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Environmental factors influencing aphid transmission of potato virus Y and potato leafroll virus

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Summary

The effect of temperature, relative humidity (RH) and light on aphid transmission of potato virus Y (PVY) and potato leafroll virus (PLRV) was studied using as vectors *Myzus persicae* Sulz. and *Aphis gossypii* Glov. Host susceptibility was enhanced by 48 h pre-inoculation exposure at 25 °C and by 48 h post-inoculation exposure to 30 °C. High RH (80 %) in both pre- or post-inoculation phases enhanced host susceptibility. Continuous fluorescent light (4000 lux) did not alter the rate of transmission of either virus. High RH (80–90 %) and high temperature (25–30 °C), when combined, increased virus transmission by 30–35 %. Transmission rates were reduced by nearly 50 % if RH was maintained at 50 % in either of the two phases even if the temperature was 25 or 30 °C. Both viruses were acquired by aphids earlier (13–20 days after inoculation) when the source plants were incubated at 25 or 30 °C. Most virus was transmitted from plants inoculated with PVY 13 to 16 days and with PLRV 15 to 20 days previously. Transmission rates of PVY were enumerated from symptom expression on test plants and by Enzyme Linked Immunosorbent Assay (ELISA) whereas those of PLRV were enumerated from symptom expression alone.

Introduction

The susceptibility of a plant to a virus infection by mechanical inoculation usually increases if the plants are subjected to reduced light and high temperatures before inoculation (Kassanis, 1957). There is little evidence that the same treatments also increase host susceptibility for infection by insect transmitted viruses. Swenson & Sohi (1961) found that more bean plants became infected with aphid-inoculated bean yellow mosaic virus (BYMV) if the test plants were first held at 18 °C, although Kostiw (1984) had observed that the ideal temperature for potato viruses Y (PVY) and M (PVM) was 22 °C.

Robert & Rouze-Jouan (1971) compared the transmission of potato leafroll virus (PLRV) by different stages of the aphids *Aulacorthum solani* Kltb., *Macrosiphum euphorbiae* Thomas and *Myzus persicae* Sulz at 6, 15 and 24 °C. No transmission or a low transmission occurred at 6, while most stages transmitted the virus efficiently at 24 °C. Bokx et al. (1978) observed a positive correlation between the relative concentration of PVY^N in potato as determined by both serology and the A6-test and its availability to *M. persicae* as assessed by its transmission to tobacco.

Swenson (1968) observed that more pea plants were infected with BYMV when kept at 30 than at 24 or 15 °C after inoculation. In another experiment plants were, however,

more susceptible when kept before inoculation at 15–18 than at 27–30 °C. Differences in water supply and light regimes had no effect. Syller (1987) showed recently that PLRV is more efficiently transmitted by *M. persicae* if the virus source plant was kept at 12 instead of at 26 °C during the pre-acquisition period. He also mentioned that optimum transmission of PLRV occurs when the acquisition and inoculation of the virus are performed at a higher (26 °C) than at a lower (12 °C) temperature.

There is no information on the effect of light, humidity and their combinations on aphid transmission of PVY or of PLRV. In this paper we present the results of experiments on the effect of pre- and post-inoculation temperature on virus source hosts and test hosts on virus transmission rates using *M. persicae* and *Aphis gossypii* Glov. clones as vectors of PVY and of PLRV.

Materials and methods

Aphids and viruses used in the infectivity tests. Clones of *M. persicae* and *A. gossypii* were collected from different host plants from several localities and elevations. Hereditary variant (HV) clones were collected from the following plants: *M. persicae* HV III and HV XII from potato and HV VII from *Capsicum annuum*; *A. gossypii* HV I from *Solanum* species, HV II and X from *Cucumis sativus* and HV IX from *Abelmoschus esculentus*.

To secure virus-free aphid clones, single viviparous apterae aphids from *M. persicae* and *A. gossypii* were multiplied on *Datura stramonium* for four generations. Thereafter *M. persicae* was multiplied on cabbage plants and *A. gossypii* on *Capsicum annuum*, immune hosts for PVY and PLRV respectively (Nagaich et al., 1970; Singh et al., 1982a). Colonies of both aphid species were maintained individually by weekly subculture. Cultures of PVY^O strain (Khurana et al., 1979) were maintained by sap inoculation on *Datura metel*. The severe strain of PLRV used was multiplied by aphid transmission on *Physalis floridana* plants (Singh et al., 1982b). Test plants of *D. metel* and *P. floridana*, 3–4 weeks old having 3–4 leaves, were transplanted singly in 10 cm earthen or plastic pots, and maintained in an insect-proof glasshouse for at least 6 weeks after inoculation.

To study the transmission of PVY under different conditions, an efficient clone of *M. persicae* HV III and of *A. gossypii* HV X and an inefficient clone of *M. persicae* HV XII and of *A. gossypii* HV IX were used. Adult apterae were fasted for 1 h and then allowed a 5 min acquisition period and a 30 min inoculation feeding on the virus source and test plant *D. metel*, respectively.

Similarly an efficient clone of *M. persicae* HV VII and of *A. gossypii* HV I and an inefficient clone of *M. persicae* HV XII and of *A. gossypii* HV II were used to study PLRV transmission. Nymphs of efficient and inefficient vector clones of both the aphid species were given a 24 h acquisition period on the virus source hosts without prior fasting and then allowed a further 24 h inoculation feeding period on test plants of *P. floridana*.

In all experiments 5 aphids per plant were used for acquisition and inoculation feedings. Unless otherwise stated at least 10 test plants were used for each treatment in each trial and the results of at least three consecutive trials were averaged.

The infection rates of both viruses were assessed on the basis of symptom expression and that of PVY was further enumerated by Enzyme Linked Immunosorbent Assay (ELISA).

For every test, the plants that served as virus-sources were inoculated individually to obtain the particular stage of infection required. The leaves inoculated with the viruses by the aphids were not used as sources but only those newly grown and fully expanded leaves that showed characteristic symptoms.

The different combinations of light, relative humidity and temperature were obtained in growth chambers (Scientific Equipment Works, New Delhi). Each chamber was illuminated by three Philips fluorescent lamps TL F20W, 45 cm, producing 4000 lux.

Test plants were treated for 48 h immediately preceding or after inoculation.

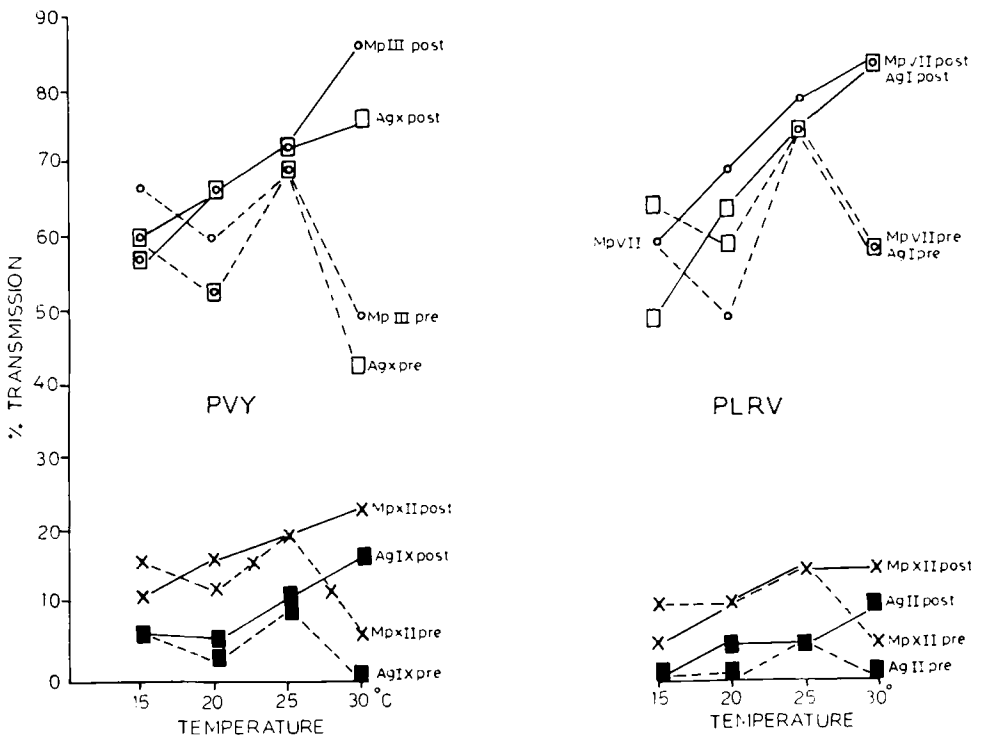

Fig. 1. The effects of pre- and post-inoculation temperature treatments of host plants on virus transmission.
Mp = *Myzus persicae;* Ag = *Aphis gossypii.*
pre: pre-inoculation; post: post-inoculation.
PVY (*M. persicae*). HV III: o---- o, o—— o efficient clones; HV XII: X--X--X, X——X inefficient clones.
PVY (*A. gossypii*). HV X: □---- □, □—— □, efficient clones; HV IX: ■---- ■, ■—— ■ inefficient clones.
PLRV (*M. persicae*). HV VII: o---- o, o—— o efficient clones; HV XII: X--X--X, X——X inefficient clones.
PLRV (*A. gossypii*). HV I: □---- □, □—— □ efficient clones; HV II: ■---- ■, ■—— ■ inefficient clones.

Temperature effects and age of infection in virus-source plants. PVY virus-source plants of *D. metel* infected 4, 7, 10, 13 or 16 days previously and PLRV virus-source plants of *P. floridana* infected 7, 10, 15 and 20 days previously were exposed to temperatures of 15, 20, 25 or 30 °C for 48 h.

Results

Effect of light. The effects of pre- and post-inoculation dark treatments on the transmission of PVY to and from *D. metel* and of PLRV to and from *P. floridana* by *M. persicae* and *A. gossypii*, respectively, were compared in a factorial experiment. The test and control plants were subjected to either continuous dark and light for 48 h before and/or after inoculation; additional control plants received a treatment of 16 h in the light followed by 8 h in the dark. All plants were held at constant temperature of 25 ± 1 °C and removed from the growth chambers 48 h after inoculation. None of the treatments had a significant effect on the number of plants infected by either virus

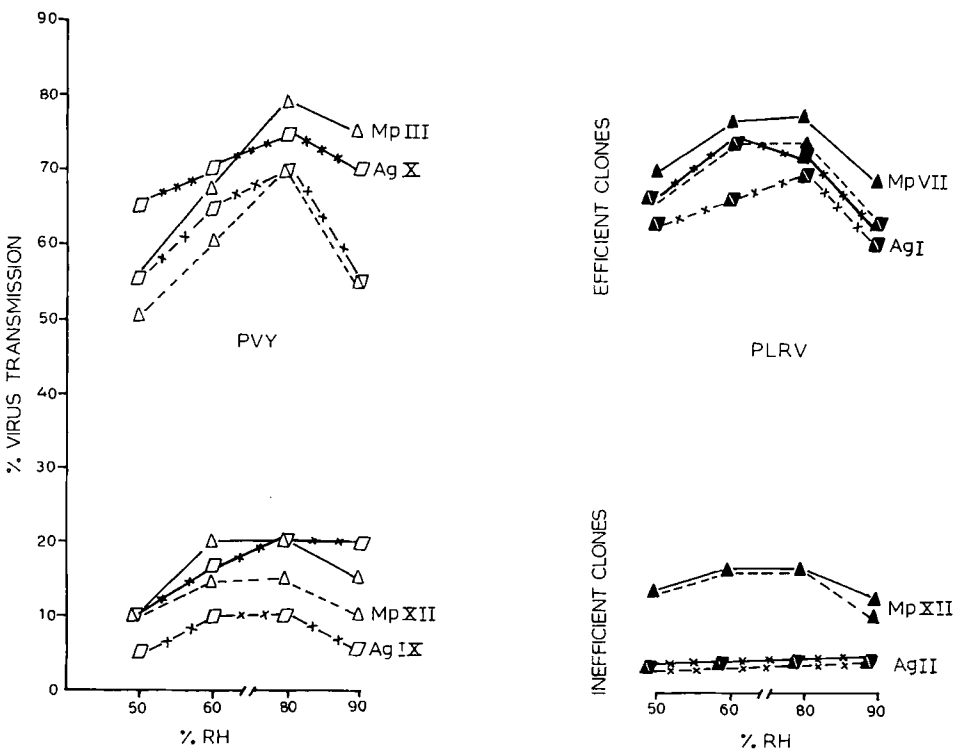

Fig. 2. The effects of pre- and of post-inoculation humidity treatments of host plants at 25 °C on virus transmission.
(---) broken lines indicate the effect of pre-inoculation treatment and (——) unbroken lines indicate the effect of post-inoculation treatment on the transmission of PVY/PLRV irrespective of aphid species, i.e. *M. persicae* and *A. gossypii* with their efficient and inefficient vector clones.

although there was a slight (5–10 %) increase in the number of infected plants following the continuous dark treatments and a slight decrease after the continuous light treatments.

Effect of temperature. Test plants were held at 15, 20, or 30 °C for 48 h either before or after aphid inoculation. Control plants were held continuously at 25±1 °C and 80 % RH.

Test plants predisposed at 30 °C had lower rate of transmissions of both viruses than plants held at 15 °C whereas in those plants treated post-inoculation, virus transmission was greater at 30 than at 15 °C (Fig. 1). The clones that were efficient continue to remain so as did the inefficient ones; their vectorial efficiency appeared to be unaffected by temperature.

Effect of relative humidity. Test plants were maintained at 50, 60, 80 or 90 % RH and at 25±1 °C for 48 h pre- or post-inoculation. The plants most susceptible to either virus were those that were pre- or post-inoculated treated at 80 %, the highest rate of

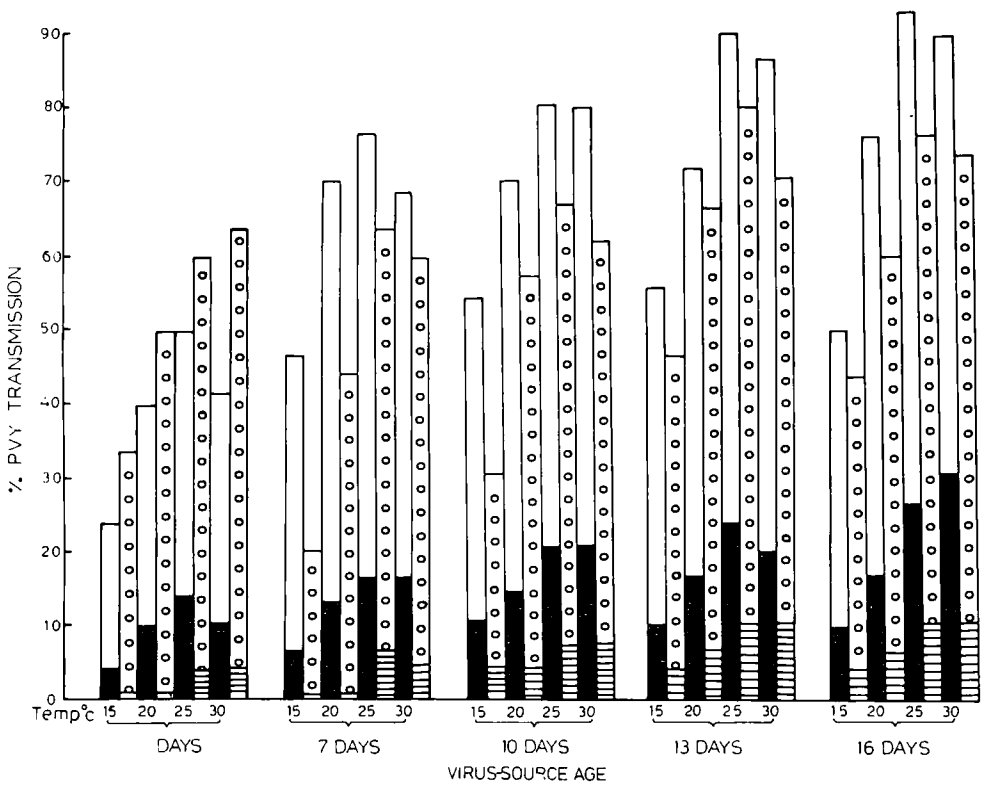

Fig. 3. Effect of temperature and age of virus-infection of source plants on PVY acquisition. □ *M. persicae* HV III efficient clone, ■ *M. persicae* HV XII inefficient clone. ◎ *A. gossypii* HV X efficient clone, ⊟ *A. gossypii* HV IX inefficient clone.

transmission being induced by the post-inoculation treatment (Fig. 2). It thus appears that varying RH alone at 25 °C does not alter host susceptibility.

Effect of temperature and age of infection in virus-source plants. Most virus was transmitted from plants treated at 25 and 30 °C and infected with PVY 13 and 16 days and with PLRV 15 and 20 days previously. Source plants exposed to 15 and 20 °C and infected 4 or 7 days previously with either virus gave low rates of transmission (Figs. 3 and 4).

Interaction of temperature and relative humidity. Test plants of *D. metel* and *P. floridana* were subjected either prior to or after aphid inoculations to combinations of three temperatures, 20, 25, or 30 °C and four RH: 50, 60, 80 or 90 % RH for 48 h with continuous illumination. Test plants treated at 25 °C and 80 % RH were most susceptible followed by plants held at either 20 or 30 °C.

Conversely a combination of 50 % RH with any of the temperature regimes during pre- or post-inoculation treatments resulted in poor transmission. Nonetheless the post-inoculation treatments at the higher temperatures (25 and 30 C°) coupled with either 80 or 90 % RH resulted in higher transmission rates (Fig. 5). Clearly, temperature alone does not determine plant susceptibility to aphid transmission of PVY or PLRV.

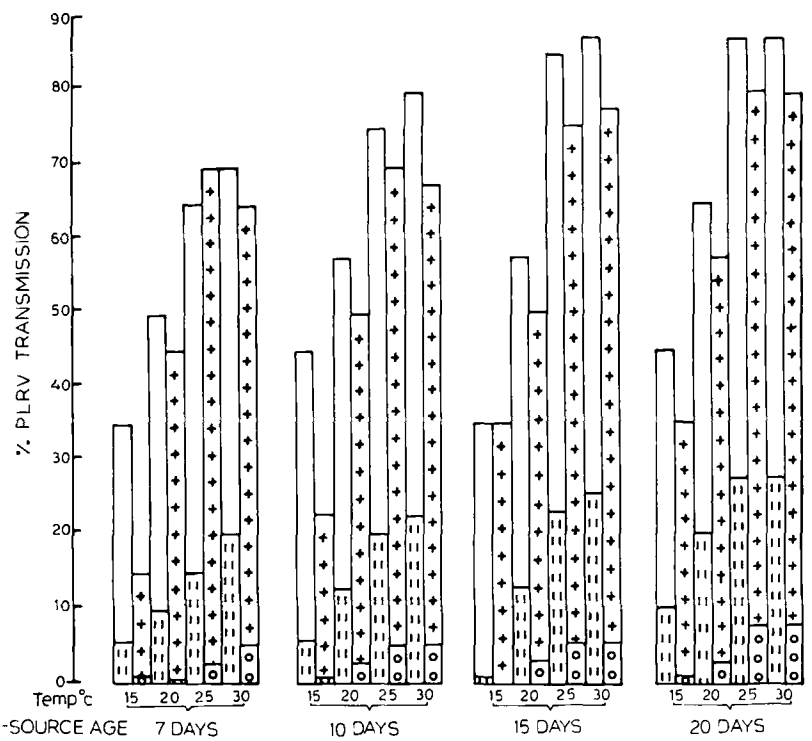

Fig. 4. Effect of temperature and age of virus-infection of source plants on PLRV acquisition. ☐ *M. persicae* HV VII efficient clone, ⊞ *M. persicae* HV XII inefficient clone. ⊞ *A. gossypii* HV I efficient clone, ◎ *A. gossypii* HV II inefficient clone.

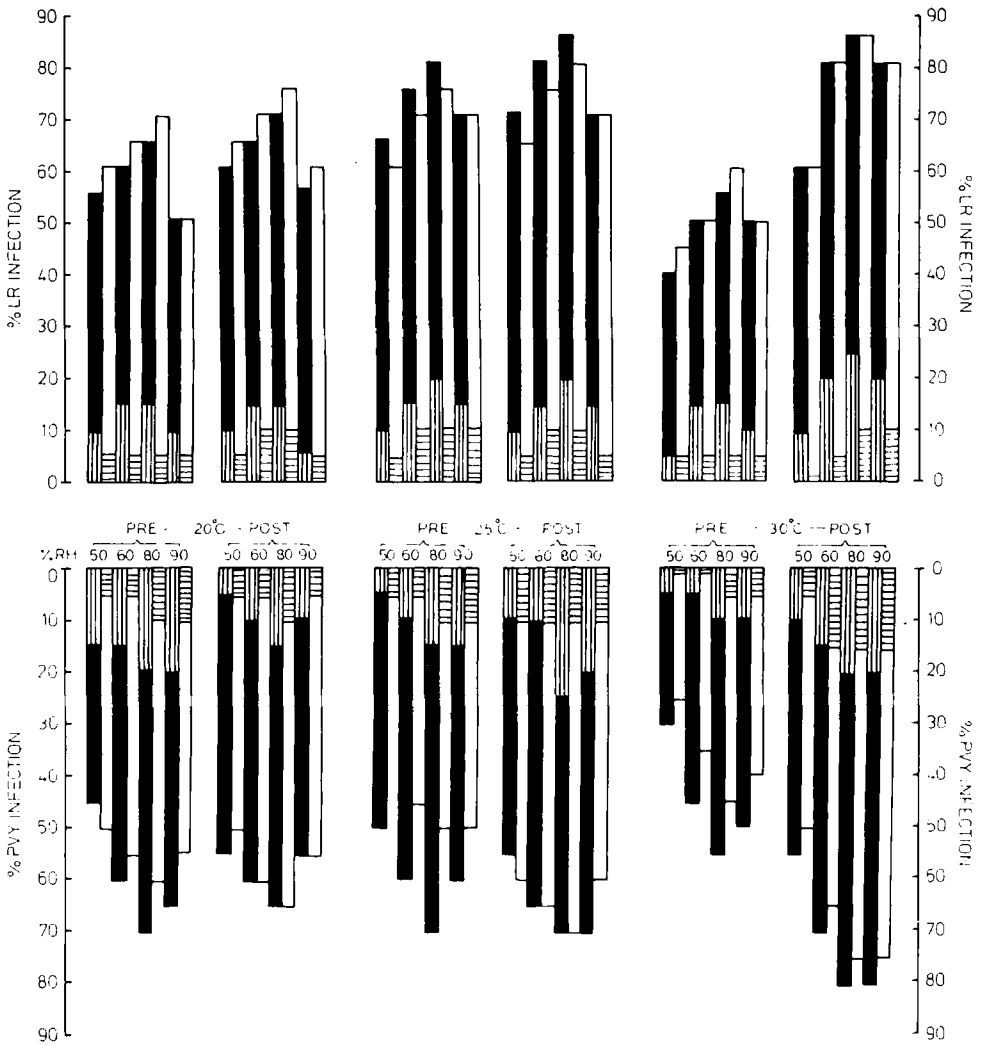

Fig. 5. Interaction of temperature and relative humidity on PVY/PLRV aphid transmission.
■ *M. persicae* (HV III, VII) efficient clones irrespective of the virus.
▥ *M. persicae* (HV XII) inefficient clones irrespective of the virus.
□ *A. gossypii* (HV I, X) efficient clones of PVY/PLRV respectively.
▤ *A. gossypii* (HV II, IX) inefficient clones of PLRV/PVY respectively.

Discussion

Our results show that neither pre- nor post-inoculation treatments with continuous light or dark altered plant susceptibility to PVY or PLRV infection by aphid inoculations. Although similar observations have been recorded for cucumber mosaic virus

(CMV) (Stimmann & Swenson, 1967a), and BYMV (Swenson, 1968), Sylvester (1955) found that the number of lettuce plants with lettuce mosaic virus increased when 24 or 48 h periods of darkness preceded aphid inoculation. The susceptibility of the host plants to both PVY and PLRV was enhanced by pre-inoculation treatment at 25 but not at 30 °C. Similarly increased transmission of BYMV has been recorded at lower pre-inoculation temperatures by Swenson (1968), Swenson & Sohi (1961) and Welton et al. (1964). There were, however, earlier reports on BYMV and maize dwarf mosaic virus by Swenson (1962), Stimmann & Swenson (1967a) and Tu & Ford (1971), that pre-inoculation treatment did not alter host susceptibility. In contrast, we found that the rates of infection of PVY and PLRV usually increased with higher (30 °C) post-inoculation temperature perhaps because higher temperature increased the rate of virus multiplication. The higher temperature may also have induced more rapid symptom development although Tsai & Bath (1970) reported that higher post-inoculation temperatures (30–44 °C) resulted in masking of symptoms of pea enation mosaic virus. Our findings agree with those of Webb (1956) who found that exposure of potato plants to 27 °C when compared to 22 °C resulted in an increased susceptibility to PLRV. Syller (1987) also found that PLRV is transmitted more efficiently by *M. persicae* when acquisition and inoculation feedings have been performed at a higher (26 °C) than at a lower (12 °C) temperature. Similar effects have been reported for BYMV, CMV, and PVY (Cheo & Pound, 1952; Stimmann & Swenson, 1967b; Welton et al., 1964; Stimmann & Swenson, 1967a; Kostiw, 1984) although Sylvester (1964) found that host post-inoculation temperature treatment did not alter the aphid transmission of cabbage mosaic virus.

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