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Note

Incidence and Distribution of Virus Diseases on Paprika (*Capsicum annuum* var. *grossum*) in Jeonnam Province of Korea

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The incidence and occurrence of virus infecting paprika (*Capsicum annuum* var. *grossum*) in Jeonnam province, the main areas of cultivation in Korea is undetermined. In this study, a total of 1,020 samples with virus-like symptoms were collected in Jeonnam province during summer season for 3 consecutive years (2002-2005) and were tested using enzyme linked immunosorbent assay (ELISA). Results showed that *Pepper mottle virus* (PepMoV), *Broad bean wilt virus* (BBWV), and *Cucumber mosaic virus* (CMV) were found to be the most prevalent viruses with a 3-year average percent incidence of 41.3, 19.8, and 4.4 respectively. Mixed infection with more than two viruses was also found with 3.5%, 17.0%, and 8.3%, respectively. Symptoms of these virus diseases were not evident at the seedling stage but slowly appeared at the transplanting stage and increased to the middle stage (4-5 months after transplanting) during the 3-year cultivation periods. Symptom appearance of infected plants however varied largely with transplanting time. Those plants transplanted from November to January were found to be infected with viruses in June, whereas symptoms appeared with in a month those plants transplanted from June to August. There were differences in the virus incidence from primary factor such as district, type of green house and variety, but these were not statistically significant (data not shown). Recommended control measures of paprika against these viruses is also discussed in this paper.

Keywords : BBWV, *Capsicum annuum* var. *grossum*, CMV, Paprika, PepMoV

Paprika (*Capsicum annuum* var. *grossum*) is an important vegetable crop in Korea. The total area cultivated in 2006 was approximately 335 ha and Jeonnam province covers a significant portion of it (Ministry of Agriculture and Forestry, 2007). Paprika production had increased by 10-fold during the last 7 years and most of its production was exported to Japan. For this reason, paprika was rendered as one of the commercially important crops in Korea.

A total of 68 viruses have been reported in pepper plants (*Capsicum* spp.) in the world (Pernezny et al., 2003). Only nine of these viruses were recorded in Korea (Cho, W. D. and Shin, H. D. 2004). However, reports on these viruses incidence in Korea showed discrepancy and even in the preliminary result of virus occurrence in red pepper based on serological method (Lee et al., 2004). Recent studies, however, indicated that *Cucumber mosaic virus* (CMV), *Pepper mottle virus* (PepMoV), *Pepper mild mottle virus* (PMMoV), *Broad bean wilt virus* (BBWV), *Tobacco mild green mosaic virus* (TMGMV), *Tomato spotted wilt virus* (TSWV), *Tomato mosaic virus* (ToMV) were known to occur in red pepper in Korea (Choi et al., 2005; Lee et al., 2004). While, CMV, PMMoV, PepMoV, BBWV, TSWV, *Potato virus* Y (PVY) were detected in paprika (Choi et al., 2005; Kim et al., 2002; Kim et al., 2004; Mun et al., 2008; Song, 2002). But there is no available data as to what virus is the most prevalent in paprika. The objective therefore of this study, is to determine the most prevalent viruses found infecting commercially grown paprika in Jeonnam province.

Viral diseases were monitored from August to May in the period of three years (from 2002 to 2005) covering 3 times cultivation in major paprika growing areas in Jeonnam province including Gangjin, Jangheung, Younggwang, and Hwasun (Fig. 1). The survey was conducted by visiting the target green houses once a month. Disease incidence was calculated as the number of plants showing virus-like symptoms by observing at least 1,000 plants per green house. Samples showing virus-like symptoms were collected and tested using double antibody sandwich enzyme linked

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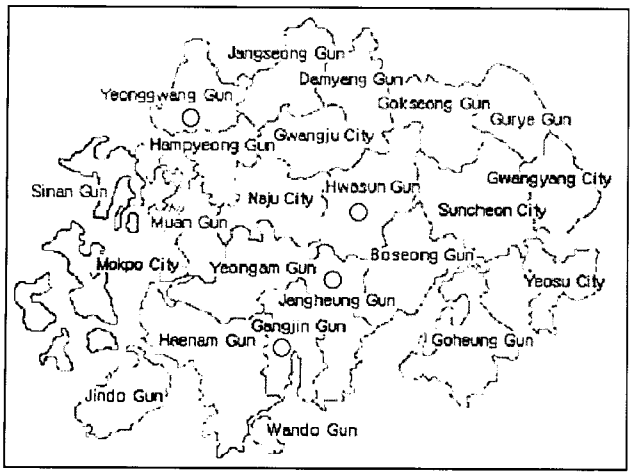

Fig. 1. Surveyed districts of virus diseases on paprika in Jeonnam province.

immunosorbent assay (DAS-ELISA) and further examined for virus particles by electron microscopy (JEM-1010 JEOL Ltd., Japan) using leaf-dip method (Horne et al., 1963). The DAS-ELISA procedure described by Clark and Adams (1977) was adapted with some modification. Samples collected from paprika were tested for the presence of CMV, BBWV, PepMoV, PMMoV, and PVY. Commercial ELISA kits were obtained from Agdia (USA). Absorbance was determined at 405 nm by an ELISA-reader (Themo max, Molecular devices Co., USA) after 60 min. Samples with absorbance values greater than or equal to two times the average of negative samples were considered infected (positive).

Disease incidence of paprika depending on cultivation period and transplanting stage ranged from 2 to 12% with 2002 to 2003 having the highest incidence while 2004 to 2005 had the lowest. The disease symptoms were not evident at the seedling stage but slowly appeared at the transplanting stage and increased to the middle stage (4-5 months after transplanting) during three times of cultivation period. The virus disease occurrence pattern was consistent for 3 years (Fig. 2). Although there were differences in the virus incidence from primary factor such as district, type of house and variety, but these were not statistically significant (data not shown). For disease incidence and symptom according to the transplanting time, two houses from the same farmhouse were compared for. Incidence of symptomatic plants varied largely with transplanting time. Symptoms were observed on the month of June when plants were transplanted from November to January, whereas those plants transplanted from June to August observed symptoms within a month (Fig. 3).

A total of 1,020 samples showing virus-like symptoms were collected from summer in 2002 to spring in 2005 and were tested using DAS-ELISA in Jeonnam province.

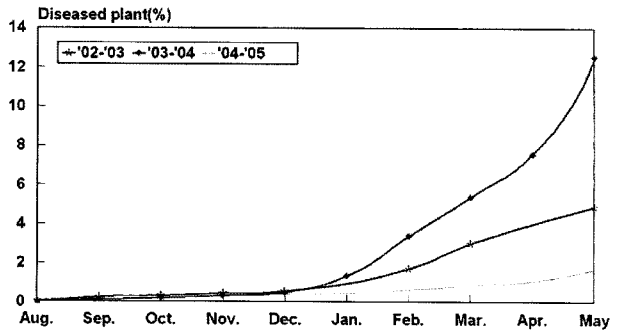

Fig. 2. Cumulative incidence of paprika virus diseases during three times of cultivation periods in ten green houses from 2002 to 2005.

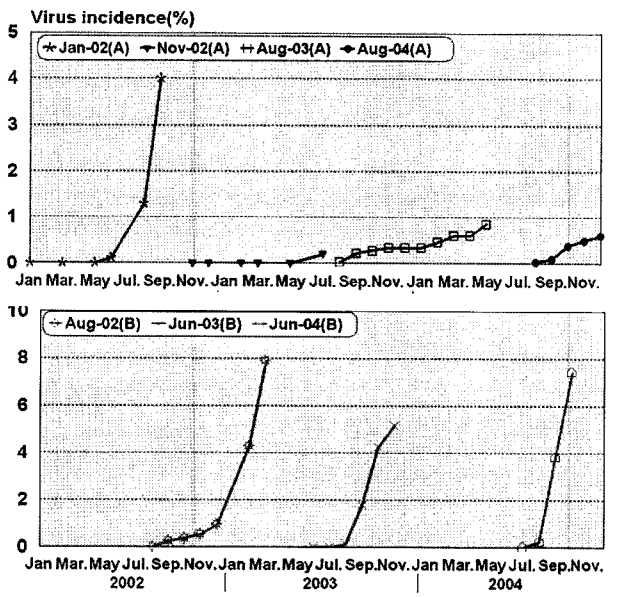

Fig. 3. Cumulative incidence of paprika viruses with transplanting times in two plastic houses.

PepMoV, BBWV, and CMV were the most frequently found viruses, accounting for 75.3%, 11.6%, and 2.5% from August in 2002 to May in 2003 43.1%, 16.4%, and 5.2% from 2003 to 2004 and 50.1%, 31.4%, and 5.7% from 2004 to 2005, respectively. Double infection was found 3.5%, 17.0%, and 7.0%, and triple infection was found 0%. 0.5%, 1.3%, respectively. Samples infected with PepMoV and BBWV were 77(7.4%), BBWV and CMV were 16 (1.5%), PepMoV and CMV were 10(1%), PepMoV and PVY were 1(0.1%), CMV, BBWV and PepMoV were 7(0.7%), and PVY, BBWV and PepMoV were 1(0.1%). We did not detect PMMoV from the paprika samples, No virus was detected from 102(9.8%). Infection rate of viruses was found similar per year. PepMoV and BBWV were detected during whole cultivation period, but CMV was detected on early growth season although it was detected on late growth season during 2004-2005.

Table 1. Detection of virus diseases occurred on paprika during three times of cultivation periods by DAS-ELISA in Jeonnam Province

Cultivation period[a]	No. of samples tested	No. of samples detected with[b]													
		single infection						mixed infection							ND
		Sub-total	CMV	BBWV	Pep-MoV	PVY	PMMoV	Sub-total	C +Pep	C +B	P +Pep	B +Pep	C+B +Pep	B+ Pep+P	
'02/'03	198	177	5	23	149	0	0	7	0	0	1	6	0	0	14
	(100)[c]	(89.4)	(2.5)	(11.6)	(75.3)	–	–	(3.5)	–	–	(0.5)	(3.0)	–	–	(7.1)
'03/'04	383	249	20	63	165	1	0	65	5	11	0	49	1	1	67
	(100)	(65.0)	(5.2)	(16.4)	(43.1)	(0.3)	–	(17.0)	(1.3)	(2.9)	–	(12.8)	(0.3)	(0.3)	(17.5)
'04/'05	459	400	26	144	230	0	0	38	5	5	0	22	6	0	21
	(100)	(87.1)	(5.7)	(31.4)	(50.1)	–	–	(8.3)	(1.1)	(1.1)	–	(4.8)	(1.3)	–	(4.6)
Total	1,040	826	51	230	544	1	0	112	10	16	1	77	7	1	102
	(100)	(79.4)	(4.9)	(22.1)	(52.3)	(0.1)	–	(10.8)	(1.0)	(1.5)	(0.1)	(7.4)	(0.7)	(0.1)	(9.8)

[a]Cultivated from August to June.
[b]CMV, *Cucumber mosaic virus*; BBWV, *Broad bean wilt virus*; PepMoV, *Pepper mottle virus*; PMMoV, *Pepper mild mottle virus*, PVY, *Potato virus* Y; Nd, not detected.
[c]Value enclosed in parenthesis is percent infection.

Our survey revealed that PepMoV, BBWV and CMV were major viruses of paprika. There was no data about occurrence and distribution of viruses infecting paprika. But we have a lot of studies in red pepper since 1970's (La et al., 1972; Kang et al., 1973; Im et al., 1991; Kim et al., 2004; Choi et al., 2005). The prevalence of each of the virus among the 163 pepper plants investigated was in the order of CMV 57%, TMV (*Tobacco mosaic virus*) 55.8%, AMV (*Alfalfa mosaic virus*) 35.6%, PVY 24.5%, PVX (*Potato virus* X) 3.7% (La et al., 1972). The majority of virus infections were known as TMV, CMV, AMV and TSWV covering about 94% of all the viruses detected in 1991. TEV (*Tobacco etch virus*), CVMV (*Chilli veinal mottle virus*), PVY and PVX constituted a minor group (Im et al., 1991). CMV, BBWV, PepMoV, PMMoV, TMGMV and ToMV were readily detected from samples by RT-PCR. But TMV, RMV, PVY, AMV, and TSWV were not detected. The dominant virus occurring in greenhouse was PMMoV, indicating that virus-infected seed stocks and infected plant debris in the growing area may be important sources of inocula. On the other hand, both CMV and BBWV were dominant viruses in open field. This result may be due to the migration of viruliferous insect vectors which is responsible for the spread of the disease throughout the pepper field (Lee et al., 2004). In 2005, among 1,056 samples analyzed, 343 (32.5%) were infected with CMV, 209(19.8 %) with PepMoV, 141(13.4%) with PMMoV, 40(3.8%) with TMGMV (*Tobacco mild green mosaic virus*), 12(1.1 %) with BBWV, 5 (0.5%) with TSWV, 250(23.7%) mixed infection with these viruses (Choi et al., 2005). There is no occurrence of *Tobamovirus* on paprika unlike with pepper but except for one report from Jeonnam and Kyeonggi province in 1999 (Song, 2002). *Tobamovirus* on pepper

Table 2. Monthly detection of major viruses infecting paprika by ELISA in 2002-2005

Year	Month	No. of samples tested	No. of samples detected with[a]						
			Nd	C	B	Pep	P	PM	Mixed infection
2002~2003	Aug.	8	0	1	0	7	0	0	0
	Sep.	30	4	3	4	17	0	0	2
	Oct.	23	1	0	3	19	0	0	0
	Nov.	20	2	0	6	11	0	0	1
	Dec.	15	1	0	1	13	0	0	0
	Feb.	31	1	0	4	25	0	0	1
	Mar.	40	4	0	1	34	0	0	1
	May	31	1	1	4	23	0	0	2
2003~2004	Aug.	12	2	1	4	4	0	0	1
	Sep.	71	15	5	15	21	1	0	14
	Oct.	23	14	1	7	1	0	0	0
	Nov.	32	11	9	8	1	0	0	3
	Dec.	11	4	4	0	0	0	0	3
	Jan.	39	0	0	7	26	0	0	6
	Feb.	33	0	0	2	25	0	0	6
	Mar.	39	8	0	5	24	0	0	2
	Apr.	56	8	0	6	30	0	0	12
	May	67	5	0	9	33	0	0	20
2004~2005	Aug.	15	1	5	3	5	0	0	1
	Sep.	40	1	7	10	19	0	0	3
	Oct.	36	0	6	20	9	0	0	1
	Nov.	29	1	0	16	12	0	0	0
	Dec.	51	0	0	14	27	0	0	10
	Jan.	44	5	0	5	16	0	0	18
	Feb.	39	0	4	10	25	0	0	0
	Mar.	48	2	1	18	25	0	0	2
	Apr.	42	0	0	10	31	0	0	1
	May	115	11	3	38	61	0	0	2

[a]Cultivated from August. refers to one cultivation period.
[b]C, *Cucumber mosaic virus;* B, *Broad bean wilt virus*; Pep, *Pepper mottle virus*; PM, *Pepper mild mottle virus*; P, *Potato virus Y*; Nd, not detected.

seem to be soil borne since it can transmit through soil by means of continuous cropping (Han et al., 1999). However, it seems that *Tobamovirus* do not infect paprika because of the good soil condition.

The major viruses infecting paprika in Korea include PepMoV, BBWV and CMV. All these viruses were transmitted by aphids in a nonpersistent manner. The population density of aphids was very low on vegetables in May, and the density increased rapidly to very high levels in June (Kim et al., 1986; Vuong et al., 2001). These results suggest that the early occurrence caused by the aphid-transmissible viruses might closely related with the population density of virus-transmissible aphid vectors. Since high infection rates occurred only in the early planting, the late planting may be a successful strategy for minimizing the impact of epidemics of aphid-borne viruses in these regions (Ko et al., 2006). Therefore, preventing aphid infestation, delaying the transplanting time or covering the plants with cheesecloth to further protect the plants from aphid infestation and early eliminating the diseased plants are the recommended tools for virus disease control.

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