Council of Agriculture Plant Protection Series No. 1.
Proceedings of the Symposium on Plant Virus
and Virus-like Diseases. pp. 213~243 (1993)

Pepper Virus Research in Taiwan and Other Asian Countries

Sylvia K. Green

Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan

ABSTRACT

Virus diseases, causing yield losses in the range of 60-100%, are considered the major constraint to the economic production of peppers (*Capsicum* sp.). Some 35 viruses are known to infect pepper. In Asia, the most important viruses are cucumber mosaic virus (CMV), chilli veinal mottle virus (CVMV), potato virus Y (PVY) and tobamoviruses, tobacco mosaic virus (TMV), tomato mosaic virus (ToMV), and pepper mild mottle virus (PMMV). Viruses of minor importance are broad bean wilt virus (BBWV), alfalfa mosaic virus (AIMV), and potato virus X (PVX). The reported presence of other viruses such as tobacco etch virus (TEV), tobacco rattle virus (TRV), tomato spotted wilt virus (TSWV), and pepper mottle virus (PeMV) needs confirmation. Extensive virus surveys and virus characterization have been conducted in most Asian countries. However, only a few countries, such as Japan, Korea, Malaysia, Taiwan, and India, are engaged in breeding for virus resistance. Research on alternative control methods, such as by management practices and biological means have been conducted in Indonesia, India, Taiwan, Korea, and Malaysia, Screening for resistance is done in almost all countries, and suitable resistance sources have been identified.

The multidisciplinary Pepper Breeding Program of the Asian Vegetable Research and Development Center (AVRDC) has recently been complemented by the pepper virus subnetwork of AVNET which aims to confirm or identify the most important viruses in the region (Thailand, Malaysia, Indonesia, the Philippines) and to find field tolerance or resistance by multilocational screening of resistant lines identified in the national agricultural research systems (NARS) or elsewhere. In another network, SAVERNET (South Asian Vegetable Research Network), six countries (Pakistan, India, Sri Lanka, Nepal, Bangladesh, Bhutan) work closely together to identify the viruses involved in the pepper leafcurl virus complex and to develop feasible control methods.

Key words: pepper, virus disease, resistance screening, pepper virus network.

INTRODUCTION

Peppers, particularly hot peppers, are an important crop in tropical and subtropical Asia, not only because of popular consumption but also because of their high market value and export potential.

Diseases, particularly those caused by viruses, are considered the major constraints to economic production of peppers (40,56,78,99) and yield losses ranging from 60-100% in the case of early infection have been reported (94,99). Some 35 viruses are known to infect peppers (36). Most of these are distributed worldwide, although some have been reported only in certain geographic areas (Table 1). A literature review summary of the viruses occurring on peppers in Asian countries is given in Table 2.

Table 1. Viruses known to occur on peppers in certain geographic areas (36)

Virus	Type	Regions reported
Chilli veinal virus (CVMV)	poty	Asia (Thailand, Taiwan, Korea, Malaysia, Indonesia, Sri Lanka)
		Africa (Tanzania* ?)
Pepper veinal mottle virus (PVMV)	"	Africa (Nigeria, Ivory Coast, Ghana)
Pepper mild mosaic virus	"	Americas (Venezuela)
Pepper mottle virus (PeMV)	"	Americas (USA, El Salvador)
		Asia (Thailand) ?
Tobacco etch virus (TEV)	"	Americas (USA, Mexico, Venezuela)
		Africa (Nigeria)
		Asia (Sri Lanka**? Thailand?, Indonesia?)
Pepper severe mosaic (PeSMV)	"	Americas (Argentina)
Bell pepper mottle virus (BPeMV)	tobamo	Americas (Argentina)
Dulcamara yellow fleck virus (DYFV)	"	Europe (Hungary)
Moroccan pepper virus	tombus	Europe
		Africa (Morocco)
Pepper mild tigr (PMTV)	gemini	Americas (Mexico)
Chino del tomate (CdTV)	"	Americas (Mexico)
Serrano golden mosaic	"	Americas (Mexico, USA)
Red pepper cryptic virus	cryptic	Asia (Japan)
Tomato ringspot virus (TomRV)	nepo	Americas
Tobacco ringspot virus (TRSV)	"	North America (USA, Canada)
Pepper yellow vein mosaic	?	Europe (England, Holland, Hungary)

* Based on ELISA tests conducted at AVRDC.

? Based on ELISA tests, but needs to be confirmed.

** Based on ELISA tests, using AGDIA kits (L. L. Black, personal communication).

Table 2. Viruses reported to infect peppers in South and East Asia (36)

Virus	China[1]	India[2]	Indonesia[3]	Japan[4]	Korea[5]	Malaysia[6]	Philippines[7]	Sri Lanka[8]	Taiwan[9]	Thailand[10]
Alfalfa mosaic	+[11]		+	+	+	+*	+**			+
Bell pepper dwarf mosaic		+								
Brinjal mosaic		+								
Broad bean wilt	+			+						
Chili leaf curl		+				+		+		
Chili veinal mottle			+*		+*	+	+*		+*	+
Cucumber mosaic	+	+	+	+	+	+	+*	+	+	+
Green veinbanding		+								
Launea mosaic		+								
Marigold mottle		+								
Pepper mild mottle virus									+	+*
Pepper mottle									+[0]	+[0]
Pepper veinal mottle		+[0]								
Pepper veinbanding		+								
Potato X	+	+	+	+	+				+	
Potato Y	+	+	+	+	+	+		+	+	+
Tobacco etch	+	+	+		+**			+		+
Tobacco leafcurl		+								
Tobacco mild green mosaic virus									+	
Tobacco mosaic	+	+		+	+	+	+	+	+	+
Tobacco rattle virus	+	+								
Tomato mosaic	+	+			+		+	+		
Tomato ringspot virus	+									
Tomato spotted wilt		+	+**		+**	+	+**	+	+**	

[1] See references 37, also Feng, Langxiang, Beijing, China, personal communication 1990.
[2] See references 2, 13, 17, 23, 24, 51, 57, 63, 64, 65, 66, 81, 82, 84, 89, 90, 96, 99, 101, 103, 106.
[3] See references 27, 28.
[4] See references 39, 58, 59, 60, 61, 62.
[5] See references 4, 7, 41, 76, 83.
[6] See references 1, 30, 69, 71, 72, 75, 109, 116.
[7] See references 8, 113.
[8] See references 93, 108, also L. Black, Louisiana State University, USA, personal communication.
[9] See references 6, 7, 19, 20, 55.
[10] See references 6, 18, 33, 114, also K. Kittipakorn, personal communication 1992.
[11] + =virus has been reported in the literature; +*=not yet reported from the respective country, but results of surveys by AVRDC gave positive reaction by ELISA; virus presence was further confirmed by isolation and host range tests; +**=not reported from respective country but ELISA positive in surveys by AVRDC; presence of virus was not confirmed by virus isolation and host range tests; +[0]=needs to be confirmed.

In our own surveys conducted in countries of Southeast and East Asia by testing randomly collected leaf samples using double antibody sandwich enzyme linked immunoassay (DAS-ELISA), we consistently recorded high incidence of cucumber mosaic virus (CMV), chilli veinal mottle virus (CVMV), potato virus Y (PVY) and tomato mosaic virus (ToMV) (Table 3).

This paper presents an update on the viruses infecting peppers in Asia and on some of the pertinent research findings concerning these viruses.

Table 3. AVRDC survey (by DAS ELISA) for viruses of pepper in Southeast and East Asia

Country (Reference)	Total no. of samples collected	% Virus infected						
		CMV	CVMV	PVY	ToMV	AMV	TSWV	PVX
Thailand (AVRDC 1990a)	139[1]	17	8	22	4	0	0	0
Philippines (AVRDC 1990c)	59[2]	6	6	?	6	6	7[3]	0
Indonesia (AVRDC 1990b)	64[1]	8	25	3	50	0	0	2
Taiwan (AVRDC 1990a)	1037[1]	22	30	19[4]	10[4]	0	0	0
(AVRDC 1990b)	486[1]	42	51	15	13	0	4[3]	0
Malaysia (AVRDC 1988)	140[6]	16	NT	9	8	0	2	0
Korea (AVRDC 1990b)	477[7]	26	2	2	33	22	14	0.2

[1] All samples were also tested for PVMV, PeMV, TEV, but found negative.

[2] All samples were also tested for presence of TEV, PVMV, PMMV, and found negative.

[3] Presence of TSWV was not confirmed.

[4] Strain-typing of isolates showed that they were PVY-0.

[5] Strain-typing of 5 isolates showed that they were ToMV-0.

[6] All samples were also tested for PVMV, TEV and PeMV but found negative.

[7] All samples were also tested for PVMV, TEV and TSWV; these viruses were detected in 68 and 7 of the samples, respectively.

ASIA

Taiwan

In Taiwan, where 2,853 ha are planted to peppers, six viruses, namely CVMV, CMV, PVY, TMV, ToMV and PMMV (in order of importance) have consistently

been found (6,7,8) (Table 3). These have all been identified by DAS ELISA, by particle morphology and by host range studies (8).

ToMV occurs as two strains in Taiwan, ToMV-0 and ToMV-1. On the other hand, only strain 0 of PVY has been found so far (7,8). More than 100 plants each of the cultivars Delray Bell and VR-2, resistant to PVY 0 but susceptible to PVY-1, were planted as "bait" plants throughout Taiwan in farmers' pepper fields. ELISA tests conducted on these plants around harvest time were consistently negative for PVY; PVY could not be isolated from such plants (Green, unpublished).

Two other viruses, PVX and PeMV, are also reported to infect peppers in Taiwan (19). Identification of these viruses was by host range tests, physical properties, ELISA, agar gel immunodiffusion and ring interface tests of purified particles (20,21).

Resistance to virus diseases is one of the major objectives of the pepper improvement program at AVRDC (117). Since 1986, intensive screening for virus resistance against CMV, CVMV, PVY and the tobamoviruses TMV, ToMV, PMMV has been conducted (7,8,9,10) and germplasm with resistance or tolerance to one or more of these viruses has been identified. The resistances of these lines are now being incorporated into AVRDC's promising breeding lines. Initial emphasis has been on CVMV and CMV.

At the Taiwan Agriculture Research Institute (TARI) and at AVRDC, experiments for the control of non-persistently transmitted aphid-borne viruses have been conducted using various reflective mulches, insecticides, mineral oil and intercropping with barrier crops. Among the reflective mulches, one from Japan was found to give highest insect repellency (Fig. 1), lowest virus incidence (Fig. 2) and highest yields (Table 4) (36).

Mainland China

Owing to its climatic diversity, both sweet and chilli peppers are important in China, the latter being widely grown on 60,000 ha in the southern provinces (Yang *et al.* 1986). Sweet pepper production on the other hand is concentrated in the suburban areas of the large cities in the eastern, northern and northeastern parts. Diseases, particularly those caused by viruses such as TMV, CMV, PVX, and PVY are the major production constraints (115). In surveys conducted from 1988-1989 in the Beijing area, seven viruses, namely CMV, TMV, PVY, TEV, PVX, AMV and broad bean wilt virus (BBWV) were detected in 55, 26, 13, 12, 12, 2 and 1% of some 200 samples tested by ELISA (Feng and Langxiang, 1989, personal communication). This was the first record of the occurrence of PVX and AMV on peppers in China.

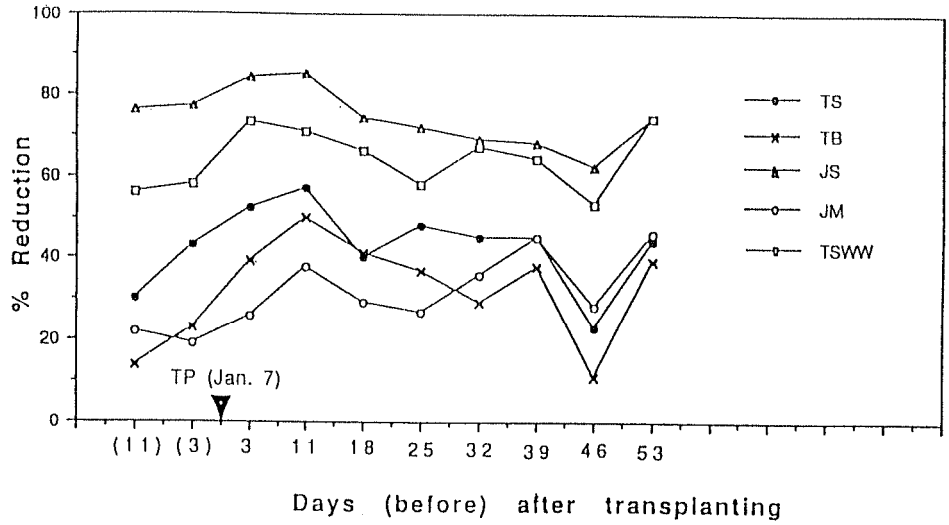

Fig. 1. Reduction (with respect to nonmulched plots) in the number of aphids trapped on yellow sticky traps, placed in the center of each plot.
TS=local reflective mulch from Taiwan; TB=local black plastic mulch from Taiwan; JS=reflective mulch from Japan (Polyshine N); JM=reflective mulch from Japan, thick, translucent; WW=white wash on the mulch.
Source: Green 1992, unpublished.

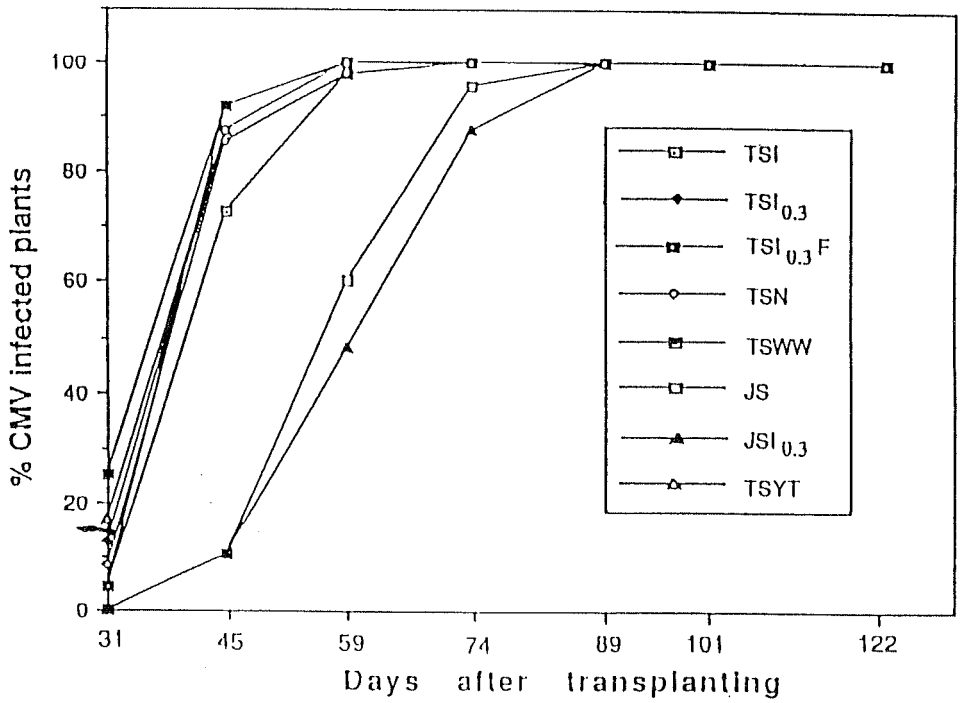

Fig. 2. Incidence of CMV in plots of hot pepper on which various virus/vector control treatments were applied (for symbols, see Table 4).
Source: Green 1992, unpublished.

Table 4. Effect of virus control measures on hot pepper yield

Treatment[3]	First 3 harvests[1]			Harvests 4-7[2]		
	Total fruit wt.[4] (kg)	Fruit no.	Ave. fruit wt. (kg)	Total fruit wt.[4] (kg)	Fruit no.	Ave. fruit wt. (kg)
TSI	4.35 b[5]	256 b	17.05 b	2.76 b	245 b	11.25 a
$TSI_{0.3}$	3.45 c	203 c	16.98 b	1.70 cd	162 c	10.48 b
$TSI_{0.3}F$	3.47 c	200 c	17.33 ab	1.76 c	166 c	10.61 b
TSN	2.62 d	149 d	17.53 ab	1.52 d	155 c	9.81 cd
TSWW	2.76 d	160 d	17.25 ab	1.06 e	113 d	9.37 d
JS	4.75 a	298 a	17.77 a	2.87 b	249 b	11.49 a
$JSI_{0.3}$	5.04 a	264 b	17.89 a	4.63 a	405 a	11.41 a
TSYT	2.17 e	136 d	15.44 c	1.13 e	114 d	9.87 c
cv	5.10	8.16	2.01	6.01	7.53	2.45
LSD	0.32	29.8	0.60	0.23	26.6	0.45

[1] the experiment was transplanted to the field on Oct. 11. The first 3 harvests were conducted on Jan. 22, Jan. 31, Feb. 10 corresponding to 103, 112 and 122 DAT.

[2] harvests 4-7 were conducted on Feb. 19, Feb. 27, March 6, and March 18 corresponding to 131, 139, 148 and 160 DAT.

[3] TS=local (Taiwan) reflective mulch; I=insecticide (weekly application of Tamaron 50% at 1:1000); $I_{0.3}$=insecticide at 1/3 strength; N=Neem (1500 ppm) at 1:200 initially and at 1:150 starting at 4 weeks after transplanting; WW=white wash on the foil plus white wash on the foliage at 4 weeks after transplanting; JS=reflective foil from Japan (Polyshine N). YT=one yellow sticky trap in the center of each plot at 10 cm above the canopy.

[4] per plot=two double row beds with 12 plants/row (the two center rows were counted).

[5] values are the means of 3 replications; mean separation within columns by DMRT (P=0.05).

(Source: Green 1992, unpublished)

A virus isolated from peppers in Hubei and suspected to be BBWV was further characterized. Diseased plants showed symptoms of fernleaf, yellow stunt and sterility. The isolate was shown to be closely related to BBWV by

immunosorbent electron microscopy. In ultrathin sections of chlorotic lesions on *Chenopodium quinoa* and systemically infected leaves of *Petunia hybrida* the microtubules and crystalline inclusions characteristic of BBWV were demonstrated. These findings indicated that this isolate of BBWV differed from that reported previously by Li and Cao (1988).

Korea

Hot peppers are one of the most important crops in Korea. The total pepper acreage is 132, 118, which is approximately 35% of the total vegetable cultivation area (40). High virus infection is responsible for reduced yield and quality. Mixed infection with two or more viruses is common (41,52). Several surveys were conducted to determine the most important viruses of peppers in the country (41,52,53). In one of the earliest surveys 163 samples were collected from various pepper growing areas and examined by microprecipitin and agar gel immunodiffusion tests (52). CMV, TMV, AMV, PVY and PVX were detected in 57, 56, 36, 25 and 4% of the samples respectively. The identity of these viruses was later confirmed by host range tests. In another study, conducted a year later, the host range, physical properties, serological reaction and particle morphology of these viruses were studied in detail (41). Two strains of TMV, i.e. tomato streak and a common strain appears to occur.

In a systematic survey conducted in cooperation with AVRDC, 477 samples of plants showing typical virus symptoms were collected from the major pepper growing areas in Korea, and tested by DAS ELISA for the presence of 10 viruses. Eight viruses were detected: TMV, CMV, AMV, TSWV, TEV, CVMV, PVY and PVX in 157, 124, 103, 68, 7, 11, 10 and one of the samples, respectively (Table 3). CVMV, TEV and TSWV had not been previously reported from Korea (AVRDC 1990b) (Table 2). The presence of TEV and TSWV should be confirmed by additional tests.

Necrotic streak symptoms frequently observed in hot pepper plantings appear to be caused by mixed infection with TMV and CMV, certain isolates of CMV or by the newly identified pepper vein chlorosis virus (42,44). Nine pepper isolates of CMV were classified into six groups by agar gel double diffusion tests, using various CMV antisera from Japan and Korea and peanut stunt virus (Table 5). However, isolates that produce necrotic spots and necrotic streaks on stems did not differ serologically from others that cause mosaic.

Pepper vein chlorosis virus, an apparently new virus, has been isolated from peppers with stem necrosis and vein chlorosis (43,46). The virus has been characterized by host range, insect transmission, serology and electron microscopy. The virus is transmitted by aphids in a non-persistent manner. It has isometric particles (20-25 nm) arranged in a tube-like array in phloem cells of infected plants,

Table 5. Serological reactions of 20 CMV isolates with seven antisera by agar gel immunodifffusion test

Virus Isolate	Source	Symptom on natural host[a]	Reactions with antiserum of						
			I[b]	II	III	IV	V	VI	VII
CMV (NF238)	Pepper	NS, YM	++	++	++	++	—	—	—
CMV (NF239)	"	NS, R	++	++	++	++	—	—	—
CMV (NF2315)	"	F, Mal	++	++	++	++	—	—	—
CMV (NF2316)	"	SM	++	++	++	++	—	—	—
CMV (NF236)	"	SN, NS	++	++	++	++	+	+	—
CMV	Tomato	M	++	++	++	++	+	+	—
CMV	Tomato	BN	++	++	++	++	+	+	—
CMV (NF2328)	Pepper	M	++	++	+	+	+	+	—
CMV	Melon	M	++	++	+	+	+	+	—
CMV	Pumpkin	M	++	++	+	+	+	+	—
CMV (2315)	Pepper	F, Mal	++	++	—	—	+	+	—
CMV-N	Japan	—	++	++	—	—	+	+	—
CMV-P	"	—	++	++	—	—	+	+	—
CMV-Y	"	—	++	++	—	—	+	+	—
CMV (238)	Pepper	NS, SM	+	+	—	—	—	—	—
CMV (NF2319)	"	YM	—	+	—	+	—	—	—
CMV	Radish	M	—	+	+	+	+	—	—
CMV	Melon	BN	—	+	+	+	—	—	—
CMV	Amaryllis	M	+	+	—	—	+	+	—
CMV	Tomato	M	—	—	—	—	—	—	—

[a] NS: necrotic spots; YM: yellow mosaic; R: rugose; F: fernleaf; Mal: malformation; SM: severe mosaic; SN: necrotic streaks on stem; BN: bud necrosis and mosaic.

[b] I: CMV antiserum obtained from Japan; II: CMV-Y antiserum from Japan; III: CMV antiserum produced from melon showing bud necrosis (obtained from virology Lab. of ASI); IV: CMV antiserum produced from pepper isolate NF238, showing necrotic streak on stem and yellow mosaic (obtained from virology lab. of ASI); V: peanut stunt virus antiserum obtained from ATCC; VI: antiserum of an isometric virus isolated from gladiolus showing yellowing streak on leaves (obtained from virology lab. of ASI); VII: CMV antiserum obtained from Japan.

[c] ++: strong precipitin line; +=weak precipitin line; +: occasional formation of precipitin line; — : no precipitin line.

Source: Kim and Lee 1991

similar to cells infected with tomato and tobacco ringspot viruses. Apparently the virus differs from CMV in not infecting *Cucumis sativus, Cucurbita pepo* and *Gomphrena globosa* and from nasturtium ringspot virus in not infecting *Chenopodium* sp. systemically. Further characterization seems to be necessary to confirm that it is indeed a new virus, since electron-micrographs show particles that are most likely CMV (Lesemann and Green, personal communication 1992).

Mineral oil sprays, reflective vinyl mulching and insecticides have been investigated for the control of pepper viruses (45). Aphid population was found lowest and yield was doubled in plots mulched with silver striped black vinyl mulch (Table 6).

Table 6. Yield of red pepper fruit in plots mulched with silver striped black vinyl and transparent vinyl

Treatmenta	Yield (kg)			
	June 20	Aug. 17	Oct. 14	Total
Silver striped black vinyl	17.70	12.70	7.50	37.90
Transparent vinyl	17.00	7.10	2.90	27.00
Non mulching	8.85	7.55	3.20	19.60

[a] Seedlings of red pepper were transplanted on May 15, 1984.
Souce: Kim *et al.* 1989

Transmission of TMV through seed was studied and found to be 6.3, 4.0, 2.3 and 2.3% in hot peppers inoculated at the 3-4 leaf stage, first, third and fifth flowering stage, respectively (47). Transmission of TMV through infested soil was 2.6% when seeds were directly sown and 31% when seedlings were transplanted. It was also observed that average transmission from sandy loam soil (6.1%) was higher than that for loam soil (3.6%) (48).

Japan

In Japan mainly sweet peppers are grown. Six viruses infect peppers in Japan: AMV, BBWV, CMV, PVX, PVY tobamoviruses (Table 2). BBWV and CMV appear to be the most prevalent (39). These viruses have been exactly characterized by host range, transmission studies, serology and electron microscopy. Most have been purified and antiserum is available. Screening and breeding for virus resistance particularly for CMV and the tobamoviruses is conducted at the National Research Institute of Vegetables, Ornamentals and Tea (NIVOT) and at NIHORT (68).

Malaysia

Active research on pepper viruses dates back to 1975 when Ong (1975) started investigating CMV infecting chilli.

The occurrence of virus diseases has become a major production constraint of hot peppers in both high- and lowlands (30). Virus incidence in hot pepper can be as high as 80%, resulting in high yield losses.

In a systematic survey conducted in 1984, five viruses, namely CVMV, ToMV, TSWV, TLCV and CMV were identified by host range tests, electron microscopic examination and agar gel immuno diffusion tests (30). CVMV was isolated from plants showing mosaic and veinbanding or mild mosaic. TSWV was found responsible for top necrosis (necrotic spots and/or necrotic streaks on leaves and fruits). ToMV was often recovered from plants with mild mosaic symptoms (30).

According to Fujisawa (1986), CMV occurs as two strains, CMV-O (ordinary strain) and CMV-C (chilli strain), causing severe yellow mosaic and leaf distortion with mosaic, respectively. Recently, however, the presence of five strains has been implied by their reaction on a set of six differential hosts (Table 7) (Chew, B. H. personal communication 1992).

Table 7. Differential host response to five local isolates of CMV

C. annuum	CMV isolate				
	JK6	2	3	6	10
Pinang 1	S	S	S	S	S
LS1631/1	S	R	S	S	S
BK Gambit 1	S	R	R	S	S
LS1621/1	R	R	R	R	S
Punjab Lal	S	R	R	R	R
VC 17a	R	R	R	R	R

Source: B. H. Chew, personal communication 1992.

Chilli veinal mottle is a newly recognized potyvirus which was first isolated from peppers in Malaysia and characterized by Ong *et al.* (1979). The host range of this virus is confined to the Solanaceae family. Transmission is by more than seven species of aphids in a non-persistent manner (74). Yield reduction as high as 60% results from early infection (72,75).

CMV and CVMV appear to be the most important viruses in terms of incidence and yield loss. Management practices for the reduction of virus diseases

of peppers have been developed. Aluminum-painted polyethylene sheets (71,87) and intercropping of maize with pepper (86) were found most effective in reducing virus incidence (Tables 8, 9).

Table 8. Comparison of the effectiveness of aluminum foil, translucent polyethylene sheet, and polyethylene sheet painted with aluminum color mulches to repel aphids (71)

Soil mulch	Total aphids trapped	Aphid repellency (%)
Aluminum foil	247 a	76.52
Translucent polyethylene sheet	343 a	67.40
Polyethylene sheet painted with aluminum color	140 a	86.69
Unmulched (control)	1052 b	–

Table 9. Effects of maize planting arrangements on winged aphid populations and viral disease incidence on chilli (86)

	No. aphids caught	Mean aphid reduction (%)	Overall mean viral disease incidence
Intercropping chilli with maize	89.3 a	59.6 a	49.4 a
Chilli surrounded by maize	121.7 b	45.0 b	64.7 b
Chilli only	221.3 c	–	71.4 c

Research on pepper viruses at MARDI and at the National University Malaysia is complemented by a highly successful breeding program at MARDI which has multiple virus resistance (particularly CMV and CVMV) as its major objective (22). . Several virus-resistant/tolerant lines have been developed (94).

Genetic studies have established the mode of inheritance of CVMV resistance as being controlled by a pair of recessive genes. There is a possibility that a number of independent resistance genes react against CVMV. Through concerted breeding efforts Malaysia has developed 19 CVMV-resistant breeding lines. These have not yet been released to the growers because they are susceptible to CMV, which usually occurs as a mixed infection with CVMV in the field. However, the

incorporation of CMV-resistant gene/genes into the existing CVMV-resistant progenies is well under way, using the resistance from *C. annuum* Lorai (India), *C. annuum* HDA 295 (INRA, France, through AVRDC) and from *C. baccatum* LS 1621 (Chew, personal communication 1992).

Thailand

The production of pungent pepper occupies about 20% of the total vegetable and flower growing area. Five viruses have been reported in early surveys conducted in the mid-70s: CMV, CVMV, a virus that resembles pepper mottle virus (PeMV) and a tobamovirus (88,111). This tobamovirus was further characterized by intensive host range studies, biological characteristics, electron microscopy and agar gel immunodiffusion tests (111). The virus was found serologically related, but not identical to TMV isolated from orchid and tobacco. It is probably ToMV. Attempts to transmit this virus by mechanical inoculation, aphids and whiteflies have been unsuccessful. So far it can only be transmitted by grafting from pepper to pepper. Another virus, tentatively called pepper yellow vein virus is also affecting the crop. This virus induces yellowing of the veins at the base of the leaves, mosaic, leaf crinkling and twisting, reduced leafsize, and distorted fruits (49). It occurs mainly in central Thailand, where incidence is 80%, although it has also been reported from the North and Northeastern part of the country.

A potyvirus which induces various types of mottle/mosaic leaf spotting, stunting of the plant and reduced flower and fruit number on bird and chilli spur peppers has been detected in the Central and Northeastern part of the country (50). The virus has been purified (50) and was later found to be CVMV by agar gel immunodiffusion and DAS ELISA by electron microscopy (Kittipakorn, personal communication, 1991).

CMV is widespread in all pepper growing areas of Thailand. The virus has been characterized by Wongkaew and Sutabutra (1974). Its most important vectors in Thailand are *Rophalosiphum pseudobrassicae* and *Aphis gossypii.* One special characteristic of this virus is that infection does not occur at temperatures above 35. The most suitable temperature for infection is between 22 and 28.

A virus believed to be pepper mottle virus was first isolated in 1975 from chilli spurpeppers where it induced mottling, green veinbanding as well as leaf and fruit distortion (111). The virus occurs throughout the country. In agar gel immunodiffusion tests the virus was found serologically related to PeMV (from Purcifull, Florida) and to TEV (PV-60, ATCC). Further tests are needed to confirm its identity as PeMV.

Surveys of aphids on pepper crops conducted in the mid-70s (11,12) have listed *Aphis gossypii, Myzus persicae, A. citricola* and possibly *A. craccivora* as

common pests of peppers. Among these, A. gossypii is the most prevalent (K. Kittipakorn, personal communication 1992).

Intensive virus surveys covering the Central, North, Northeastern and Southern provinces and resistance screening for CVMV and CMV have been conducted since then by K. Kittipakorn *et al.* (1991), as part of the AVRDC collaborative activities of the ADB-funded Asian Vegetable Network. In addition to the above-mentioned viruses, TEV, TSWV, alfalfa mosaic virus (AMV) and pepper mild mottle virus (PMMV) have been detected by DAS-ELISA. According to these surveys CVMV is the most prevalent, followed by CMV, PVY, AMV, TEV, PeMV, TSWV, TMV, ToMV and PMMV (Table 10). The identity of TEV and PeMV needs to be confirmed by further characterization. In these surveys tobacco has been found as a new natural host plant of CVMV (Kittipakorn personal communication 1992).

Table 10. Detection of viruses of peppers in Central, Northern, Northeastern and Southern Thailand by DAS ELISA, in 1989, 1990 and 1991

Location	No. of samples	No. of samples positive for									
		CVMV	CMV	PVY	PMMV	TSWV	AMV	TEV	TMV	ToMV	PeMV
Central	513	258	61	86	—	5[1]	70	57	14	2	—
North	541	315	168	214	4[3]	16[4]	97	80	37	48	34[2]
Northeast	264	173	129	31	—	—	18	22	16	1	—
South	42	42	22	7	—	—	19	10	1	3	—
Total	1360	788	380	338	208	208	204	169	68	54	34/341

[1] -=not tested
[2] only 341 samples tested
[3] only 208 samples tested
[4] only 208 samples tested
Source: K. Kittipakorn, personal communication, 1992.

Screening for resistance to pepper viruses has been initiated in 1986 by Satjapong, Kiratiya-angul, Teepapan and Charanpanitah at the Horticultural Research Institute in the Sri Saket Province (3) and is being continued by K. Kittipakorn of the Department of Agriculture, Bangkhen. Several local cultivars with resistance to CMV (Kheenoo Tonetung, Pichit 08, Pichit 14) and CVMV (Chau Maukau, Huay Seetone 5/1, Kheeno Chinda No. 4, Kheeno Raisurat Toom) were identified following mechanical inoculations (K. Kittipakorn, personal communication 1992).

The Philippines

Production of hot peppers is limited to very small scattered areas, often in

backyards. Sweet peppers, on the other hand, are grown on 1,450 ha, producing 3,606 t. The average yield is 25 kg/ha (106). Viruses are prevalent year round in all production areas (L. Dolores, personal communication 1992).

So far only mosaic, caused by the green and yellow strains of TMV has been investigated in depth. Distinct yellow and green mosaic symptoms were first reported by Fajardo in 1934. Twenty percent of the pepper crop was affected by the disease (del Rosario and Mangabat 1968). Later it was established that two strains (isolates) of TMV are involved which differ in host range, symptomatology and physical properties (Pangramuyen and del Rosario 1967).

Another, different mosaic disease, caused by a virus with flexuous rod shaped particles, was also reported (Retuerma 1976). The virus, which causes vein clearing, severe mottling, crinkling and cupping of the leaves, is transmitted by sap and aphids (*A. gossypii, A. euonymi* and *M. persicae*) in a nonpersistent manner and is believed to be PVY (L. Dolores, personal communication 1992).

As part of the activities of the ADB-funded Asian Vegetable Network, initiated in 1989, a systematic virus survey was conducted in 19 provinces during 1989 to 1992. ToMV and TMV were shown to be the most prevalent viruses, followed by CMV, CVMV, PVY, TEV and PeMV (Table 11). Mixed infection with more than one virus was common.

Screening for resistance to the two tobamoviruses has been initiated in 1984 (113). Resistance has been found in several local (Kawit strain 2, 7, PIP VG X 9161) and introduced cultivars (Cayenne Large Red Thick, Anaheim TMR).

Indonesia

Chilli peppers, are grown mainly in the lowlands of Java on 340,000 ha (=27.6% of the total vegetable area in Indonesia). Yields are generally low with a national average of 1.32 t/ha (14). Infection with viruses, usually as high as 100% (A. S. Duriat, personal communication 1992) is believed to be one of the main reasons for this low productivity, next to insect damage.

In 1989 a first systematic virus survey, covering West Java, Central/East Java, Sumatra, Bali and Lombok was conducted. Almost 700 samples were collected and tested by DAS-ELISA for the presence of 10 viruses. The following viruses were detected: CMV, PVY, TMV, TRV, TEV, tobacco streak virus (TSV), tobacco ringspot virus (TRSV), potato virus M (PVM), PVX and alfalfa mosaic virus (AMV) (Table 12) in order of highest incidence (A. S. Duriat 1989 unpublished results).

In another large-scale survey covering West and Central Java, West and North Sumatra, more than a thousand samples were collected and tested by DAS ELISA for the presence of six viruses. Incidence of CVMV was found to be highest, followed by CMV, TEV, PVY, AMV and TMV (Table 13) (27). A new potyvirus, tentatively named chilli veinal yellowing virus, has also been detected (Sulyo 1992

Table 11. Survey for viruses of peppers in the Philippines

Provinces/Cities Surveyed	No. of Localities sampled	(%) of samples infected with					
		TMV/ToMV	CMV	PVY	CVMV	TEV	PeMV
Laguna	2	100	6	83	97	32	—
Cavite	4	15	2	—	—	—	—
Batangas	2	33	13	33	13	27	—
Zambales	5	40	22	18	—	1	36
Pampanga	2	— [1]	—	—	17	12	—
Tarlac	1	—	—	—	17	—	—
Pangasinan	2	33	13	—	—	—	—
La Union	1	33	—	67	—	—	—
Benguet	2	—	—	—	—	—	—
Ilocos Sur	4	30	50	—	—	—	—
Ilocos Norte	3	—	—	—	—	—	—
Isabela	4	—	20	—	—	—	—
Nueva Vizoaya	8	16	50	10	—	—	—
Nueva Ecija	6	—	—	26	—	30	—
Camarines Norte	6	8	79	10	5	1	—
Camarines Sur	8	99	35	—	—	33	—
Albay	12	100	50	50	60	—	—
Davao City	2	5	25	—	—	20	—
Gen. Santos City	4	15	10	—	—	—	—
AVE		28	20	16	11	8	2

[1] - not detected

Ref.: L. Dolores, personal communication, 1992.

personal communication). There are also indications that a geminivirus is present on peppers grown in the lowlands of Java showing symptoms such as yellow vein mosaic (Y. Sulyo, personal communication 1992). This virus is considered potentially important.

Yield losses due to CMV range from 37 to 74%, depending on the cultivar infected (110). In cooperation with Dr. J. M. Kaper (Microbiology and Plant Pathology Laboratory, United States Department of Agriculture, Beltsville, U. S. A.), research is being conducted to reduce CMV incidence and virus symptoms by cross protection using an attenuated local strain of CMV plus satellite RNA (26).

India

Hot peppers are widely grown in India and are an important commercial crop,

Table 12. Detection of viral diseases of pepper in Indonesia by DAS ELISA

Location	Number of samples tested	No. of samples positive for									
		CMV	PVY	TRV[1]	TEV	TMV[2]	TSV[3]	TRSV[4]	PVM[5]	PVX	AMV
1. West Java	176	81[6]	19	—	8	17	10	—	8	3	—
Bandung	215	94	14	55	28	79	38	26	6	4	—
Bekasi	37	18	9	13	14	—	0	8	—	0	—
Lembang	40	21	13	0	8	—	14[7]	5	—	5	5
Rajamandala/ Subang	19	10	13	18	0	—	—	0	—	0	—
Other locations	81	37	21	—	0	—	0	0	0	0	—
2. Central/ East Java	34	18	2	—	18	—	—	—	0	0	—
3. Sumatra, Lampung	67	30	18	28	11	—	0	10	—	0	—
4. Bali and Lombok	22	7	9	—	15	—	—	0	—	0	—
Total	691	316	118	114	102	96	52	49	14	12	5

[1] TRV=tobacco rattle virus
[2] TMV was tested by inoculation of tobacco
[3] TSV=tobacco streak virus
[4] TRSV=tomato ringspot virus
[5] PVM=polaho virus M
[6] Number of samples that reacted with the antiserum
[7] Three samples of healthy looking plants also reacted with this antiserum
- Not tested
Source of antisera: PVY, CMV, TEV, AMV, PVY, TSV: ATCC, USA
TRSV, TRV: IPO, the Netherlands
PVM: Lisse, the Netherlands
Ref.: Ati, S. D. 1989 (personal communication)

occupying an area of 891,800 hectares, and producing 677,300 t of dry chillies. About 2% is exported to countries such as the USA, Nepal, Malaysia and the USSR (99). Sixteen viruses have been reported to infect peppers in India: dwarf mosaic, brinjal mosaic, CMV, green veinbanding, launea mosaic, marigold mottle, pepper veinbanding, potato X (PVX), PVY, pepper veinal mottle, tobacco etch (TEV), tobacco mosaic (TMV), tobacco rattle (TRV), ToMV, tomato spotted wilt (TSWV) and the chilli leafcurl complex (Table 2) (36).

Table 13. Detection of pepper viruses in Indonesia

Date	Location	Total no. of samples tested	No. of samples positive					
			CMV	CVMV	PVY	TEV	AMV	ToMV
July-Aug. 89	Subang	164	110	—[1]	45	63	—	—
Aug.-Dec.89	Brebes	163	131	100	33	114	57	29
Nov. 89	Segunung	20	3	17	7	15	9	9
May 90	Subang	223	90	111	72	115	95	75
May 90	Lembang	35	5	1	13	3	2	2
June-Aug. 90	Subang	386	136	213	117	75	30	43
June 92	Solok	59	25	19	7	—	—	14
July 92	Brastagi	11	3	1	0[2]	—	—	1
Total		1061	503	463	294	385	193	173

[1] -=not tested
[2] 0=no reaction
Source of antisera: As in table 7, except CMV from LEHRI, Indonesia and CVMV from AVRDC, Taiwan.
Ref.: Duriat *et al.* 1992

Virus characterization was generally based on host range and transmission studies, virus- vector relationship, biological properties and electron microscopy. Some of these viruses have been identified only by the symptoms they cause and have not been exactly characterized, particularly by serological comparisons. The leafcurl complex, CMV, tobamoviruses, PVY, PVX and TSWV are considered the most important viruses and thus have been investigated in more detail.

Incidences of 100% have been reported for the leafcurl virus complex. Yield losses up to 92% can occur during the summer months when plants become infected shortly after transplanting (103). The effect on yield and evaluation of control methods by biological and chemical means and by management practices has also been extensively investigated for some of the above listed viruses, particularly CMV (24) and the leafcurl virus complex (97,103,104).

Screening for virus resistance by mechanical inoculation and by natural infection has been conducted and germplasm with resistance/tolerance to CMV, tobamoviruses, PVY, PVX and to the leafcurl virus complex has been identified (79, 84,91,96,97,98,101,112).

Breeding programs which emphasize virus resistance exist in several institutions throughout the country (Rahuri; Maharashtra; Punjab Agricultural University, Ludhiana; IIHR, Hesserghatta). They have resulted in the release of high yielding,

well adapted cultivars with virus resistance such as Pant C-1, Punjab Lal, Lorai, Perennial, Longi S20-1, Bangla Green, Tiwari, Laichhi, Delhi Local, 38-2-1, 96-4-9-3, and 141-2-33 (99). Some of these materials such as 'Perennial' developed by S. J. Singh of Punjab University, Ludhiana, are now used by breeders throughout the world as donors for virus resistance (Chew, B. H., MARDI, Malaysia; Palloix, A., Pochard, R., INRA, Avignon, France; Poulos, J. M., AVRDC, Taiwan, Peto Seed Co.).

Sri Lanka

In Sri Lanka hot peppers are an important crop with an annual production of about 30,000 metric tons on 25-30,000 ha. The average yield is around 1.5-2 t/ha on dry weight basis. Virus diseases are reported as the major production problem (A. Perera, personal communication).

Systematic virus surveys have been conducted from 1969 to 1970 in a joint endeavor between the Plant Pathology Division of the Sri Lanka Department of Agriculture and the Tropical Agriculture Research Center (TARC) of Japan (108). Two symptom types are commonly observed: mosaic and leafcurl. The viruses involved in mosaic type symptoms were identified as TMV, PVY and CMV (108). The involvement of a virus in the leafcurl disease complex (77) has been implied in the early 60s, when Fernando and Peiris (1953) found that the disease was whitefly-transmitted. Further studies on host range and whitefly transmission suggested that the virus was a strain of tobacco leaf curl virus (108).

During 1990-91 Dr. L. L. Black of Louisiana State University, in conjunction with the Mahaweli Agriculture and Rural Development (MARD) project of the Mahaweli Authority of Sri Lanka and the United States Agency for International Development conducted disease surveys on hot peppers in the irrigated dry lands of north-central Sri Lanka. Incidence of plants with virus-like symptoms ranged from 5 to 95%. The most frequently detected virus was CMV, followed by CVMV, TEV, PVY, pepper mild mottle virus (PMMV), TSWV and TMV, respectively (Table 14).

Another virus which causes chlorotic spots on older leaves and vein yellowing on young leaves also infects peppers. The virus has not been well characterized. It has a narrow host range and no vector has been found yet.

A virus-like problem, referred to as narrow leaf disorder (NLD) was first observed in 1982 and has since become a serious problem in dry and irrigated cropping systems (25). Symptoms include narrow strapped leaves with a prominent midvein, bud proliferation, shortened internodes and flower drop. The etiology of NLD remains undetermined, but most evidence suggests that no infectious agent is involved. Hypotheses most commonly advanced as to the cause of NLD in chilli include: a metabolite(s) from a nonpathogenic soil microorganism, a micronutrient

Table 14. Viruses detected by ELISA on hot peppers in Sri Lanka[1]

	Total no. of samples collected	CMV	CVMV	TEV	PVY	PMMV	TSWV	TMV
August 90	58[2]	23[5]	NT	15	11	7	8	3
February 91	92[3]	54	NT	17	3	3	0	1
August 91	84[4]	13	51[5]	8	0	1	0	0
Total		90	51	40	14	11	8	4

[1] Research conducted under auspices of the Mahaweli Agriculture and Rural Development Project of USAID and Sri Lanka.
[2] Samples collected from 30 fields.
[3] Samples collected from 51 fields.
[4] Samples collected from 51 fields.
[5] Number of samples reacting positively with antiserum to the particular virus.
[6] ELISA assays for chilli veinal mottle virus conducted by S. K. Green at AVRDC.
Source: L. L. Black, Louisiana State Univ., personal communication 1992.

imbalance, and exposure to phenoxy herbicides.

The extent of damage caused by NLD to chilli in Sri Lanka may be overestimated because symptoms of NLD are at times confused with thrips feeding injury, mite feeding injury, and CMV symptoms (L. L. Black, personal communication, 1992).

Although Sri Lanka has a well recognized pepper breeding program, resistance to virus diseases has, so far, not been emphasized (A. Perera, personal communication 1992). Virus research is conducted at the Central Agricultural Research Institute in Peradeniya.

Nepal

Peppers, particularly hot peppers, are an important crop in Nepal. Viruses, next to fruit borers (*Helicoverpa armigera*) are believed to be the main reason for the decline of pepper production in Nepal. The most popular sweet pepper variety is California Wonder; however, most hot peppers are of local origin. Virus incidence as high as 82% has been reported in farmers' fields. Typical virus symptoms observed are yellow and dark green mosaic, reduced leaf and fruit size, and dwarfing or bushiness of the plants in case of severe infection. The viruses involved have not yet been identified (P. M. Pradhanang, Lumle Agricultural Centre, Pokhara, personal communication 1992).

CONCLUDING REMARKS

It is evident that infection of peppers with viruses is very high in each of the surveyed countries and that viruses are an important production constraint.

Of the more than 35 viruses reported to occur on peppers worldwide, only about a dozen seem to be infecting peppers in Asia.

Among these, CVMV, CMV, PVY and the tobamoviruses are the most commonly found. Tobacco etch virus, PeMV and TSWV also appear to be important, although their exact identity needs to be confirmed. Alfalfa mosaic virus appears to be more common on peppers grown in the cooler regions of Asia, such as Korea and Japan and the highlands of Indonesia and the Philippines.

Similarly, BBWV seems to occur only in the temperate pepper growing regions of Asia, such as Japan and China.

The leafcurl virus complex may be a potentially important, especially in lowland production areas, particularly since whiteflies (its vector) are reported to have increased on almost all economically important crops in the region (A. Varma, personal communication, 1991).

The only effective economical and feasible control appears to be the planting of resistant or tolerant cultivars. Most national programs in the region have realized this and some, particularly those where peppers are an economically important crop, have initiated breeding programs emphasizing among others, multivirus resistance.

AVRDC's efforts on this particular aspect should also deserve recognition. Its active multidisciplinary breeding program at AVRDC headquarters has been complemented since 1989 by the pepper virus subnetwork of AVNET. This subnetwork aims to identify or confirm the most important viruses in the region (Thailand, Malaysia, Indonesia and the Philippines), to find field tolerance or resistance in local landraces and/or introduced pepper cultivars, to conduct multilocational screening of resistant lines identified by the respective National Agricultural Research Systems (NARS) or elsewhere and to determine whether strains of important viruses such as CVMV and CMV do exist in the region.

The above pertains mainly to hot peppers and not to sweet peppers, which are generally grown in the highlands, or during the cooler season in the lowlands. Commercial cultivars of sweet peppers suitable for these climatic conditions and which already carry resistance to several important viruses such as PVY, TEV, PeMV and the tobamoviruses should be readily available.

ACKNOWLEDGENTS

The assistance of L. L. Black, B. H. Chew, L. Dolores, A. S. Duriat, K. Kittipakorn, M. Roff, R. B. Valdez and C. Y. Yang in obtaining, verifying and completing information on pepper viruses from the above countries/regions is highly appreciated.

LITERATURE CITED

1. Abu Kassim, A. B. 1986. Virus disease of horticultural crops in Malaysia. p. 3-6. In: Food and Fertilizer Technology Center for the Asian and Pacific Region. FFTC, Taipei, Taiwan.
2. Anjaneyulu, A., and Apparao, A. 1967. Natural occurrence of cucumber mosaic virus on chilli in India. Indian Phytopathology 20:380-381.
3. Anonymous. 1986. Annual Report of the Department of Agriculture. Thailand. 135 p.
4. Anonymous. 1986. Directory of plant diseases, insect pests and weeds in Korea (revised version). Korean Society for Plant Protection.
5. AVRDC. 1988. 1986 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C. 540 p.
6. AVRDC. 1990a. 1987 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C. 482 p.
7. AVRDC. 1990b. 1988 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C. 414 p.
8. AVRDC. 1990c. 1989 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C. 351 p.
9. AVRDC. 1991. 1990 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C. 312 p.
10. AVRDC. 1992. 1991 Progress Report. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C. 410 p.
11. Banziger, H. 1976. Keys for dentification of aphids (Homoptera) I. winged aphids of species economically important in Thailand. Plant Protection Service Technical Bulletin (PPSTB) 30:41.
12. Banziger, H. 1977. Keys for dentification of aphids (Homoptera) II. field identification of common wingless aphids of crops in Thailand. Plant Protection Service Technical Bulletin (PPSTB) 37:22.
13. Bidari, V. B., and Reddy, H. R. 1984. Tomato spotted wilt virus - A new record on chilli in India. Current Science 53:1045-1046.
14. Biro Pusat Statistik (BPS) 1989. Produksi tanaman sayuran dan buah -

buahan di Indonesia (Central Statistics Bureau. 1989. The Production of Vegetable and Fruits in Indonesia), Jakarta, Indonesia.

15. Brunt, A. A. 1980. Plant virus diseases in Fiji. UNDP/FAO SPEC Survey of Agricultural Pests and Diseases. 31p.
16. Burgmans, J. L., Fry, P. R., and Sunde., R. G. 1986. Peppers: survey of virus diseases of *Capsicum annuum* in Hawke's Bay and Poverty Bay. New Zealand J. of Experimental Agriculture 14:459-463.
17. Butter, N. S., and Rataul, H. S. 1977. The virus-vector relationship of the tomato leaf curl virus (TLCV) and its vector, Bemisia tabaci Genn. (Hemiptera: Aleyrodidae). Phytoparasitica 5:173-186.
18. Chandrasrikul, A., and Patrakosol, P. 1986. Virus diseases of horticultural crops in Thailand. p. 8-11. In: Plant Virus Diseases of Horticultural Crops in the Tropics and Subtropics. Food and Fertilizer Technology Center for the Asian and Pacific Region. Taipei, Taiwan, R.O.C. 193 p.
19. Chen, T. H. 1982. Studies on three elongated viruses affecting pepper (*Capsicum annuum* L.) in Taiwan. MS thesis, National Chung Hsing University, 38 p.
20. Chen, T. H., and Lu, Y. T. 1985a. Partial characterization of three elongated viruses infecting peppers (*Capsicum annuum* L.) in Taiwan. Bull. National Pingtung Inst. Agr. 26:126-137.
21. Chen, T. H., and Lu, Y. T. 1985b. Application of the enzyme-linked immunosorbent assay for detection of potato virus X and pepper mottle virus in pepper plants (*Capsicum annuum* L.). Pingtung Agr. Inst. Bulletin No. 26:138-145.
22. Chew, B. H., and Ong, C. A. 1990. Genetics and breeding for chilli veinal mottle and cucumber mosaic virus resistance in hot pepper. p. 55-58. in: Proc. 3rd Int. Conf. Pl. Prot. in Tropics. Genting Highlands, 20-23 March, MAPPS.
23. Chowfla, S. C., Pal, J., Bhardwaj, S. V., and Baruah, B. P. 1985. Bell pepper dwarf mosaic - a new disease in Himachal Pradesh. Indian J. Plant Pathol. 3: 252-254.
24. Deol, G. S., and Rataul, H. S. 1978. Influence of plant age at inoculation by cucumber mosaic virus on disease incidence and yield of chilli. Indian J. Plant Protection 6:82-83.
25. De Zoysa, I. J. 1987. Narrow leaf disorder of chilli. Tropical Agriculturist 87.
26. Duriat, A. S., Sulyo, Y., Sutarya, R., and Asandhi, A. A. 1991. New approach of plant biotechnology for controlling cucumber mosaic virus on pepper. Paper presented at the workshop on Agricultural Biotechnology, CRIFC, AARD, Bogor. 21-24 May 1991.
27. Duriat, A. S., Sulyo, Y., Sutarya, R., Gunaeni, N., and Korlina, E. 1992.

Studies on virus diseases of pepper. in: Final Report of AVNET-1 presented at the AVNET phase-I final workshop. Lembang, Indonesia. 22-26 September 1992.

28. Duriat, A. S., Vos, J. G. M., Suhatini, T., and Kusandriani, Y. 1988. Inventarisation of pests, diseases and germplasm of chilli peppers in lowland areas of Indonesia. Internal Communication LEHRI/ATA - 395 No. 1. 20 p.
29. Fernando, H. E., and Peiris, J. W. L. 1957. Investigation of the chilli leafcurl complex and its control. Tropical Agric. CXIII:305-323.
30. Fujisawa, I., Hanada, T., and Anang, S. B. 1986. Virus diseases occurring on some vegetable crops in West Malaysia. Jpn. Agr. Res. Quarterly 20:78-84.
31. Fujisawa, I., Hanada, T., and Saharan, H. A. 1988. Identification and control of the virus diseases affecting chilli in West Malaysia. In: Paper presented at the FFTC Symposium. Kyoto, Japan,
32. Gebre Selassie, K., Marchoux, G., Delecolle, B., and Pochard, E. 1985. Variabilite naturelle des souches du virus Y de la pomme de terre dans les cultures de piment du sud-est de la France. Caracterisation et classification en pathotypes. Agronomie 5:621-630.
33. Giatgong, P. 1980. Host index of plant diseases in Thailand (2nd ed.). 118 p.
34. Gracia, O., and Feldman, J. M. 1974. Tobacco streak virus in pepper. Phytopathol. Z. 80:313-323.
35. Graham, K. M. 1971. Plant Diseases of Fiji. HMSO. Overseas research publication, Ministry of Overseas Development, London, England, No. 17, 250p.
36. Green, S. K., and Kim, J. S. 1991. Characteristics and control of viruses infecting peppers: a literature review. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, ROC. Technical Bulletin No. 18. 60 p.
37. Ho, S. C., Fan, H. C., Gao, C. W., and Lou, S. H. 1982. Identification of the causal viruses of the mosaic disease of pepper in the suburb of Guangzhou. J. South China Agr. College 3: 73-86.
38. Huang, Y. T. 1992. Isolation and identification of sweet pepper virus. MS thesis, National Chung Hsing University, 55 p.
39. Imoto, M. 1975. Studies on mosaic disease of sweet pepper (*Capsicum frutescens* L.) 2. Occurrence of mosaic disease of sweet pepper and kinds of its causal viruses in Hiroshima prefecture. Bull. Hiroshima Agr. Expt. Station, Japan 36:56-66.
40. Kang, K. Y. 1989. Tomato and pepper production and research in Korea. p. 490-503. in: S. K. Green, T. D. Griggs and B. T. McLean (eds.) Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March. Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan, ROC.

41. Kang, K. Y., Choi, J. I., and La, Y. J. 1973. Isolation and identification of viruses affecting pepper (*Capsicum annuum*) in Korea. J. of the Korean Soc. Horti. Sci. 13:35-44.
42. Kim, J. S., Kim, S. K., Choi, G. S., and Lee, M. W. 1990a. Virus disease incidence and symptom appearance in red pepper. Korean J. of Plant Pathol. 6:125-132.
43. Kim, J. S., Kim, S. K., Lee, S. H., and Lee, M. W. 1990b. A pepper vein chlorosis virus causing stem necrosis and vein chlorosis on red pepper in Korea. Korean J. Plant Pathol. 6:376-381.
44. Kim, J. S., and Lee, K. H. 1991. Virus disease incidence and symptom expression on peppers cultivated in vinyl-house, and serological relationship of CMV isolates from peppers. Res. Rept. RDA (C. P) 33:8-14.
45. Kim, J. S., Lee, K. H., and Lee, M. W. 1989. Effect of oil spraying and vinyl mulching for the control of virus disease on red pepper. Res. Rept. RDA (C. P) 31:7-12.
46. Kim, J. S., Lee, K. H., and Lee, S. H. 1991. Identification and characteristics of a pepper vein mosaic virus from red pepper. Res. Rept. RDA (C. P) 33:12-17.
47. Kim, J. S., Lee, S. H., and Lee, M. W. 1989a. Seed transmission of TMV in red pepper (*Capsicum annuum* L.). Res. Rept. RDA (C. P.) 31:10-13.
48. Kim, J. S., Lee, S. H., and Lee, M. W. 1989b. Transmission of TMV by infected soils in red pepper (*Capsicum annuum* L.). Res. Rept. RDA. (C. P) 31:6-9.
49. Kiratiya-angul, K., and Deema, N. 1979. Study on yellow vein disease of hot pepper. p. 63-67. in: Annual Report of the Division of Plant Pathology, Department of Agriculture, Bangkok, Thailand (in Thai),.
50. Kiratiya-angul, K., Prommintara, M., Choopanya, D., and Deema, N. 1987. Purification and antiserum-production of a potyvirus causing a mosaic disease in pepper. p. 105-109. in: Annual Report of the Plant Virology Section. Div. of Plant Pathology and Microbiology, Department of Agriculture. Bangkok, Thailand (in Thai).
51. Krishna, A., Nema, G. A., Nadkurni, P. G., and Bhalla, P. L. 1983. Evaluation of chemicals for control of leaf curl of chillies. p. 167-169. in: Proceedings of the national seminar on the production technology of tomato and chillies. Coimbatore, India.
52. La, Y. J., Choi, J. I., and Kang, K. Y. 1972. Serological investigation of virus disease of red pepper plant. Kor. J. of Botany 15:23-27.
53. Lee, S. H. 1981. Studies on virus disease occurring on various crops in Korea. Res. Rept. RDA (P. M., and U.) 23:62-74.
54. Li, X. H., and Cao, S. X. 1988. Identification of a virus isolate causing

mosaic and top blight of pepper (*Capsicum frutescens*). Acta Phytopathologica Sinica 18:143-149.

55. Lu, Y. C. 1981. Purification of sweet pepper viruses. Plant Protection Bull. (Taiwan, ROC) 23:264.
56. Manee, N., and Pipob, L. 1989. Tomato and pepper production and improvement in Thailand. p. 566-575. in: S. K. Green, T. D. Griggs and B. T. McLean (eds). Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March, Asian Vegetable Research and Development Center.
57. Mayee, C. D., Kaul, D. L., and Thakur, M. R. 1975. A method for field evaluation or resistance of chilli to leaf curl disease. J. Plant Dis., and Protection 82:566-569.
58. Miyamoto, Y., Miyamoto, S., Takeuchi, T., and Oguni, A. 1963. Virus diseases of pepper plants I. Science Reports of the Hyogo University of Agriculture 6:1-12 (in Japanese).
59. Miyamoto, Y., Miyamoto, S., Takeuchi, T., and Oguni, A. 1964. Virus diseases of pepper plants II. Science Reports of the Hyogo University of Agriculture 6:37-42 (in Japanese).
60. Nagai, Y. 1981. Control of mosaic diseases of tomato and sweet pepper caused by tomato mosaic virus. Plant Protection Research, Tokyo, Japan 14:73-94.
61. Nagai, Y., Choi, Y. M., and Tochihara, H. 1987. TMV-U, a new strain of tobacco mosaic virus isolated from sweet pepper. Ann. Phytopath. Soc. Japan 53:540-543 (in Japanese).
62. Nagai, Y., Takeuchi, T., and Tochihara, H. 1981. A mosaic disease of sweet pepper caused by pepper strain of tobacco mosaic virus. Ann. Phytopath. Soc. Japan 47:541-546 (in Japanese).
63. Nagaraju and Reddy, H. R. 1980. Natural occurrence of pepper veinal mottle virus on bell pepper. Indian Phytopathology 33:282-284.
64. Nagaraju and Reddy, H. R. 1981. Natural occurrence of pepper veinbanding virus on bell pepper. Mysore J. Agr. Sci. 14:50-53.
65. Nagaraju and Reddy, H. R. 1982. Occurrence of cucumber mosaic virus on bell pepper. Indian J. Mycol., and Plant Pathol. 12:217-219.
66. Naqvi, Q. A., Haseeb, A., Saxena, S. K., and Mahmood, K. 1978. Influence of marigold mottle virus (MMV), the reniform nematode, *Rotylenchulus reniformis* and the stunt nematode on the growth of chilli and on nematode multiplication. Acta Bot. 6:174-175.
67. Naqvi, Q. A., and Mahmood, K. 1975. Reaction of different varieties of brinjal, tomato and pepper to the new strain of brinjal mosaic virus. Geobios 2:189-190.

68. Narikawa, T., Hida, K., and Zhang, B. 1987. Breeding sweet pepper resistant to cucumber mosaic virus. Capsicum Newsletter 6:61-62.
69. Noraini, A. S. 1986. Identification of virus infecting chilli *Capsicum annuum* L. in Malaysia. p. 413. in: 2nd International Conference on Plant Protection in the Tropics, 17-20 March 1986. Extended Abstracts. Universiti Pertanian Malaysia. Serdang, Selangor, Malaysia.
70. Ong, C. A. 1975. Studies of a mosaic disease of chilli (*Capsicum annuum* L.) in Peninsular Malaysia. M. Agric. Sc. Thesis, Fac. of Agric. University of Malaysia. 100 p.
71. Ong, C. A. 1984. Reducing the spread of chilli veinal mottle virus using reflective surfaces. MARDI Res. Bull. 12:200-204.
72. Ong, C. A., and Ting, W. P. 1977. A review of plant virus disease in Peninsular Malaysia. p. 155-164. in: Proceedings of a Symposium on Tropical Agriculture Research. Tsukuba, Japan No. 10:155-164.
73. Ong, C. A., Varghese, G., and Ting, W. P. 1979. Aetiological investigations on a veinal mottle virus of chilli (*Capsicum annuum* L.) newly recorded from Peninsular Malaysia. MARDI Res. Bull. 7:78-88.
74. Ong, C. A., Ting, W. P., and Varghese, G. 1978. Role of aphid vectors in the spread of chilli veinal mottle virus. p. 53-60. in: Proc. Plant Protection Conference. Kuala Lumpur, Kuala Lumpur: MAPPS.
75. Ong, C. A., Varghese, G., and Ting, W. P. 1980. The effect of chilli veinal mottle virus on yield of chilli (*Capsicum annuum* L.) newly recorded from Peninsular Malaysia. Malaysian Agricultural Research and Development Institute. MARDI Res. Bull. 8:74-79.
76. Park, S. G., Kim, B. S., and Yung, B. Y. 1987. Diagnosis of Physiological Disorders and Diseases of under Structure Vegetables. Seoul Seed Co., Seoul Press. 341 p.
77. Peiris, J. W. L. 1953. Chilli leafcurl complex. Tropic. Agric. CIX:210.
78. Permadi, A. H. 1989. Tomato and pepper production in Indonesia: Problems, Research and Progress. p. 472-479. in: S. K. Green, T. D. Griggs and B. T. McLean (eds.). Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C.
79. Peshney, N. L., and Moghe, P. G. 1988. Reaction of chilli (*Capsicum* species) to tobacco mosaic (TMV) and cucumber mosaic virus (CMV). Ind. J. Agri. Sci. 58(9):720-21.
80. Prasada Rao, R. D. 1977. Characterization and identification of some chilli mosaic viruses. Mysore J. Agr. Sci. 11:254.
81. Prasada Rao, R. D., and Yaraguntaiah, R. C. 1979a. A key for diagnosis of

some chilli mosaic viruses. Mysore J. Agr. Sci. 13:442-445.

82. Prasada Rao, R. D., and Yaraguntaiah, R. C. 1979b. The occurrence of pepper veinal mottle virus on chilli in India. Mysore J. Agr. Sci. 13:445-448.
83. Pyou, H. G., Choi, J. I., and Lee, K. H. 1980. Horticultural crops. Hwangmungsa Co. 398 p.
84. Ramakrishnan, K., Kandaswamy, T. K., and Thangamani, G. 1966. Reaction of chilli (*Capsicum* spp.) to TMV. South Ind. Hort. 14:8-12.
85. Rao, R. D. V. J. P., Chakrabarty, S. K., Rajeswari, R., and Reddy, A. S. 1987. Occurrence of tomato spotted wilt virus on cowpea (*Vigna unguiculata* (L.) Walp), chilli (*Capsicum annuum* L.) and brinjal (*Solanum melongena* L.). Indian J. Plant Protection.
86. Roff, M. N., and Ho, B. L. 1991. Maize as a barrier crop in reducing aphids, the virus vector of chilli. MARDI Res. J. 9:251-258.
87. Roff, M. M. N., and Ong, C. A. 1991. Reflective plastic mulch to reduce and delay virus disease incidences of chilli. Teknol. Sagur-Sayuran, J. 7:35-41.
88. Saelim, S. 1976. A preliminary study on tobacco mosaic virus isolated from pepper and tobacco in Thailand. M.S. Thesis, Kasetsart University, Bangkok, Thailand, 47 p. (In Thai with English abstract).
89. Seth, M. L., and Dhanraj, K. S. 1972. A new strain of tobacco leaf curl causing enations in chilli (*Capsicum annuum* L.). Phytopathol. Z. 73:365-370.
90. Sharma, O. P., Sharma, P. P., and Chowfla, S. C. 1989. Inheritance of resistance to potato virus Y in garden pepper (*Capsicum annuum* L.). Euphytica 42:31-33.
91. Sharma, O. P., and Singh, J. 1985. Reaction of different genotypes of pepper to cucumber mosaic and tobacco mosaic virus. Capsicum Newsletter 4:47.
92. Sherwood, J. L., Reddick, B. B., and Conway, K. E. 1986. Reaction of Bahamian hot pepper to single and double infection with tobacco mosaic virus (TMV) and potato virus Y (PVY). Phytopathology 76:1126 (Abst.).
93. Shivanthan, P. 1982. Epidemiology of chilli leaf curl disease in Sri Lanka. Trop. Agr. 138:99-109.
94. Shukor, N. M., Chew, B. H., Noraini, S., and Roff, M. N. M. 1989. Tomato and chilli pepper growing in Malaysia. p. 508-520. in: S. K. Green, T. D. Griggs and B. T. McLean eds. Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, R.O.C.
95. Singh, B. R., and Singh, D. R. 1976. A new strain of CMV causing mosaic of chilli at Kanpur. Indian J. Farm Sci. 4:127-129.
96. Singh, J., and Kaur, S. 1986. Present status of hot pepper breeding for multiple resistance in Punjab. p. 111-114. in: Proceedings VI European

Meeting on Genetics and Breeding on *Capsicum* and Eggplant. Zaragoza, Spain. Oct. 21-24, 1986.

97. Singh, J., and Thakur, M. R. 1977. Genetics of resistance to tobacco mosaic virus, cucumber mosaic virus and leafcurl virus in hot pepper (*Capsicum annuum* L.), p. 119-126. in: Capsicum 77, Comptes Rendus du 3e Congres EUCARPIA sur la Genetique et la Selection du Piment, 5-8 July, INRA, Avignon, Montfavet, France, 312 p.
98. Singh, J., and Thakur, M. R. 1979. Reaction of some pepper lines (*Capsicum annuum* (L) to cucumber mosaic virus. Indian Journal of Microbiology and Plant Pathology 9(2):276.
99. Singh, J. H., and Cheema, D. S. 1989. Present status of tomato and pepper production in the tropics. p. 452-471. in: S. K. Green, T. D. Griggs and B. T. McLean eds. Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March, Asian Vegetable Research and Development Center.
100. Singh, R., and Singh, A. K. 1976. Effect of tobacco leaf curl virus infection on the nitrogen content of chilli. Food, Farming and Agriculture 8:5-7.
101. Singh, S., and Chenulu, V. V. 1980. Studies on resistance to virus diseases in *Capsicum* species. I. Sources of resistance to potato virus X and Y. Indian Phytopathology 33:574-577.
102. Singh, S. J. 1989. Virus and mycoplasm diseases on vegetable crops. p. 68-75. In: Indian Horticulture. April-June 1989, January-March 1990. Vegetable Special.
103. Singh, S. J., and Sastry, K. S. M. 1976. Tomato leaf curl and its control. Indian Horticulture 21:9.
104. Singh, S. J., Sastry, K. S. M., and Sastry, K. S. 1973. Effect of oil spray on the control of tomato leaf curl virus in field. Indian J. Agrc. Sci. 43:669-672.
105. Singh, S. J., Sastry, K. S., and Sastry, K. S. M. 1979. Efficacy of different insecticides and oil in the control of leaf curl virus disease of chillies. J. Plant Dis. and Protection 86:253-256.
106. Soriano, J. M., Villareal, R. L., and Roxas, V. P. 1989. Tomato and pepper production in the Philippines. p. 549-560. in: S. K. Green, T. D. Griggs and B. T. McLean eds. Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March, Asian Vegetable Research and Development Center.
107. Su, T. H. 1982. Aphid vectors of sweet pepper viruses. Plant Protection Bull. (Taiwan, R.O.C.) 24:257-264.
108. Sugiura, M., Bandaranayake, C. M., and Hemachandra, G. H. 1975. Chilli virus diseases in Sri Lanka. Ministry of Agriculture, Forestry and Fisheries. Technical Bulletin, Tropical Agricultural Research Report 8. 62 p.

109. Sulaiman, I., and Gim, W. N. 1981. Symptomatology of TMV and chilli veinal mottle virus (CVMV) on six local chilli. Pertanika 4:10-15.
110. Sulyo, Y. 1984. Penurunan hasil beberapa varietas lombok akibat infeksi CMV di rumah kace. Laporan Hasil Penelitian Balai Penehitian Horticultura Lembang 1982/1983 BPH: 242-249.
111. Sutabutra, T., Kositratana, W., Suttipongse, U., and Saelim, S. 1985. Virus disease of tomato and chilli pepper. p. 157. in: Abstracts of Tomato Research 1987. Thailand, Committee on Research and Improvement of Vegetable Crops.
112. Tewari, V. P., and Viswanath, S. M. 1986. Breeding for multiple virus resistance in red pepper (*Capsicum annuum* L.). Capsicum Newsletter 5:49.
113. Valdez, R. B., and Dolores, L. M. 1984. Screening hot and sweet pepper accessions and cultivars for resistance to tobacco mosaic virus. 19th Annual Seminar Workshop Soc. for Adv. Veg. Ind.
114. Wongkew, S., and Sutabutra, T. 1974. Isolation of cucumber mosaic virus, the causal agent of pepper mosaic in Thailand, from the virus complex. Kasetsart Journal (Kasetsart University, Thailand) 8:1-4.
115. Yang, C. Y., Zhu, T. W., and Lee, S. D. 1989. Production and utilization of pepper and tomato in Taiwan, China. p. 416-421. in: S. K. Green, T. D. Griggs and B. T. McLean eds. Tomato and Pepper Production in the Tropics. Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, ROC.
116. Yap, T. H., and Ng, K. Y. 1986. Influence of pesticides on the incidence of virus disease and leaf curl symptoms in chilli (*Capsicum annuum*) in Malaysia. p. 154. in: 2nd International Conference on Plant Protection in the Tropics. Serdang, Selangor, Malaysia. 17-20 March 1986. Universiti Pertanian Malaysia. 413 p.
117. Yoon, J. Y., Green, S. K., Tschanz, A. T., Tsou, S. C. S., and Chang, L. C. 1989. Pepper improvement for the tropics: Problems and the AVRDC approach. p. 86-88. in: S. K. Green, T. D. Griggs and B. T. McLean (eds.). Tomato and Pepper Production in the Tropics. Proceedings of the International Symposium on Integrated Management Practices. Tainan, 21-26 March, Asian Vegetable Research and Development Center. Shanhua, Tainan, Taiwan, ROC.

摘　要

Sylvia K. Green. 1993. 台灣及其他亞洲國家辣椒病毒之研究. (台南縣善化鎮　亞洲蔬菜研究發展中心).

病毒病害是辣椒經濟生產上的主要限制因子，造成的產量損失可達60～100％。已知有35種病毒可感染辣椒，在亞洲，最重要的病毒包括cucumber mosaic virus (CMV)，chilli veinal mottle virus (CVMV)，potato virus Y (PVY)，tobacco mosaic virus (TMV)，tomato mosaic virus (ToMV)，及pepper mild mottle virus (PMMV)。較次要的病毒包括broad bean wilt virus (BBWV)，alfalfa mosaic virus (ALMV)及potato virus X (PVX)。其他如tobacco etch virus (TEV)，tobacco rattle virus (TRV)，tomato spotted wilt virus (TSWV)及pepper mottle virus (PeMV)也曾被報告，但需進一步確認。多數的亞洲國家都曾進行廣泛的病毒調查及病毒特性之研究，然而僅少數的國家如日本、韓國、馬來西亞、台灣及印度有抗病毒育種的工作。替代性的防治方法諸如栽培管理及生物方法，也在印尼、印度、台灣、韓國及馬來西亞進行。抗病篩選的工作在所有的國家均進行，且適當的抗病性來源已被選出。

亞洲蔬菜研究發展中心辣椒多元性育種計劃，最近補充了一項AVNET辣椒病毒次研究網，此研究網的目標是確認鑑定區域內(包括泰國、馬來西亞、印尼、菲律賓)最重要的病毒，並將已被國家農業研究系統鑑定的抗病品系種植於不同地點，以篩選田間耐病或抗病性之品系。在SAVERNET (South Asian Vegetable Research Network)研究網有六個國家(巴基斯坦、印度、斯里蘭卡、尼泊爾、孟加拉、布丹)共同合作鑑定造成辣椒捲葉病的病毒及發展防治方法。

關鍵字：辣椒、病毒病害、抗病篩選、辣椒病毒研究網路。