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Studies on the Aphid Transmission of Some Cruciferous Viruses

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十字花科植物 바이러스의 진딧물 媒介에 關한 硏究

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ABSTRACT

This is the fist report on detailed aphid transnsmission studies of cruciferous virus in Korea, and experiments aimed to get basic informations for control of vectors.

Aphid transmission of turnip mosaic virus prevalent on radish in the field was studied.

Results obtained were as follows :

1. *Myzus persicae*, *Lipaphis erysimi*, *Aphis gossypii* and *Aphis craccivora* were found to transmit turnip mosaic virus.
2. The proper time for turnip mosaic virus transmission by *Myzus persicae* was 1 hour of fasting, 3 minutes for acquisition, and 1 minute for inoculation: *Lipaphis erysimi* was 2 hours for fasting, 5 minutes for acquisition, and 3 miuutes for inoculation: while *Aphis gossypii* needed 1 hour for fasting, and 3 minutes for each of the acquisition and inoculation periods.
3. There was no great difference in probing patterns between nonfasted and fasted aphids for 2 hours. All the fasted aphids began feeding after 4 minutes.
4. When *Myzus persicae* were transferred artificially at 1-2 minute intervals, the number of probes with aphids fasted for 2 hours was much greater than that of nonfasted aphids. Aphids fasted for 2 hours mainly transmitted the virus before 4 minutes, with an acquisition feeing period of less than 3 minutes

INTRODUCTION

everal virus diseases of cruciferous crops have ·ld-wide distribution, and virus disease of cruciferous ɔs such as radish and chinese cabbage are serious ‹orea.

ince Schultz[11] reported virus diseases occurring on chinese cabbage, mustard, and turnip in the U.S.A., many reports on cruciferous viruses had been published throughout the world.

In Korea, Paik[8] and Kwack[7] reviewed foreign literature concerning the reported cruciferous viruses. Park et al.[10] and Ko and Kim[6] classified turnip mosaic virus and cauliflower mosaic virus-like on diseased cruciferous crops by means of symptoms and infection of indicator plants.

Aphids are vectors of turnip and cauliflower mosaic virus. Kennedy et al.[5] reported 40 species of aphids as vectors of turnip mosaic virus, and Park[9] reported 8 species of aphids were capable of transmitting turnip mosaic virus in Korea.

Sylvester[13] reported all instars of *Myzus persicae* could transmit turnip mosaic virus. Aphids fasted for 1–2 hours acquired the virus in less than 1 minute. Aphids could transmit turnip mosaic virus for 60 minutes after acquisition, and there was no latent transmitability period remaining for up to 4 hours after acquisition.

Kasai[4] reported the acquisition and inoculation periods were less than 5 minutes, and the aphids could transmit the virus for 3 hours after acquisition.

In the Korean literature there have been scarce reports of the insect transmission of cruciferous viruses, with the exception of potato[1,2] and carnation viuses[3].

MATERIALS AND METHODS

The source of turnip mosaic virus were isolated from infected radish collected in the fields, and stock cultures of turnip mosaic virus obtained from Plant Pathology Department, Institute of Agricultural Sciences.

Indicator plants used were: *Chenopodium amaranticolor*, *Chrysantheum coronarium*, *Nicotiana tabacum* var. Bright Yellow, *Raphanus sativus* and *Brassica rapa*. The physical properties of turnip mosaic virus were examined from the symptoms on *Chenopodium amaranticolor.*

Ten species of aphids were used: *Myzus persicae*, *Lipaphis erysimi*, *Aphis gossypii*, *Aphis craccivora*, *Aulacothum solani Aphis rumicis*, *Macrosiphum euphorbiae*, *Macrosiphum avenae*, *Aphis spiraecola*, and *Macrosiphoniella sanborni*.

Aphids collected in the fields were kept on healthy radish or other hosts, and tested as 3rd-4th instar apterae.

Aphids were kept in plastic or glass containers with lids and fasted for 2 hours in a cool place (15±5°C) and then allowed to feed for less than 3 minutes on infected radish leaves. One aphid per plant was fed on the Simudaigeun radish variety at 1-2 leaf stage for 1 day. They were killed with insecticides removing the screen cover. Aphids were transferred with No. 1 and 2 water-color paint brushes, and symptoms were checked after one week.

Effective number of aphids

Myzus persicae, *Lipaphis erysimi*, *Aphis gossypii* and *Aphis craccivora* were used, with ten replications for each of 1, 3, 5, and 7 individuals fed on a test plant. The other methods were the same as described before.

Effect of fasting

Myzus persicae, *Lipaphis erysimi*, and *Aphi. gossypii* were used. Aphids were fasted for 0, 0.5, 1, 2, 4, and 8 hours, and inoculated on radish witl up to 12 repaications. The other methods were th same as described before.

Acquisition and inoculation feeding period

Myzus persicae, *Lipaphis erysimi*, and *Aphis gossyp* were employed and tested for periods of 1, 3, 5, 10 30, anc 60 miuntes using up to 12 replications. Acqu sition and inoculation fee ding periods were recorded by stop-watch. To test acquisition feeding periods, aphid were fasted for 2 hours and fed on the host plants fo 1 day. To test inoculaiion feeding periods, they ha been fasted for 2 hours and fed on the infected pla for the periods of less than 3 minutes to acquire the vir

Probing, feeing and infectivity of aphids

Myzus persicae was used in these tests. Nonfast aphids were reared on the turnip mosaic virus infect radish, and fasted for 2 hours were treated accordi to the methods described before. Nonfasted aphids f 2 hours were released on the healthy plants a examined the number of probes, feeing patterns a transmitability. The aphids were transferred one a two minute intervals. The other methods were the sa as described before.

RESULTS

Symptoms of turnip mosaic virus on several indica plants are as follows: local lesion on *Nicotiana taba* var. Broght Yellow and *Chenopodium amarantico* mosaic symptom on *Chrysantheum coronarium* *Raphanus sativus.*

The physical properties of turnip mosaic virus v as follows: thermal inactivation point was 55°C, dilution end point was 1 : 10^{-4} and longevity in vitro was 3 days.

The symptom of turnip mosaic virus inoculated mechanically to eleven radish varieties was generally a yellowish-green mosaic, ranging from insignificant to distinct and clear symptoms. Simudaigeun showed clearer symptoms than others with a higher susceptible reaction

Confirmation as vectors

The transmitabitity of turnip masaic virus is shown in Table 1. Four species of aphids: *Myzus persicae, Lipaphis erysimi, Aphis gossypii,* and *Aphis craccivora* were found as vectors of turnip mosaic virus among he ten species tested. *Myzus persicae* showed 80% nfectivity, *Lipaphis erysimi* showed 50%, *Aphis gossypii* showed 20% and *Aphis craccivora* showed 30%. As a result, different infectivity levels were ound depending on aphid species.

Table 1. Aphid transmission of turnip mosaic virus on radish.

Aphid species	Infection rate	Number of inoculated plant
lyzus persicae	82%	28
ipaphis erysimi	50	42
phis craccivora	33	36
phis gossypii	20	30
ulacorthum solani	0	23
phis rumicis	0	20
Macrosiphum euphorbiae	0	16
Macrosiphum avenae	0	22
Aphis spiraecola	0	21
Macrosiphoniella sanborni	0	19

Effective number of aphids

The effects of the different number of aphids on transmission of turnip mosaic virus are shown in Table 2.

In polts with single *Myzus persicae, Lipaphis erysimi, Aphis gossypii,* and *Aphis craccivora* showed as high a rate of transmission as where 5 and 7 aphids were introduced. Although the higher infectivity was generally related to number of individuals, there was no significant difference in virus transmission in relation to actual number of aphids.

Table 2. Virus transmission in relation to number of aphid

Aphid species	Number of aphid			
	1	3	5	7
Myzus persicae	80(10)	75 (8)	100(6)	75(4)
Lipaphis erysimi	47(15)	50(12)	42(12)	60(5)
Aphis gossypii	17(12)	22 (9)	17(6)	33(3)
Aphis craccivora	25(12)	33 (9)	44(9)	33(6)

the figure; percentage of infectivity
figure in the parenthesis; inoculated plants

Effects of fasting

Figure 1 shows the data on the effects of the fasting

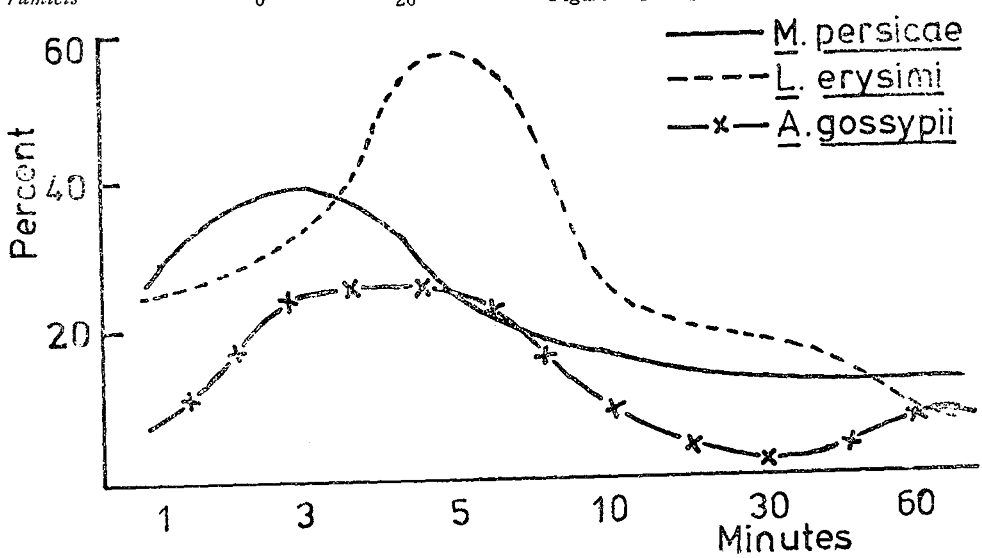

Figure 1 Effect of fasting on the transmission of the turnip mosaic virus

period on the aphids on transmitting turnip mosaic virus.

With *Myzus persicae* there were maximum effects at 1 hour of fasting to 2 hours. *Lipaphis erysimi* showed maximum effects of fasting at 2 hours, and Aphis gossypii showed the maximum effects of fasting at 1 hour, which decreased gradually and was highest at 4 hours.

Acquisition feeding period

Figure 2 present data on the acquisition feeding period of *Myzus persicae*, *Lipahis erysimi*, and *Aphis gossypii*.

The maximum acquisition of the virus was obtained with 3 minute feeding periods for *Myzus persicae*, and 5 minutes for *Lipaphis erysimi*. with *Aphis gossypii*, the peak was produecd in acquisition feeding period in from 3 to 5 minutes.

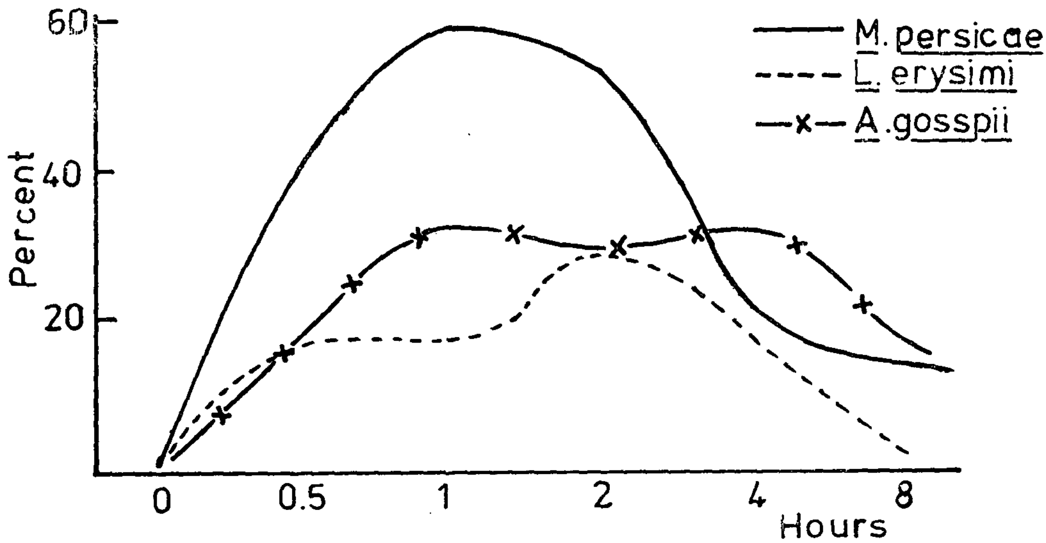

Figure 2 Effective acquisition feeding period for turnip mosaic virus

Inoculation feedıng period

Figure 3 shows the most effective inoculation feeding period of *Myzus persicae*, *Lipaphis erysimi*, and *Aphis gossypii*.

with *Aphis gossypii and Lipaphis erysimi* the rε of transmission reached a maximum at 3 minutes. Tl gradually decreased with time and continued, wh *Myzus persicae* showed a peak at 1 minute, with t

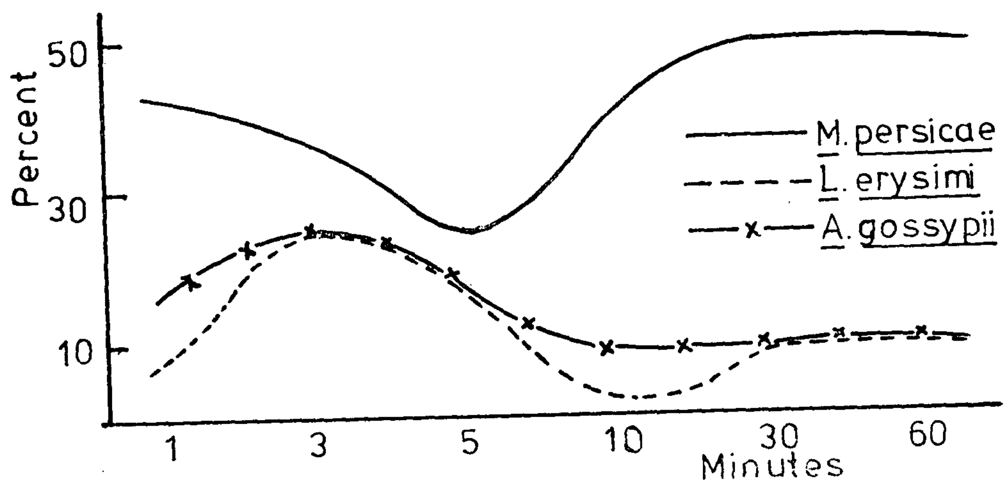

Figure 3 Effective inoculation feeding period for turinp mosaic virvs

same tendency of arriving to a maximum at an early stage. This decreased gradually with time and showed a peak again al 30 and 60 minutes.

Probing and feeding patterns

The probing and feeding patterns of *Myzus persicae* are shown in Table 3.

There were no differences in probing times between nonfasted aphids and those fasted for 2 hours. However, the nonfasted aphids showed various types of feeding: one fed many times, the other a few times, and others fed not at all. The aphids fasted for 2 hours showed a certain pattern of feeding: all fed a long time, and there was probing before feeding.

Table 3. Probing and feeding patterns of the nonfasted and fasted for 2 hours aphids

Time(min)	1	2	3	4	5	6	7	8	9	10
aphid		v		v	v·····	·····	·····		v·····	·····
nonfasted	vv	vv·····	·····	·····	v·····	·····	·····	v ·····	·····	·····
	vvv	vv ·····	·····	·····	·····	·····	·····	·····	·····	·····
					v					
			v·····	·····	·····	v	v·····			
			v·····	·····	·····	·····	·····	·····	·····	·····
aphid fasted	v	v·····	·····	·····	·····	·····	·····	·····	·····	·····
for 2 hours	vv	v·····	·····	·····	·····	·····	·····	·····	·····	·····
	v	vv	v	v·····	·····	·····	·····	·····	·····	·····
	vvv	v·····	·····	·····	·····	·····	·····	·····	·····	·····

v; one time probing

Different phases of aphid transmission

Table 4 presents the differences in aphid transmission : turnip mosaic virus between nonfasted and 2 hours isted *Myzus persicae*.

When *Myzus persicae* were transferred artificially at ·2 minute intervals, some differences were observed. The number of probes for aphids fasted for 2 hours was slightly greater than that of nonfasted aphids, and the virus infectivity of fasted aphids was much higher. Aphid transmission of turnip mosaic virus was mainly performed before 4 minutes.

ıble 4. Number of probes and infected plants

ime(min)	1	2	3	4	5	6	7	8	9	10		12	14	16	18	20
hid	−	+	⊕	−	+	−	+	−	−	+						
nfested	−	−	+	−	+	−	+	+	−	−						
	−	−	+	⊕	−	−	−	+	+	−						
	−	+	+	−	−	+	−	+	+	−						
	−	+	⊕	−	+	−	+	+	−	−						
	0	3	5(2)	1(1)	3	1	3	4	2	1	23(3)					
ıid	⊕	+	−	+	+	+	+	−	+	+						
:ed	−	+	⊕	−	+	−	−	+	+	⊕						
2	⊕	−	+	⊕	+	−	−	+	⊕	+						
rs	−	⊕	+	−	−	+	⊕	+	−	+						
	⊕	⊕	−	+	+	⊕	−	−	−	+						
	3(3)	4(2)	3(1)	3(1)	4	3(1)	2(1)	3	3(1)	5(1)	33(11)					

aphid	+	+	−	+	++	−	⊕	−	+	+	
nonfast	−	−	+	+	−	+	+	+	−	−	
	−	+	⊕	−	−	−	+	−	+	+	
	+	−	−	−	+	+	+	−	+	−	
	−	−	+	+	−	+	+	−	−	+	
	2	2	3(1)	3	3	3	5(1)	1	3	3	28(2)
aphid	−	⊕	−	+	+	+	⊕	−	+	+	
fasted	⊕	⊕	+	+	−	+	−	+	+	+	
for 2	−	+	+	+	−	+	−	+	+	+	
hours	⊕	+	−	+	+	+	⊕	−	+	−	
	⊕	⊕	+	−	+	+	−	+	−	+	
	3(3)	5(3)	3	4	3	5	2(2)	3	4	4	38(8)

−; no probing
+; one time probing
++; twice probing
+; infected plant

figure; number of probes
figure in parenthesis; infected plants

DISCUSSION

Symptoms of turnip mosaic virus on indicator plant coincided well with the results of Tomlinson[14]. The varieties showing highest infectivity were Simudaigeun, Cheongsugungjung, Seouldanchu, and Junggugcheongpi. Simudaigeun was used as a test plant throughout this experiment, because it was found to be the most highly infected variety and showed the clearest symptoms.

Four species of aphids: *Myzus persicae*, *Lipaphis ersymi*, *Aphis gossypii* and *Aphis craccivora*, were found to transmit turnip mosaic virus among the ten species of aphids tested for transmission; and infectivity rates varied. The differences in infectivity rate may be attributed to the fine structure of the outer surface of the stylets, as suggested by van der Want[16] Van Hoof[15] supported Want's suggestion by examining the differential structure of aphid stylets with the electron microscope. In addition, there are possible differences in probing and feeding sites of aphid species, according to host plants. *Aulacorthum solani* and *Macrosiphoniella sanborni*, both of which have been reported as vectors of turnip mosaic virus by Kennedy et al.[5] and Paik[9] could not transmit the virus in this experiment.

In relation to fasting time, *Aphis gossypii* showed maximum infectivity at 1 and 4 hours of fasting. With *Myzus persicae* and *Lipaphis erysimi* this was at 1 and 2 hours of fasting. The bimodal or double peak in effect of fasting time on *Aphis gossypii* could be interpreted as a continuous level of infection capability ranging from one to four hours. The reason for decreased infectivity at 2 hours of fasting was in part due to differences in small replications. Severin and Tompkins[12] and Kasai[4] also reported maximum infectivity with aphids fasted for 2–3 hours,

The maximum infectivity for the acquisition feedin time of *Lipaphis erysimi* was 5 minutes, 3 minutes fc *Myzus persicae*, and 3 and 5 minutes for *Aph gossypii*. Kasai[4] used a 5 minute period in his test and Sylvester[13] and others[14] found 1 minute w sufficient. The time in this test was not actual acquisiti feeding period, but involved the lapse time in th period on infected plants. Considering the duration probing and feeding period in these experiments, resu were the same as those obtained by other investigato

Virus transmission of *Aphis gossypii* and *Lipapl erysimi* in relation to inoculation feeding period reacl a maximum at 3 minutes and gradually decreased w time and continued. *Myzus persicae* showed a peak 1 minute, with the same tendency for gradual decre with time, and a resurgence of the peak at 30 and minutes. This result indicated 3 minutes is suffic for inoculation, although the reason which *My persicae* showed maximum peaks at 30 and 60 min might be due to unknown factors or experimental err The consequence after 1 hour in infectivity did conducted in this experiment, but Sylvester[13] and ot [4,18] reported infectivity could persist up to 4 ho The reason 3 minute is a maximum inoculation ti and infectivity decreases gradully afterwards, may e to aphid stylet penetration through epidermal cells which the stylet-borne virus particles concentrated in › plant. As for the acquisition feeding periods, Kasai[4] ted a time of less than 5 minutes and Sylvester[13] d Tomlinson[14] reported 1 minute was sufficient for culation.

No differences in the number of the probes was found ween fasted and nonfasted aphids. But aphids forced fast for 2 hours starded to feed within 4 minutes, ile nonfasted aphids tented to feed intermittently. ectivity of turnip mosaic virus was the highest for ted aphids. It was also found that the number of bes of fasted aphids could be increased by transferring ificially at 1 and 2 minute intervals. The fasted iids supposedly transfer the virus to other plants ing the early period of probing because of the high ectivity of plants on which fasted aphids probed ly. The reason for aphid transmission of the virus ing early stages is supposed to be due to the form, ich is more stable of introduced virus. Van Hoof[15] nd the aphid transmissible stylet-borne viruses were viral nucleic acid type, rather than protein-coated us particles.

n summary, the effect of fasting was recognized in aphid transmission of stylet-borne viruses by tson[17]. He attributed this to "preliminary fasting" t caused physiological changes within aphids. Research this subject has been conducted by many workers, watson's idea is still considered valid. For the case acquisition and inoculatin feeding period, those of than a few minutes are more effective than longer s. These results coincided with the evidence to date. › reason is believed to be due to aphid stylet etration through the epidermal cells in which stylet-ne viruses are concentrated. This also perhaps lains, in part, why allowing aphids to feed for onged periods does not increase virus iefection.

'here are still questions regarding the transmission stylet-borne viruses are related to the complexity of id behaviour and other factors. Additional research required for a more full understanding of the hanism on virus transmission by aphids.

摘 要

:外의 무우에서 많이 發生하고 있는 turnip mosaic s에 대한 性質과 이의 虫媒傳染에 대하여 몇 가지 을 [illegible]하여 다음과 같은 結果를 얻었다.

1) 採集된 TuMV의 物理的性質은 [illegible] 하였고 [illegible]의 [illegible]이 가장 높았다.

2) TuMV의 媒介昆虫은 *Myzus persicae*, *Lipaphis erysimi*, *Aphis gossypii*, *Aphis craccivora*의 4種이었다.

3) TuMV의 진딧물에 의한 傳染에서 가장 適當한 處理時間은 *Myzus persicae*는 1時間絶食, 3分吸汁, 1分接種이었으며, *Lipaphis erysimi*는 2時間絶食, 5分吸汁, 3分接種이었고, *Aphis gossypii*는 1時間絶食 3分吸汁, 3分接種이었다.

4) 진딧물의 Probing 횟수는 2時間 絶食시킨 진딧물과 絶食시키지 않는 것에 큰 差異가 없었고, 絶食시킨 진딧물의 全媒體가 4分經過時부터 攝食하기 始作하였다.

5) 복숭아 혹 진딧물을 1~2分 間隔으로 人爲的으로 옮겨주었을 때, 2時間 絶食시킨 진딧물의 Probing 횟수가 絶食시키지 않은 것의 Probing 횟수보다 훨씬 많았고, 2時間 絶食시킨 진딧물이 주로 3分以內의 獲得吸汁時間後 4分以內에 Virus를 媒介하였다.

LITERATURE CITED

1) Choe, C. I. 1969. Studies on the potato virus X and potato leafroll virus for production of virus free stock. Jour. Kor. Soc. Crop Sci. 7:31—63. (in English summary)

2) Han, B. H. and E. H. Kang 1972. Investigations for the strains and infectivity of potato viruses. Ann. Rep. Alpine Exp. Stat. 109—114 (in Korean)

3) Hong, Y. P. and K. H. Ko. 1969. Investigation of carnation virus disease in Korea. I. Isolation and identification of carnation viruses in Korea. Res. Rep. O.R.D., 12:2:83-89. (in Korean with English summary)

4) Kasai, T. 1950. Transmissions of the mosaic disease of Japanese radish by *Myzus persicae*. Ann. Phytopath Soc. Jap. 15:3—6.

5) Kennedy, J. S., M. F. Day and V. F. Eastop. 1962. A conspectus of aphids as vectors of plant viruses. Commonwealth Institute of Entomology.

6. Ko, G. Y. and K. S. Kim. 1965. Isolation of the viruses occurred in radish and chinese cabbage. Ann. Rep. Hort. Exp. Stat. 63—82. (in Korean)

7) Kwack, B. H. 1966. Studies on radish diseases. Research bulletin of Hyosung Women's College 239—270. (in English)

8) Paik, W.H. 1960. Viruses of crucifers. Agricultural Biology. 4:36—55 (in English)

9) Paik, W.H. 1970. A list of plant viruses which are transmitted by the Korean aphids. Pesticide 44—56. (in Korean)

10) Park, Y.S., K. W. Song and E. H. Kang. 1963. Studies on control of the virus of cruciferous vegetables (1): I. Isolation of the viruses of radish mosaic. Res. Rep. O. R. D. 6:1:93—99. (in Korean with English summary)

11) Schultz, E. S. 1921. A transmissible mosaic disease of chinese cabbage, mustard and turnip. J. Arg. Res. 22:173—178.

12) Severin, H. H. P. and Tompkins C. M. 1948. Aphid transmission of severe mosaic virus of annual stock (Four platus). Hilgerdia 20:93—108. (RAM 30:569)

13) Sylvester, E. S. 1954. Aphid transmission of nonpersistent plant viruses with special reference to the brassica nigra virus. Hilgardia 23:3:53—98.

14) Tomlison. J. A. 1970. Turnip mosaic virus : C. M. I. / A. A. B. Descriptions of plant viruses.

15) Van Hoof, H. A. 1958. Onderzoekingen over de biologische overdracht van een nonpersistent virus. Doctorial thesis. Wageoingen Agr. Univ., Var Putten & Oortmekjer, 66 pp.

16) Want, J.P.H. van der. 1954. Onderzoekingen ove Virusziekten van de Boon (*Phaseolus vulgaris* L.) H. Veenman and Zonnen, Wageningen, Netherlands 84 pp.

17) Watson, M. A. 1938. Further studies on th relationships between Hyoscyamus virus 3 and th aphid *Myzus persicae* (Sulz) with special referenc to the effect of fasting. Proc. Roy. Soc. (London) 125 B, 144—170.

18) Yoshii, H. 1966. Transmission of turnip mosa virus by *Myzus persicae* (Sulz) : Mode of styl insertion and infection site of the virus. An Phytopath. Soc. Jap. 32 : 46—51. (in Japanese wi English summary)