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Viruses of Legume Crops in Taiwan

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ABSTRACT

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Legume crops of economic importance in Taiwan include peanut, vegetable soybean, soybean, adzuki bean, pea, kidney bean, mungbean, and common bean. Nine different viruses have been detected from these crops. They are bean common mosaic virus (BCMV), blackeye cowpea mosaic virus (BlCMV), cowpea aphid-borne mosaic virus (CAMV), cucumber mosaic virus (CMV), mungbean yellow mottle virus (MYMV), peanut mottle virus (PMoV), pea seed-borne mosaic virus (PSBMV), peanut stripe virus (PStV) and soybean mosaic virus (SMV). In Adzuki beans, BCMV, PStV, BlCMV, and CMV were isolated in 1990, with BlCMV being the most prevelent one. Three viruses including BlCMV, CMV and CAMV were detected from asparagus beans in 1983. Mixed infection of this bean with BlCMV and CMV resulting a severe "rugose mosaic" disease, was frequently found. In common beans, CMV is the only virus isolated up to now. Three different viruses namely BlCMV, PStV, and CMV were detected from mungbeans in 1986. PSBMV was first isolated from pea in 1989 and has become the most widespread virus in pea fields ever since. Two other viruses attacking peas are CMV and PMoV. PMoV was first documented in Taiwan early in 1978 as a causal agent of peanut mottle disease. Recently PStV was also found in peanut fields to induce severe mosaic, stunt and necrosis symptoms. In soybeans, SMV, PStV and PMoV were detected. Among the nine legume viruses, CMV belongs to cucumovirus group, MYMV is a geminivirus while others are all potyviruses. Properties including mode of transmission, differential host systems, serological properties of capsid proteins and cylindrical inclusion proteins of these legume viruses have been established. These information are useful for virus disease diagnosis. Most of these legume viruses have been reported to be seed-borne. Except MYMV which is transmitted persistently by whiteflies, all eight other viruses are transmissible mechanically and by aphids with non-persistent manner. Virus-infected seeds are believed to be the major primary inoculum sources of legume viruses in the fields. Epidemics of legume virus diseases usually occurs through the assistance of insect transmission.

Key words: legume crops, legume viruses, virus.

INTRODUCTION

Legume crops are consumed either as fresh vegetables or as food in Taiwan (33). They provide both human beings and animals with good sources of plant proteins. With the capability of nitrogen fixation in root system, through the symbiosis with rizobiums, legume crops also contribute to the improvement of soil fertilities (33). In Taiwan, more than 10 different legumes are grown but in terms of planting acreage the leading ones are: peanut, vegetable soybean, adzuki bean, pea, soybean, kidney bean, common bean and mungbean (2). The total acreage for these legumes was around 68,445 hectares in 1991 which covered about 7.74% of the total farming land acreage on the island (Fig. 1)(2). Production of legumes is not only vital for local consumptions but also important as food sources for people of nearby countries, because parts of the production are exported (4,33). As a subtropical island, the environment of Taiwan all year round greatly contribute to the continuous presence of insects in the fields. Therefore, virus diseases, especially those transmitted by insect vectors, have become a constant threat to the production of many important crops including legumes (11). This report summarizes the information accumulated, in the last 30 years in Taiwan, about virus diseases of legume crops. It is to serve as a easy reference for those who may be interested in this area, to grasp instantly what has been done and what is needed for further study about legume viruses occurring

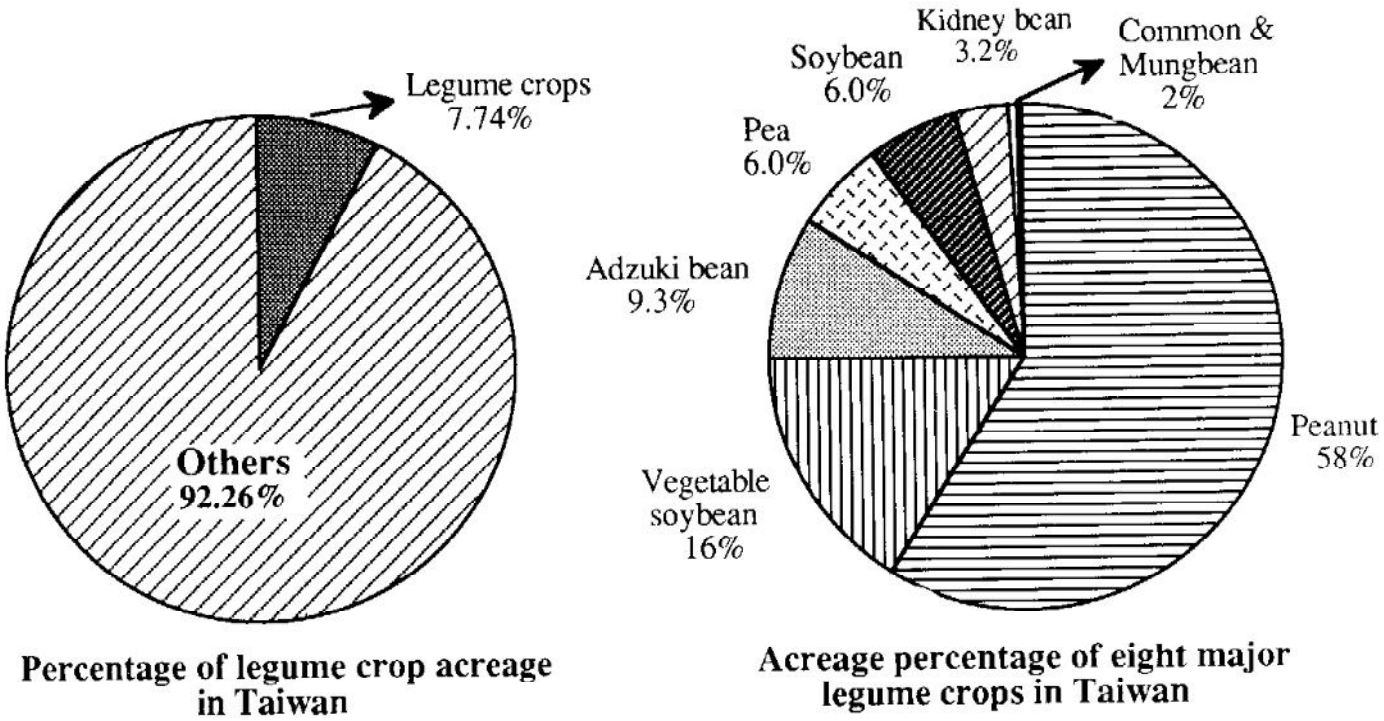

Fig. 1. Pie charts showing the percentage in planting area of legume crops (Left) and the percentage of eight major legume crops (Right) grown in Taiwan. Data are based on the 1992 edition of Taiwan Agricultural Yearbook.

in Taiwan. It is also hoped that a better understanding of these viruses will lead to their effective control in the near future.

VIRUSES OCCURRING ON LEGUME CROPS IN TAIWAN

Adzuki bean (*Vigna angularis* (Willd.) Ohwi & Ohasi)

In 1980, a virus isolate, designated as peanut mosaic virus (7,8), was detected in adzuki bean in Pintung area (Table 1). The virus was later found to be a severe strain of peanut stripe virus (19). In 1987, Hseu et al. detected a virus isolate from adzuki bean which is similar in serological and biological properties to bean common mosaic virus (BCMV)(32). Actually, this was the first time for the detection of BCMV in Taiwan (Table 1). In 1990, we conducted a large-scale survey on adzuki bean again in Pintung area and detected cucumber mosaic virus (CMV) and blackeye cowpea mosaic virus (BlCMV)(Table 1)(14). In this survey, about 80% of diseased samples collected were identified to be isolates of BlCMV. These isolates were found serologically indistinguishable, though there were biological differences to serve as criteria to differentiate them into three strains. Adzuki bean infected by CMV usually first appeared with severe vein necrosis but the symptoms gradually became masked, with only leaf mottling afterward(14). BCMV, BlCMV and PStV all induced similar type of mosaic or vein-banding symptoms (14). Symptomatology alone is not a reliable basis for identifying the causal virus on adzuki bean.

Asparagus bean (*V. unguiculata* (L.) Walp. ssp. *sesquipedalis* (L.) Verdc.)

Asparagus bean is the most seriously virus-affected legume crop nowadays in Taiwan. Fields with almost 100% infection at the end of harvest season are rather common in the major production area such as Pintung and Changhwa. A cultivar of asparagus bean, "Kaoshiung green pod", which has very good horticultural properties, was the most popular cultivar in Taiwan about three years ago. However, because of its high susceptibility to virus diseases, farmers have gradually abandoned and replaced it with a cultivar more tolerant to virus diseases but with lower horticultural properties. There were three viruses, namely BlCMV, CMV and cowpea aphid-borne mosaic virus (CAMV), detected in asparagus bean in 1983 (Table 1)(9,16). BlCMV induced vein-banding or mosaic symptoms on asparagus bean and CMV induced only very mild mottling symptoms (9). These two viruses caused only minor damages on asparagus bean when they infected the host singly. However, when mixed infection occurred, a synergistic effect resulted (9). The concentration of both viruses increased

TABLE 1. Viruses occurring in several major legume crops in Taiwan

Legume crops	Virus	Citation No.
Adzuki bean	Peanut stripe virus (PStV)	(7,8,19)
	Bean common mosaic virus (BCMV)	(32)
	Blackeye cowpea mosaic virus (BlCMV)	(14)
	Cucumber mosaic virus (CMV)	(14)
Asparagus bean	Blackeye cowpea mosaic virus (BlCMV)	(9)
	Cowpea aphid-borne mosaic virus (CAMV)	(16)
	Cucumber mosaic virus (CMV)	(9)
Common bean	Cucumber mosaic virus (CMV)	(11)
Mungbean	Blackeye cowpea mosaic virus (BlCMV)	(29)
	Peanut stripe virus (PStV)	(29)
	Cucumber mosaic virus (CMV)	(29)
	Mungbean yellow mottle virus (MYMV)	(2)
Pea	Pea seed-borne mosaic virus (PSBMV)	(12)
	Peanut mottle virus (PMoV)	(13)
	Cucumber mosaic virus (CMV)	(11)
Peanut	Peanut stripe virus (PStV)	(10,19,28)
	Peanut mottle virus (PMoV)	(13,44)
Soybean	Soybean mosaic virus (SMV)	(38)
	Peanut stripe virus (PStV)	(28)
	Peanut mottle virus (PMoV)	(3)

tremendously within a week. The symptoms developed on the leaves became severe rugose mosaic and the bean pod became malformed. Because the concentration of both viruses increased in the infected plant, the possibilities of either virus being transmitted by aphids also increased (9). Consequently, the disease spreaded more quickly and an epidemic usually occurred.

CAMV isolated in 1983 induced severe mosaic symptoms on asparagus bean (16). Usually, CAMV-infected leaves developed necrotic areas. This was in contrast to BlCMV whose symptoms were often milder. Unlike BlCMV, CAMV by itself is able to induce severe damages on asparagus bean (16). Interestingly, the virus had not been detected again from the field since 1983.

Common bean (*Phaseolus vulgaris* L.)

In Taiwan, vine type cultivars are the major common bean cultivated. CMV is the only virus ever found from this crop (Table 1)(11). Interestingly, BCMV which is the most prevalent virus in common bean in other countries (37), has not been detected from this crop grown in Taiwan. The vine typed common beans which usually carries resistant genes against BCMV is exclusively grown in Taiwan. This might explain this odd situation. Depending the strain variation, some CMV strains induced severe chlorosis and rugose symptoms especially on newly developing leaves, while others induced mild mottle or mosaic symptoms (Chang, unpublished). In the major common bean growing area such as Pintung county, incidence of CMV is not high, while in some other counties, such as in Nantou, CMV infection on common bean is more frequent.

Mungbean (*Vigna radiata* (L.) Wilczek)

The Asian Vegetable Research and Development Center (AVRDC) reported in 1974 that a geminivirus designated as mungbean yellow mottle virus (MYMV) was detected in their experiment fields in Shanhua (Table 1)(3). The virus was not transmissible by mechanical means, instead it could be transmitted by whiteflies with persistent manner. A large scaled virus survey conducted by AVRDC in 1986 detected BlCMV, PStV and CMV on mungbeans (Table 1)(29). However, virus diseases are not considered as a limiting factor for mungbean production in Taiwan.

Pea (*Pisum sativum* L.)

At least three viruses have been detected from pea field (Table 1). They are pea seed-borne mosaic virus (PSbMV)(12), peanut mottle virus (PMoV)(13) and CMV (11). PSBMV is currently the most widely spread virus in pea fields (11). During a regular survey conducted in 1990 we noticed that many pea fields in

TABLE 2. Some properties of legume viruses occurring in Taiwan

Virus[1]	Taxonomic Goup[2]	Vector	Mode of Transmission[3]	Host found[4]	Seed-borne
BCMV	Poty-	Aphid	NPt	Ad	+[5]
BlCMV	Poty-	Aphid	NPt	Ad, As, M	+
CAMV	Poty-	Aphid	NPt	As	+
CMV	Cucumo-	Aphid	NPt	Ad, As, C, M, Pe	+
MYMV	Gemini-	Whitefly	Pt	M	+
PMoV	Poty-	Aphid	NPt	Pe, Pn	+
PSBMV	Poty-	Aphid	NPt	Pe	+
PStV	Poty-	Aphid	NPt	Ad, M, Pn, S	+
SMV	Poty-	Aphid	NPt	S	+

[1] BCMV = bean common mosaic virus; BlCMV = blackeye cowpea mosaic virus; CAMV = cowpea aphid-borne mosaic virus; CMV = cucumber mosaic virus; MYMV = mungbean yellow mottle virus; PMoV = peanut mottle virus; PSBMV = pea seed-borne mosaic virus; PStV = peanut stripe virus; SMV = soybean mosaic virus.

[2] Poty- = potyvirus group; Cucumo- = cucumovirus group.

[3] NPt = Non-persistent type transmission; Pt = Persitent type transmission.

[4] Ad = Adzuki bean; As = Asparagus bean; B = Broad bean; C = Common bean; M = Mungbean; Pe = Pea; Pn = Peanut; S = Soybean.

[5] + = Virus is transmissible through seeds from infected plant.

Changhwa county were nearly 100% infected by PSBMV at the end of harvest season. The first isolate of PSBMV, Ps8, we obtained induced mild mottling symptom on pea cultivar "Taichung No. 11"(12). However, we have recently found some PSBMV isolates which induced mosaic and downward leaf curling symptoms on the same cultivar.

PMoV was isolated from Changhwa area in 1989 (13). Three isolates were isolated from the field and they were found serologically and biologically indistinguishable to PMoV isolate from the USA. This is the first envidence that PMoV naturally occurring in pea fields. In the literature, PMoV was only considered to infect pea under experimental conditions (30). The three PMoV isolates all induced very mild mottling symptom on Taichung No. 11 pea cultivar.

A diseased sample with severe rugose mosaic symptoms was obtained from a survey conducted in 1991. The symptoms were later found to be associating consistently with dual infection of CMV and PSBMV (Chang, unpublised). Mild mottling symptoms were obtained when both viruses were inoculated on pea alone, suggesting that synergistic effect of CMV and PSBMV, similar to those induced by BlCMV and CMV on asparagus beans, also occurred on peas. Based on ELISA results, concentration of both viruses in the doubly infected plants were much higher than those in the plants infected by each individual virus (Chang, unpublished).

Peanut (*Arachis hypogaea* L.)

PMoV was the first virus reported to infect peanut in Taiwan (Table 1)(44). The virus caused only mild mottling foliar symptoms. The growth vigor of infected plant usually was not significantly affected (6). In 1979, a virus isolate causing severe mosaic, stunt, and necrosis symptoms which were different from those induced by PMoV was detected from Pintung area. The virus was designated as peanut mosaic virus at that time (7,8). However, it was later found to be synonymous to peanut stripe virus (PStV) reported by Demski et al. (Table 1)(10). Because the isolate induced a lot more severe symptoms on peanut than those induced by other known PStV isolates, it was thus designated as Taiwan severe strain of PStV (PStV-Ts)(19). Unlike the situation in most peanut growing countries, peanut virus diseases in Taiwan were considered of minor importance to peanut productions.

Soybean (*Glycine max* (L.) Merr.)

Although there have been three viruses detected from soybean fields in Taiwan (Table 1), soybean production is generally not affected by virus diseases however. Soybean mosaic virus (SMV) was first detected in soybean in 1959 (38). It induced mosaic or vein-banding symptoms on the soybean leaves. PStV was isolated from soybean in 1986 (28). The virus induced necrosis or mosaic symptoms which were usually more severe than those induced by SMV (28). PMoV causing mild mottling symptom on soybean was detected by Green et al. in 1986 (3).

CHARACTERISTICS OF LEGUME VIRUSES

Virus particle morphology

As indicated in Table 2, of the nine viruses found in legume crops in Taiwan, seven are potyviruses, CMV

TABLE 3. Cytological properties of legume viruses in Taiwan

Virus[2]	Type of Inclusion[1]			
	NI	CI	AI	C
BCMV	—[3]	Granular	—	—
BlCMV	—	Bundle	—	—
BYMV	+	Granular	—	+
PMoV	+	Granular	—	—
PSbMV	—	Granular	+*	—
PStV	—	Granular	—	—
SMV	—	Granular	—	—
CMV	—	—	—	+*
MYMV	+*	—	—	—

[1] NI=nuclear inclusion; CI=cylindrical inclusion; AI=amorphous inclusion; C=cristalline inclusion.

[2] BCMV=bean common mosaic virus; BlCMV=blackeye cowpea mosaic virus; BYMV=bean yellow mosaic virus; PMoV=peanut mottle virus; PSbMV=pea seed-borne mosaic virus; PStV=peanut stripe virus; SMV=soybean mosaic virus; CMV=cucumber mosaic virus; MYMV=mungbean yellow mosaic virus.

[3] +=inclusion detected by light microscopy, those followed with * are inclusions which could be stained by both Calcomine orange and green stain mixture and Azure A, whereas those followed without * are inclusions which could only be stained by Calcomine orange and green stain mixture; —=inclusion not found.

is belonging to cucumovirus group and MYMV is a geminivirus. By electronmicroscopic observation, the potyviruses with elongated particles can be readily distinguished from CMV and MYMV whose particles are isometric and gemini-like, respectively.

Transmission

MYMV, a geminivirus, is unique among the nine legume viruses found in Taiwan in the capabilities of being transmitted by whiteflies with persistent manner (2). The other viruses including CMV and potyviruses are all transmissible by aphids non-persistently (Table 2) (26,27).

Inclusion bodies

Light microscopy techniques developed by Cristie and Edwardson in 1977 to observe virus-induced inclusion bodies in infected cells were found very useful as an alternative to identify viruses within a short period of time (27). Table 3 lists specific types of inclusion as observed by light microscope in the infected tissues for the nine legume viruses. Some of the viruses are known to induce distinct inclusions which can be used to distinguish them from the other viruses. For example, geminiviruses are known to induce nuclear inclusions which can be stained by Azure A (20). Although MYMV has not been reported to induce nuclear inclusions but the possibility for the virus having this property is high. No other legume viruses found so far in Taiwan has the same properties. Azure A stainable crystalline inclusions in cytoplasm are also frequently applied for the identification of CMV infection (26). BYMV-induced nuclear inclusions which are not stainable by Azure A have been recognized as a unique property for distinguishing BYMV from other potyviruses (15).

TABLE 4. A list of differential host and their reactions to eight different legume viruses found in Taiwan

Host species	Legume viruses[1]							
	BYMV	BCMV	BlCMV	PStV	PMoV	CAMV	SMV	PSBMV
Adzuki bean	—[2]	+	+	+	+	+	—	—
Asparagus bean	—	—	+	+	—	+	—	—
Black bean	—	+	+	+	+	+	—	—
Common bean								
(cv. Dubbele Witte)	—	+	+	—	+	?	—	—
(cv. SGR)	+	+	+	+	+	?	+	—
Cowpea	—	—	+	+	—	+	—	—
Pea	+	—	—	—	+	+	+	+
Peanut	—	—	—	+	+	—	—	—
Soybean	—	—	+	+	+	—	+	—

[1] BYMV=bean yellow mosaic virus; BCMV=bean common mosaic virus; BlCMV=blackeye cowpea mosaic virus; PStV=peanut stripe virus; PMoV=peanut mottle virus; CAMV=cowpea aphid-borne mosaic virus; SMV=soybean mosaic virus; PSBMV=pea seed-borne mosaic virus. Note that mungbean yellow mottle virus is not on the list due to its inability to be mechanically transmissible.

[2] +=infection occurred; —=no infection; ?=information not available.

TABLE 5. Summary of antigenic relationships between capsid proteins of some legume viruses occurring in Taiwan as determined in SDS-immunodiffusion tests[1]

Antiserum to	Cross-reactivities to SDS-treated antigens of [2,3]								
	BYMV	BCMV	BlCMV	CAMV	PMoV	PStV	PSBMV	SMV	CMV
BYMV	I	—	—	—	—	—	—	—	—
BCMV	—	I	S	S	—	S	—	S	—
BlCMV	—	S	I	S	—	S	S	S	—
CAMV	—	S	S	I	—	S	—	—	—
PStV	—	S	S	S	—	I	—	S	—
PMoV	—	—	—	—	I	S	—	S	—
PSBMV	—	—	—	—	—	—	I	—	—
SMV	—	—	—	—	—	—	—	I	—
CMV	—	—	—	—	—	—	—	—	I

[1] SDS-immunodiffusion test was done as described by Purcifull and Batchelor (39). Serological data of mungbean yellow mottle virus is not on the list because its antiserum is not available.

[2] BYMV = bean yellow mosaic virus; BCMV = bean common mosaic virus; BlCMV = blackeye cowpea mosaic virus; CAMV = cowpea aphid-borne mosaic virus; PMoV = peanut mottle virus; PStV = peanut stripe virus; PSBMV = pea seed-borne mosaic virus; SMV = soybean mosaic virus; CMV = cucumber mosaic virus.

[3] Results of cross-reactivities were indicated as the reactions between homologous and heterologous antigens; I = identical to antigen homologous to the antiserum used; S = cross-reacted with the antiserum used, but spur reaction was observed between precipitation lines of homologous and heterologous antigens; — = no cross-reactivity.

Host reactions and range

It is acceptable that different viruses will induce different response on the same host that can be used as a criterion for virus diagnosis (26,27). Table 4 shows a differential host system developed in my laboratory since 1980. Based on the infectivities on this set of host, the identities of viruses under study can be primarily determined. However, we emphasize that host reactions could be variable among isolates of a same virus. The variations might also be amplified by different experimental conditions. Consequently, the host reaction results should be carefully explained before making final conclusion. To deal with this problem, other properties should also be considered as alternative criteria for virus identification.

Serological properties

I have determined the serological relationships among the different legume viruses, exclusive of MYMV, found in Taiwan by SDS-immunodiffusion tests (Table 5). In general, the identities of virus under study could be readily recognized on the basis of this information. Sometimes, different virus isolates collected from different areas or hosts might have serological variations as well. For example, isolates of bean yellow mosaic virus (BYMV) usually are variable among their capsid protein (CP) antigenicities, therefore, it is difficult to judge whether they are isolates of the same virus or they represent completely different viruses if only CP antigenicity was considered (18). To solve this problem, I develop another basic information on the serological properties of viral inclusion proteins such as cylindrical inclusion protein (CIP) and nuclear inclusion protein (NIP)(15). Table 6 shows the antigenic relationships among nine different legume viruses based on their cross-reactivities with six different antisera against inclusion proteins. We have found this information very useful as an alternative criterium for legume virus identification as reported by others (11,39,40,45).

Physical and Chemical properties

Table 7 summarizes some of the physical and chemical properties of the legume viruses found in Taiwan. Most of the information is derived from the excellent review paper of Edwardson and Christie (27), while the remaining part is based on the auther's published results. These properties, especially the types and molecular weights of viral proteins, are useful alternative criteria for identification of legume viruses. However, it should be noticed that variation among isolates of the same virus might be greater than those between different viruses, thus resulting equivocal differentiation. Therefore, as many as properties should be taken into consideration when precise virus identification is pursued.

TABLE 6. Summary of antigenic relationships among some legume viruses occurring in Taiwan as determined by antisera against inclusion proteins in SDS-immunodiffusion tests[1]

	Cross-reactivities to SDS-treated antigens of [2,3]								
Antiserum	BYMV	BCMV	BlCMV	CAMV	PMoV	PStV	PSBMV	SMV	CMV
PStV-CIP	—	I	I	?	—	I	—	S	—
BlCMV-CIP	—	I	I	?	—	I	—	S	—
BCMV-CIP	—	I	I	?	—	I	—	S	—
BYMV-CIP	I	—	—	?	—	—	—	—	—
BYMV-NIP	I	—	—	S	S	—	—	—	—
CYVV-NIP	S	—	—	S	S	—	—	—	—

[1] SDS-immunodiffusion test was done as described by Purcifull and Batchelor (39).

[2] BYMV = bean yellow mosaic virus; BCMV = bean common mosaic virus; BlCMV = blackeye cowpea mosaic virus; CAMV = cowpea aphid-borne mosaic virus; PMoV = peanut mottle virus; PStV = peanut stripe virus; PSBMV = pea seed-borne mosaic virus; SMV = soybean mosaic virus; CMV = cucumber mosaic virus; CIP = cylindrical inclusion protein; NIP = nuclear inclusion protein.

[3] Results of cross-reactivities were indicated as the reactions between homologous and heterologous antigens; I = identical to antigen homologous to the antiserum used; S = cross-reacted with the antiserum used, but spur reaction was observed between precipitation lines of homologous and heterologous antigens; — = no cross-reactivity; ? = data not available.

TABLE 7. Some chemical and physical properties of legume potyviruses found in Taiwan

		Sedimentation coeficient (S)		Molecular weights				Optical density	Buoyant density	Citations for[2] those with *
				RNA	Viral Proteins (Kd)					
Viruses[1]	RNA%	RNA	Virus	(x 10^6)	CP	CIP	NIP	(A_{260}/A_{280})		
BCMV	5.5-6		154		33			1.2-1.37		
BlCMV		38.41	150-159	2.9	34			1.20		
BYMV	5.5-6		140-166	3.0	28-35	73*	54,49*	1.24	1.318	(15)
PMoV	5.5-6		151	3.1	34			1.21-1.29		
PSBMV	5.3		148-154		29*,34	74*		1.14-1.25		(12)
PStV				3.1	36*	71*		1.23		(19)
SMV	5.3	39.7		3.18	33			1.7		

[1] BCMV = bean common mosaic virus; BlCMV = blackeye cowpea mosaic virus; BYMV = bean yellow mosaic virus; PMoV = peanut mottle virus; PSBMV = pea seed-borne mosaic virus; PStV = peanut stripe virus; SMV = soybean mosaic virus.

[2] Data are mainly based on the review paper of Edwardson and Christie (27), some are from the author's publications as indicated with *.

Ecology and transmission of legume viruses in the field

Besides MYMV, the legume viruses found in Taiwan have been documented as transmissible through seeds of the infected plant (Table 8). Table 8 outlines seed transmission percentages of some legume crops when infected by the nine different legume viruses. These datas were partially obtained in the anthor's laboratory and partially from others. Among the legume crops grown currently in Taiwan, asparagus beans and peas are threatened the most by virus diseases. This is closely related to the relatively high seed transmission percentages of BlCMV and PSBMV in these two crops (11). During a consecutive two year extensive field surveys conducted in 1988 and 1989 on asparagus beans in Taiwan (17), it was found that CMV incidence was variable, but that of BlCMV was consistently high year after year. Higher incidence of CMV in 1989 than in 1988 was correlated with the unusually high aphid population because of the long period of drought in 1989. On the contrary, irrespective of the aphid population fluctuation, BlCMV was always over 90% of incidence every year. We considered, this had resulted from the primary inoculum of BlCMV through seed transmission to consistently exist in

TABLE 8. Seed transmission percentage of some legume viruses occurring in Taiwan

Virus[1]	Host	Percentage (%) of seed transmission	Citation No.
BCMV	Common bean	0-93	(26)
BlCMV	Cowpea	1.2-30.9	(26)
	Asparagus bean	1-12.4	Chang (unpublished)
BYMV	Common bean	7	(21)
CAMV	Cowpea	1.2-30.9	(35)
	Asparagus bean	4.7	(16)
CMV	Common bean	1-30	(36)
	Asparagus bean	4-28	(1)
	Mungbean	11	(34)
MYMV	Mungbean	+[2]	(2)
PMoV	Peanu	0.02-2.0	(6)
PSBMV	Pea	30-90	(31)
	Pea (Taichung No.11)	25.4	Chang (unpublished)
PStV	Peanut	2-37	(23)
	Peanut	12.5	(19)
SMV	Soybean	0-64	(26)

[1] BCMV = bean common mosaic virus; BlCMV = blackeye cowpea mosaic virus; BYMV = bean yellow mosaic virus; CAMV = cowpea aphid-borne mosaic virus; CMV = cucumber mosaic virus; MYMV = mungbean yellow mottle virus; PMoV = peanut mottle virus; PSBMV – pea seed-borne mosaic virus; PStV = peanut stripe virus; SMV = soybean mosaic virus.

[2] Seed transmission was confirmed but no definitive percentage data shown.

asparagus bean fields at the very beginning of growing season. Therefore, only a low density of aphid population was enough to build up an eventually high BlCMV incidence. On the other hand, the seed transmission rate of CMV in asparagus beans was much lower than BlCMV (Chang, unpublished), so that the primary CMV inoculum in asparagus bean fields was mainly from other hosts through aphid transmission. This was possibly why CMV incidence in asparagus beans was dependent mostly on aphid population fluctuations.

Similar situation was recently found in pea. A currently most popular pea cultivar, 'Taichung No. 11', is now having trouble with the high seed transmission of PSBMV. Up to 25.4% of seed transmission was detected (11), which means one out of four seedlings emerging out of soil are already PSBMV-infected. Under this circumstance, with some help from aphids a whole crop could be easily 100% infected within a short period of time.

Importing legume seeds from other countries for direct planting or for germplasms collections are important possible routes of bringing in new seed-borne viruses. There have been reports on the outbreaks of new viruses through infected seeds introduced from other countries (23,24). To our knowledge, this type of transmission is extremely difficult to prevent. More sensitive, reliable and, most importantly, feasible techniques are not available now to intercept seed-borne viruses before they become established in a new geographical area.

Together with seed transmission, aphid transmission is also an important route for the establishment of legume viruses in the fields. Table 9 lists the aphid species which have been found in Taiwan (41) and their transmissibility for nine legume viruses as reviewed by Edwardson and Christie (26). Among the 12 species listed, only *Myzus persicae* Sulze. has been confirmed in Taiwan, capable of transmitting legume viruses (9,13,16,19). Capabilities of the other aphid species to transmit legume viruses remain to be determined. On the other hand, only very limited information dealing with time course study of population fluctuation and general ecology of aphids was accumulated in Taiwan (43). This type of information is necessary for generating successful control recommandations against virus diseases.

CONCLUDING REMARKS

Legumes are important sources of plant proteins. Although virus diseases have not been a limiting factor for most of the legume crops grown in Taiwan, except for asparagus bean and pea (11). However, due to the seed-borne and aphid-transmitting properties, it is possible that legume virus diseases may gradually become more widely disseminated in the future years. The lacking of seed certification and virus-free seed

TABLE 9. Aphid species documented in Taiwan which have been confirmed capable of transmitting legume viruses occurring in Taiwan

Aphid species[1]	Legume viruses occurring in Taiwan[2]								
	BYMV	BCMV	BlCMV	CAMV	PMoV	PStV	PSBMV	SMV	CMV
Acyrthosiphon pisum	+[3]	+	?	+	?	?	+	+	+
Aphis craccivora	+	+	?	+	+	+	+	+	+
A. glycines	?	?	?	?	?	?	?	?	?
A. gossypii	+	+	+	+	+	?	?	+	+
A. pomi	?	+	?	?	?	?	?	?	+
Brevicoryne brassicae	+	+	?	?	?	?	?	?	+
Lipaphis erysimi	?	?	?	?	?	?	?	?	+
Myzus persicae	+	+	+	+	+	+	+	+	+
Rhopalosiphum maidis	+	?	?	?	?	?	?	+	+
R. padi	?	+	?	?	+	?	+	+	+

[1] Aphid species found in Taiwan as described by Tao (41).

[2] BYMV = bean yellow mosaic virus; BCMV = bean common mosaic virus; BlCMV = blackeye cowpea mosaic virus; CAMV = cowpea aphid-borne mosaic virus; PMoV = peanut mottle virus; PStV = peanut stripe virus; PSBMV = pea seed-borne mosaic virus; SMV = soybean mosaic virus; CMV = cucumber mosaic virus. Note that mungbean yellow mottle virus is not on the list due to its inability to be transmitted by aphid.

[3] + = virus is transmissible by the aphid species as reviewed by Edwardson and Christie (26). ? = transmissibility uncertain.

production programs for legume crops in Taiwan will undoubtedly worsen the situation. Until someday when the percentage of seed transmission reaches a certain level, the damage of virus will become evident enough to the farmers. Unfortunately, the situation then is usually too difficult to be dealt with. This is actually what has been happening with asparagus bean production during the last 10 years in Taiwan. Therefore, we strongly suggest that seed certification and virus-free seed production programs should be established for all legume crops as early as possible before virus diseases become limiting factors for crop production. With seed certification program normally functioning, only those legume seeds with virus transmission percentage lower than the allowable one can be imported or sold locally. Seeds introduced for germplasm collection purposes have to go through required quarantine procedures before being put into field trials. For those legumes already having high seed transmission percentage, virus-free seed production program should be enforced as soon as possible in order to rescue the cultivar and restore its productivities. A virus-free seed production program was established in 1990 to restore productivities of asparagus beans in Taiwan (17). Growing virus-free seeds thus obtained resulted in a delay of virus epidemic and an increase of bean production (17). Extension workers should take the responsibilities of teaching and convincing farmers not to collect legume seeds by themselves for next crops as they used to, instead seeds should only be bought from reliable seed companies who produce seeds of various crops under strict seed certification programs.

The establishment of seed certification programs requires sensitive and feasible techniques for indexing viruses in seeds. Most techniques applied currently involve immuno-procedures using polyclonal and/or monoclonal antibodies (22,25). Whether these procedures are applicable for all types of legume seeds are not known and require further confirmation. Another technique using complementary DNA as probes to detect seed-borne viruses, which is more sensitive than the conventional immuno-procedures, has been developed (5). However, whether it can be applied in a daily and large-scaled seed indexing program remains further studied.

As reviewed in this report, most of the basic information about legume viruses occurring in Taiwan has been available. Nevertheless, there are still some aspects need further investigation. These include aphid species capable of transmitting legume viruses, ecology of vector aphids, seed transmission percentage of each cultivar of the major legume crops when infected by individual legume viruses, and incidences of viruses on some minor legume crops such as kidney bean, broad bean and lima bean.

Screening and breeding for resistance have been shown to be a most effective measure to control legume viruses (26). This type of work, however, is not of interest to the breeders in private seed companies in Taiwan who are emphasizing, for commercial reasons, their breeding works mainly on cross-pollination crops.

The Asian Vegetable Research and Development Center is the one actively involved in virus resistance screening of mungbean and soybean germplasms. The Taiwan Agricultural Research Institute (TARI) is also currently conducting a program to breed for resistance against asparagus bean viruses. Since there are so many other important legume crops in Taiwan, more other institutes or experiment stations should be involved in this area of research.

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LITERATURE CITED

1. Anderson, C. W. 1957. Seed transmission of three viruses in cowpea. Phytopathology 47:515.
2. Anon. 1974. Annual Report 1974. Asian Vegetable Research and Development Center, Shanhua, Taiwan, R.O.C. 142 pp.
3. Anon. 1988. Progress Report 1986. Asian Vegetable Research and Development Center, Shanhua, Taiwan, R.O.C. 540 pp.
4. Anon. 1992. Taiwan Agricultural Yearbook 1992. Department of Agriculture and Forestry, Taiwan Provincial Government, Wu-Feng, Taichung, Taiwan, ROC. 1992, 396 pp.
5. Bijaisoradat, M., and Kuhn, C. W. 1988. Detection of two viruses in peanut seeds by complementary DNA hybridization tests. Plant Dis. 72:956-959.
6. Bock, K. R., and Kuhn, C. W. 1975. Peanut mottle virus. C.M.I./A.A.B. Description of Plant Viruses. No. 141, 4 pp.
7. Chang, C. A. 1980. An unrecognized virus occurring in peanut and adzuki bean. Plant Prot. Bull. 22:426-427. (Abstract, in Chinese)
8. Chang, C. A. 1980. Purificaiton of peanut mosaic virus, a newly recognized virus in peanut. Plant Prot. Bull. 22:426. (Abstract)
9. Chang, C. A. 1983. Rugose mosaic of asparagus bean caused by dual infection with cucumber mosaic virus and blackeye cowpea mosaic virus. Plant Prot. Bull. 25:177-190.
10. Chang, C. A. 1987. Antigenic comparison of two strains of peanut stripe virus originally recognmized as peanut mosaic virus in Taiwan. Plant Prot. Bull. 29:439. (Abstract)
11. Chang, C. A. 1991. Virus diseases and their vectors of legume crops in Taiwan. Pages 99-110 *in* Integrated Control of Plant Virus Diseases. 1991 FFTC Supplement No. 1, 156 pp.
12. Chang, C. A., Chen, C. M., Chen, H. C., Deng, T. C., and Huang, C. H. 1989. Pea seed-borne mosaic virus causing pea mottling in Taiwan. Plant Prot. Bull. 31:366-376.
13. Chang, C. A., and Chen, H. C. 1989. Isolation of peanut mottle virus naturally occurring in pea field. Plant Prot. Bull. 31:410. (Abstract)
14. Chang, C. A., and Chen, H. C. 1990. Survey and identification of adzuki bean viruses occurring in southern Taiwan. Plant Prot. Bull. 32:331. (Abstract)
15. Chang, C. A., Hiebert, E., and Purcifull, D. E. 1988. Purification, characterization and immunological analysis of nuclear inclusions induced by bean yellow mosaic and clover yellow vein potyviruses. Phytopathology 78:1266-1275.
16. Chang, C. A., and Kuo, Y. J. 1983. Cowpea Aphid-borne mosaic virus and its effect on the yield and quality of asparagus bean. J. Agric. Res. China 32:270-278.
17. Chang, C. A., Lin, H. H., and Chang, H. H. 1991. Establishment of large-scale virus-free seeds propagation system and its uses in controlling asparagus bean virus diseases. Plant Prot. Bull. 33:425-426. (Abstract, in Chinese)
18. Chang, C. A., Purcifull, D. E., and Hiebert, E. 1986. Differentiation of clover yellow vein virus from bean yellow mosaic virus based on antigenic distinctions between nuclear inclusions. Phytopathology 76:1061.
19. Chang, C. A., Purcifull, D. E., and Zettler, F. W. 1990. A comparison of two strains of peanut stripe virus in Taiwan. Plant Dis. 74:593-596.
20. Christie, R. G., Ko, N.-J., Falk, B. W., Hiebert, E., Lastra, R., Bird, J., and Kim, K. S. 1986. Light microscopy of geminivirus-induced nuclear inclusion bodies. Phytopathology 76:124-126.
21. Crowley, N. C. 1957. Studies on the seed transmission of plant virus diseases. Australian Journal of Biological Sciences 10:449-464.
22. Culver, J. N., and Sherwood, J. L. 1988. Detection of peanut stripe virus in peanut seed by an indirect enzyme-linked immunosorbent assay using a monoclonal antibody. Plant Dis. 72:676-679.
23. Demski, J. W., and Lovell, G. R. 1985. Peanut stripe virus and the distribution of peanut seed. Plant Dis. 69:734-738.
24. Demski, J. W., Reddy, D. V. R., Sowell, G. Jr., and Bays, D. 1984. Peanut stripe virus a new seed-borne potyvirus from China infecting groundnut (*Arachis hypogaea*). Ann. Appl. Biol. 105:495-501.

25. Demski, J. W., and Warwick, D. 1986. Testing peanut seeds for peanut stripe virus. Peanut Sci. 13:38-40.
26. Edwardson, J. R., and Christie, R. G. 1986. Viruses Infecting Forage Legumes. Fla. Agric. Exp. Stn. Mongr. No. 14, 742 pp.
27. Edwardson, J. R., and Christie, R. G. 1991. The Potyvirus Group. Fla. Agric. Exp. Stn. Mongr. No. 16, 1244 pp.
28. Green, S. K., Lee, D. R., Lesemann, D. E., and Vetten, H. J. 1986. The occurrence of peanut stripe virus on peanut and soybean in Taiwan. Plant Prot. Bull. 28:445-446. (Abstract)
29. Green, S. K., Lee, D. R., and Vetten, H. J. 1987. Characterization of three viruses, blackeye cowpea mosaic virus, cucumber mosaic virus and peanut stripe virus, isolated from mungbean (*Vigna radiata* (L.) R Wilczek). Plant Prot. Bull. 29:440-441. (Abstract)
30. Hampton, R. O. 1984. Diseases caused by viruses. Pages 31-37 *in* Compendium of Pea Diseases, D. J. Hagedorn ed., The American Phytopathological Society. 57 pp.
31. Hampton, R. O., and Mink, G. I. 1975. Pea seed-borne mosaic virus. C.M.I./A.A.B. Description of Plant Viruses No. 146, 4 pp.
32. Hsu, S. H., Huang, C. H., and Chang, C. A. 1987. Identification of bean common mosaic virus isolated from adzuki beans. Plant Prot. Bull. 29:447. (Abstract, in Chinese)
33. Huang, H. 1979. Beans and peas. *in* Book Division, Harvest Farm Magazine, A Nonprofit Organization, N. N. Liang ed., Taipei, Taiwan, R.O.C. 152 pp.
34. Iwaki, M. 1978. Seed transmission of a cucumber mosaic virus in mungbean (*Vigna radiata*). Annals of the Phytopathological Society of Japan 44:337-339.
35. Kaiser, W. J., and Mossahebi, G. H. 1975. Studies with cowpea aphid-borne mosaic virus and its effects on cowpea in Iran. FAO Plant Prot. Bull. 23:33-39.
36. Marchoux, G., Quoit, J. B., and Denvergne, J. C. 1977. Caracterisation d'un isolat du virus de la mosaique du concombre transmis par les graines du haricot (*Phaseolus vulgaris* L.). Annales de Phytopathologie 9:421-434.
37. Morales, F. J., and Castano, M. 1987. Seed transmission characteristics of selected bean common mosaic virus strains in differential bean cultivars. Plant Dis. 71:51-53.
38. Murayama, D., and Han, Y. H. 1971. Occurrence of soybean mosaic virus in Taiwan. Plant Prot. Bull. 13: 75-86.
39. Purcifull, D. E., and Batchelor, D. L. 1977. Immunodiffusion Tests with Sodium Dodecyl Sulfate (SDS) Treated Plant Viruses and Plant Viral Inclusions. Fla. Agric. Exp. Stn. Tech. Bull. 788, 39 pp.
40. Quiot-Douine, L., Purcifull, D. E., Hiebert, E., and de Mejia, M. V. G. 1986. Serological relationships and in vitro translation of an antigenically distinct strain of papaya ringspot virus. Phytopathology 76:346-351.
41. Tao, C. C. 1990. Aphid *Fauna* of Taiwan, China. Taiwan Provincial Museum, 335 pp.
42. Thongmeearkom, P., Honda, Y., Saito, Y., and Syamananda, R. 1981. Nuclear ultrastructural changes and aggregates of viruslike particles in mungbean cells affected by mungbean yellow mosaic disease. Phytopathology 71:41-44.
43. Wang, H. L., Wang, C. C., Chiu, R. J., and Sun, M. H. 1978. A preliminary study of papaya ringspot virus in Taiwan. Plant Prot. Bull. 20:133-140.
44. Wu, W. S., and Su, H. J. 1978. Preliminary study on peanut mottle disease in Taiwan. Plant Prot. Bull. 20:277-282.
45. Yeh, S.-D., and Gonsalves, D. 1985. Purification and immunological analyses of cylindrical inclusion protein induced by papaya ringspot virus and watermelon mosaic virus 1. Phytopathology 74:1273-1278.

摘　　要

張清安，1993．發生於台灣豆類作物之病毒．植病會刊2:149-160．（台中縣霧峰鄉　台灣省農業試驗所植物病理系）

由台灣較具經濟重要性之八種豆類作物中共分離得到九種不同病毒。此九種病毒中有菜豆普通嵌紋病毒 (Bean common mosaic virus，簡稱 BCMV)、黑眼豇豆嵌紋病毒 (Blackeye cowpea mosaic virus，簡稱 BlCMV)、豇豆蚜媒嵌紋病毒 (Cowpea aphid-borne mosaic virus，簡稱 CAMV)、花生斑紋病毒 (Peanut mottle virus，簡稱 PMoV)、豌豆種媒嵌紋病毒 (Pea seed-borne mosaic virus，簡稱 PSBMV)、花生條斑病毒 (Peanut stripe virus，簡稱 PStV) 及大豆嵌紋病毒 (Soybean mosaic virus，簡稱 SMV) 等七種屬於馬鈴薯 Y 群病毒 (Potyviruses)。另外有一種屬於 Cucumoviruses 群之胡瓜嵌紋病毒 (Cucumber mosaic virus，簡稱 CMV) 及一種屬於

Geminiviruses群之綠豆黃化嵌紋病毒(Mungbean yellow mottle virus，簡稱MYMV)。在紅豆上共發現BCMV、PStV、BlCMV及CMV等四種病毒存在，其中以BlCMV之發生最爲普遍。危害豇豆之病毒自1983起共發現BlCMV、CMV及CAMV等三種。其中BlCMV若與CMV發生複合感染則會形成嚴重的皺葉嵌紋病徵，對豇豆生育影響極大。本省菜豆受病毒危害之情形極爲輕微，截至目前僅有CMV一種病毒被發現，但其發生不甚普遍。在綠豆上則有BlCMV、CMV、PStV及MYMV等四種病毒曾經被報告過，但其危害程度亦仍輕微。本省豌豆被病毒感染之情形極爲普遍，最常見之病毒爲具有高度種子傳毒能力之PSBMV，另外CMV及PMoV亦均曾被發現有危害豌豆情形。在花生上PMoV乃最早被發現之病毒但其危害輕，分佈也不廣，而近年來所發現之PStV則危害較劇，分佈亦較普遍。在大豆上共曾分離到SMV、PStV及PMoV等三種病毒，其中以前者發生最爲普遍。上述九種病毒除MYMV外，其基本特性資料包括寄主範圍與反應，鑑別寄主種類，理化性質，血清類緣關係，細胞內含體形態及傳播方式等均已建立完成並詳述於本文中。經由種子帶毒傳播乃豆類病毒之共有特性，此特性並被認爲是豆類病毒於田間流行之主要原因。

關鍵詞：豆類作物、病毒病害、病毒鑑定。