87	17,906	1,194	7.46
Northeast	8,309	1,179	7.37	4,619	985	6.15
Central	3,888	871	5.44	942	801	5.01
East	2,493	1,211	7.56	491	875	5.47
West	16,836	874	5.46	15,356	1,046	6.54
South	99	251	1.56	2,314	637	3.98

DISCUSSION

Q. (S. Kosiyachinda)
Do you have any plans for developing equipment for the automatic sorting of baby corn?

A. Yes, we are developing a prototype of such a sorter.

Comment: (R.L. Villareal)
Another way of achieving uniform size would be to grow F1 hybrid baby corn. We have tried this in the Philippines and have produced one type which gives corns of very uniform size.

Q. (T. Tonguthaisri)
You suggest that the future of baby corn as a processing commodity is not promising, due to the competitive market. Could you please elaborate? I feel that the future for baby corn processing is good.

A. The international price of baby corn was about U.S.$17 per carton in 1984, but this has now dropped to only U.S.$13.50. Thus to remain competitive it is necessary to reduce the cost of the raw material, because production costs cannot be any lower. The processing is labor intensive, but this is difficult to change.

Comment:
Four months ago we had a meeting on the problems of baby corn collection. The baby corn goes from farmer to collector to factory, and it deteriorates on the way.

A. There are too many steps in the chain the baby corn should travel direct from farm to factory. We need to solve this problem for the sake of both farmers and manufacturers. Factories cannot guarantee their prices, because farmers also sell baby corn in the fresh vegetable market. Alternatively, the middleman should chill the baby corn, but the cost then has to be added to that of the final product.

CONCLUDING REMARKS
FUTURE RESEARCH AND DEVELOPMENT NEEDS FOR IMPROVING VEGETABLE PRODUCTION IN ASIA

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Vegetables are an important and substantial source of food, and contribute significantly to the quality of our diet, providing variety and nutrition. Various parts of innumerable kinds of vegetables make otherwise unappetizing meals of staple foods flavorsome and pleasing to the eye. The major nutritional contribution of vegetables to the human diet are the vitamins A and C and minerals such as iron, calcium, etc. Tuber type vegetables store starch, and are recognised as highly efficient converters of solar energy. Potato, for example, is second only to sugarcane as a producer of calories per land unit area, and second to soybean as a protein producer. However, even in developed countries only a small percentage of farmers' incomes is derived from vegetable production about 6% of total agricultural production value in the U S.A.

Perhaps partly because vegetables comprise such a vast number of crops they have been given a relatively low priority in funding and planning in both national and international agricultural research and development programs. This is reflected in the low rate of implementation of new technology. Growers of vegetables under subtropical and tropical conditions face almost insurmountable difficulties in vegetable production lack of resistance to biotic and abiotic environmental stress, diseases, pests, induced physiological disorders, heat, humidity, drought, floods and soil nutrient imbalances. To combat these, more work in varietal improvement is essential. Further, growers in the tropics are handicapped by problems of post-harvest management, underdeveloped vegetable processing facilities, insufficient seed production and processing facilities, and very rudimentary marketing systems and consumer education.

The scientists in the field of vegetable improvement in the tropics, though hard pressed for funds, have made remarkable progress, both in varietal improvement and in overcoming constraints to the cultivation of vegetables of temperate origin. Some of this progress has been demonstrated in the papers presented at this seminar.

AVRDC has concentrated much research on adapting tomato and Chinese cabbage to the hot humid tropics. This adaptation consists of enhancing their tolerance to heat and humidity, and their resistance to major tropical pests and diseases. Growth during the heading process in Chinese cabbage plays a major role in deciding yield under high temperature conditions. During heading in a heat tolerant cultivar, leaf turgidity is maintained despite high temperatures due to the plant's ability to keep a stable water balance. Heat tolerant Chinese cabbage cultivars have a lower shoot/root ratio than heat sensitive cultivars. In recent years, the AVRDC tomato breeding program has emphasized further improvement of the best tropical lines by sequentially incorporating additional resistance to major diseases with improved fruit quality. New traits added include resistance to tomato mosaic virus with the Tm-2^{a} gene, resistance to fruit cracking, greater fruit firmness and larger fruit size. A few of the tropical tomato lines incorporating these traits will soon be available from AVRDC.

A trial of AVRDC tomato stock in the

hot tropical lowlands of the island of St. Lucia demonstrated the superiority of these lines over the locally popular Caraibe varieties with respect to heat and arid stress tolerance. The most successful heat tolerant varieties tested were CL 5915-22D_4-0-4-0, CL 5915-22D_4-1-5-0 and CL 591522D_4-1-1-0.

The Institute of Plant Breeding (IPB) of the Philippines has made steady progress in building up a germplasm collection, in screening different vegetable varieties for disease resistance, stress tolerance and earliness, and in the search for nitrogen fixing vegetable crops. The Institute has taken two approaches to breeding: one of developing F_1 hybrid cultivars for intensive commercial cultivation, and the other of seeking cultivars that will thrive under the low input conditions of poorer farms. New aspects of biotechnology are being implemented, along with conventional breeding methods, for producing and selecting plants resistant to pests, diseases and environmental stresses. Biotechnology provides a means of identifying and isolating useful genes, increasing our understanding of genetic and physiological processes in plants, providing new basic knowledge for the possible transfer of genetic information, and of controling genetic expression.

Asparagus production in Taiwan depends on a modified mother stalk cultural method which adapts this temperate crop to the subtropical climate of Taiwan. This method has doubled asparagus yields. Extensive selection trials have singled out Mary Washington as the cultivar best suited to this type of asparagus production. However, a shortage of good seed forced Taiwan plant breeders to develop their own seed production, and as a result, the hybrid cultivars Tainan Nos. 1, 2, and 3 were specially bred for the subtropical conditions of Taiwan and successfully released. Tainan No. 1 has performed very well in an international asparagus cultivar trial. In further selection, breeders are concentrating on achieving tight-tipped spears important for the canning process. Breeders are currently working on producing all-male asparagus varieties which yield larger spears, and on including the persistant green character which should be advantageous to the winter production of asparagus in the southern part of Taiwan.

In potato, morphological characteristics and physiological responses have been utilized to develop screening tests for heat tolerance. Crop emergence, tuberization, expression of stolen tips in hot soils, susceptibility to bacterial disease in hot soils, growth response, tuber induction, dry matter partitioning and growth analyses of cultivars in different climates are some of the aspects which have been studied with a view to determining their individual and cumulative roles in the complex picture of heat tolerance. The development of computer simulation models for potato offers hope that the interactions of these aspects may be analyzed. Important individual characteristics are the response of potato cultivars to temperature, the extent of tissue damage on exposure to hot dry winds, and tolerance to drought induced by high temperature. The International Potato Center is advocating the targeting of appropriate heat stress characters, in order to breed suitable potato accessions for different tropical locations.

In developing the year-round production of radish, scientists in Korea have learned that seed storage conditions, and day length and light intensity during growth, all contribute to flower stalk initiation and the incidence of bolting. Cold in winter crops causes vernalization, and induces them to bolt before full tuber development. In summer-grown crops, it was shown that long day length, even without vernalization, can induce flower differentiation. Bolting is variety dependent, and in Korea the currently used summer variety is popular because it has a low incidence of bolting, although it has a poor eating texture. Korean research aims at breeding a more suitable summer variety or utilizing one of better texture through revised seed storage practices. Under current storage practices, the longer the seed is stored, the more rapidly the flower buds tend to be induced during growth.

The cause of tipburn and internal rot in Chinese cabbage has been elucidated by AVRDC's scientists:

Tipburn is the result of water stress due to root damage caused by ammonia (NH_4-N) toxicity. Cultural practices which can help reduce tipburn are to avoid heavy basal fertilizer applications and apply nitrogen fertilizers (particularly NH_4-N fertilizer) in split applications. Applying compost to increase the soil CEC and minimize soil moisture fluctation, and covering the outer plant leaves with rice straw to suppress initial plant growth, are also effective.

Internal rot is associated with vigorous growth rates in round-headed cabbage cultivars. Although internal rot is generally believed to be caused by insufficient translocation of Ca^{++} to the leaves, AVRDC's scientists could not establish any correlation between Ca^{++} content in the head leaves and the incidence of internal rot. To reduce internal rot in Chinese cabbage, split nitrogen applications should be used: covering the outer leaves before head formation is also effective. Foliar sprays of calcium citrate, accelerating rooting by water management, and selection of long headed cultivars are also effective measures. ASVEG #1, a round-headed cultivar with particularly vigorous growth under good conditions, is highly susceptible to internal rot, while Fong-luh, a long-headed variety, is not very susceptible and will give equivalent harvest yields. Drip irrigation, giving a controlled supply of water and fertilizer, can completely control internal rot.

Verticulture is a relatively new cultural method for vegetable crop cultivation. The yield in verticulture is dependent upon the type of irrigation system, nutrient supply and pollulator used. Crops with short growth duration and a relatively small leaf canopy are most suitable for verticulture. Strawberry was the most suitable crop for profitable cultivation under verticulture of those tested in Taiwan.

Chemical weed control for vegetable crops is increasing. The intensive management of vegetable crops, and especially the practices of mulching, intertillage, sidedressing and the application of soil fumigants, result in a lower rate of weed emergence than in cereal crops. Most of the weeds that do emerge in vegetable plots tend to be broadleaf weeds. Weed control is critical in spring-planted crops in Japan, which are threatened by summer annual weeds. Weed control in vegetables is generally of central importance between sowing and the 4-5 leaf stage. Tolerance to herbicides differs among different vegetable crops, and in the same crop at different growth stages. Three main vegetable crop weeding practices used in Japan are hand weeding, soil fumigants and paraquat applications. Selective herbicides such as diphenamide are not widely accepted in Japan, and chemical controls are generally combined with hand weeding. Microgranules and flowable herbicide formulations promise to provide herbicides which are uniform, stable and labor saving in use. Flowable forms include chemicals which are safer to crops than paraquat.

Suitable varieties and reliable seeds are the cornerstones of vegetable production in developed countries. They are equally important for the development of vegetable production in Southeast Asia. Vegetable varieties should meet the crop requirements of the environment in which they are cultivated for season, disease resistance, product quality and suitability to the farming system. Great improvements can be made in the yield of solanaceous and curcubit crops by developing new varieties. The experience of developed countries has shown that a seed industry based on the private sector and supported by government research is the best system for a supply of high quality seeds which meet market demand. New varieties of vegetable seeds are in great demand among the vegetable growers of Southeast Asia.

Vegetable seed production in Thailand is centered on two areas. Most open pollinated seed production takes place in the central and lower north, while F1 hybrid vegetable seed production is found in Northeast Thailand. More input is needed in varietal introduction and improvement programs. Disease problems in Thailand's vegetable seed production include stem rot by *Sclerotinia sclerotiorum*, which lowers lettuce seed production, tipburn in lettuce and cabbage, iron and magnesium soil deficiencies which reduce seed yield in lettuce and leaf mustard, and a general lack of infrastructure and extension support. Both seed production and fruit production in tomato are limited by heat, bacterial wilt, yellow leaf curl and late blight. Processing tomatoes are usually grown by farmers under contract to processing plants established in the production areas. The plants pay a farm-gate price of about U.S. 5 cents/kg. Good commercial farms are achieving tomato yields of up to 60 mt/ha, but the average is much lower. Thailand has a strong demand for tomato paste, and is cutting down on imports as tomato production rises. Thailand's baby corn exporters have suffered a decline in export price (from U.S. $17 per carton in 1984 to U.S. $13 in 1986). Higher yields and better handling are required to overcome this setback. The farm-gate price is currently U.S. 80 cents/kg. Baby corn is grown around Bangkok and transported north for processing.

In Taiwan's onion seed production, vernalization of bulbs in cold storage is required for flower induction. High humidity prior to harvest and poor storage conditions are major constraints to onion seed production in the tropics. Varieties with a high dry matter ratio, a high pyruvic acid content and a low nitrogen content have better storage qualities. Bulb storage qualities can be improved by good cultural practices, increased curing time and controlled temperature storage.

Taiwan has a well-developed seed supply for tomato. Good production of tomato seed is dependent on good growth in the parent plant, and in southern Taiwan autumn and winter provide a mild sunny climate ideal for tomato seed production. F1 hybrid seed is produced. The production of F1 hybrid tomato seed demands a careful scheduling of operations, from the nursery stage to harvest, to ensure that the emasculation and pollination procedures are well coordinated and make efficient use of available labor.

Vegetables are perishable by nature. Many postharvest problems in vegetable production, for example soft-rot infection and tipburn, result from poor preharvest and harvest management. In Thailand, postharvest losses are mainly due to improper handling. Damage is commonly due to inadequate transport, mechanical trauma, excessive trimming, insect and mold infestation, and cracking and softening of overripe fruit, among other causes. Marketing may be divided into three levels: local, distant domestic and export. At each level, appropriate packing, sorting and storage facilities are needed to minimize postharvest losses.

Two areas which need to be strengthened in future research and development for improved vegetable production in Asia are the vegetable germplasm collections, and the establishment of international vegetable cultivar trials throughout Asia. More improved vegetable varieties are needed which incorporate a higher level of disease and insect resistance, and are more tolerant to the stresses of the tropical environment. The biotechnology of tissue culture, anther/pollen culture, somatic cloning and protoplasmic fusion needs to be integrated into conventional breeding programs in the region. In many places, the infrastructure for quality vegetable seed production is in need of development. Much can be done through improved vegetable cultivation techniques, more extension programs, and the integration of home gardens into the total agricultural system. Improved postharvest and processing facilities are also essential for efficient marketing. Vegetable information and marketing networks could be developed to promote the industry. In order to meet these needs in vegetable improvement in Asia, closer and more dynamic links for cooperation must be forged at both a national and an international level, and especially between the public and private sectors of the industry.

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