WESTERN FLOWER THRIPS, A SERIOUS PEST OF FLORICULTURAL CROPS

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The western flower thrips, *Frankliniella occidentalis* (Pergande), has recently become one of the most serious pest problems facing the ornamental industry (Robb & Parrella 1988). It is polyphagous and has been collected from plants of almost every order of the Spermatophyta in California (Watson 1923, Bailey 1933, Bryan & Smith 1956). However, western flower thrips probably has a greater impact on ornamental crops than any other crop. It attacks essentially all floricultural crops and also transmits the tomato spotted wilt virus to numerous ornamental plants (Best 1968).

Tomato spotted wilt virus, like western flower thrips, has a very broad host range, which includes numerous field crops, vegetables, weeds and ornamental crops (Best 1968). Tomato spotted wilt virus is only transmitted by a few thrips species; no other vectors have been identified. Western flower thrips is one species known to vector this virus and it is currently the primary vector associated with this disease in United States; on the East Coast (Da Graca et al. 1985), in the southern states (Barnes & Halliwell 1985, Greenhough et al. 1985), the western states and Hawaii (Allen et. al. 1983, Cho et al. 1987, Robb et al. 1988), as well as in Canada (Allen & Broadbent 1986, Broadbent et al. 1987).

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Damage thresholds for floricultural crops are very low or non-existent. This is especially true for pests such as the western flower thrips which attack the flower, the most important part of these aesthetic crops (Parrella & Jones 1987). Flower losses caused by thrips damage, because of reduced crop yields and market values, as well as increased costs for additional pesticide applications, have been staggering for many ornamental crop producers (Robb & Parrella 1988). Despite its broad host range, vector capabilities and the economic importance of this pest, there have been surprisingly few studies on its biology.

Development of Western Flower Thrips

Although this insect is occasionally found on the foliage of some plants, it is primarily anthophilous. Eggs are deposited within plant tissue and first instars begin feeding upon egg eclosion. Second instars are also active feeders. Both larval instars are thigmotactic and are generally found in the protection of the perianth of the flower or within developing terminal foliage. Second instars become whitish in color just prior to the next molt and usually move down the plant to pupate in the soil or plant litter. Prepupae and pupae are quiescent non-feeding stages whereas the adult resumes feeding. Females are larger than males and can vary in coloration from yellow to dark brown while males are always pale yellow. Females arise only from fertilized eggs, but they are facultatively arrhenotokous and can produce male offspring from unfertilized eggs.

Under field conditions in California, Bailey (1933) reported a life cycle length of 15-20 days for the western flower thrips. Bryan & Smith (1956) determined the developmental times of western flower thrips at 15°, 20°, and 26.7°C on wild radish leaves and Lublinkhof & Foster (1977) evaluated development times and fecundity at 15°, 20° and 30°C on green bean sections. However, since there had been no evaluations of western flower thrips development on an ornamental crop, a trial was conducted to determine their development on the ornamental host, chrysanthemum, at selected constant temperatures.

Western flower thrips were confined to chrysanthemum, cv. Hurricane, leaves using a modified Munger cell design (Munger 1942, Morse et al. 1986, Robb 1989). Pollen was provided to the thrips. Leaf petioles were suspended in water, and the leaves were changed at least every three days.

Adult female thrips were exposed to chrysanthemum leaves for oviposition for four hours at a constant temperature of 25°C. The adults were removed and the leaves were held in temperature cabinets at 15°, 20°, 25°, 27.2°, 30° or 35°C. The development of each thrips was monitored every four hours until it became an adult.

The highest rate for total development from egg to adult was 30°C (Table 1). Plotting the development rates against temperature revealed a sigmoidal curve. The development rates determined by this experiment were fit by the biophysical model of Wagner et al. (1984) (Fig. 1). A four-parameter model, with high temperature inhibition, best fit the developmental data with 50% high temperature inhibition at 33.26°C.

Table 1. Egg to adult development times of *Frankliniella occidentalis* (Pergande) at selected constant temperatures

Temperature Regime (°C)	n^a	Mean hours	(±SE)	Development Rate (Time^{-1})
15	44	939.16	(14.191)	0.001065
20	33	625.85	(20.436)	0.001598
25	51	309.95	(9.161)	0.003226
27.2	25	245.57	(4.275)	0.004035
30	36	223.33	(4.444)	0.004478
35	33	257.79	(5.183)	0.003879

[a] Total number of individuals evaluated, trials replicated at least three times for each temperature regime.

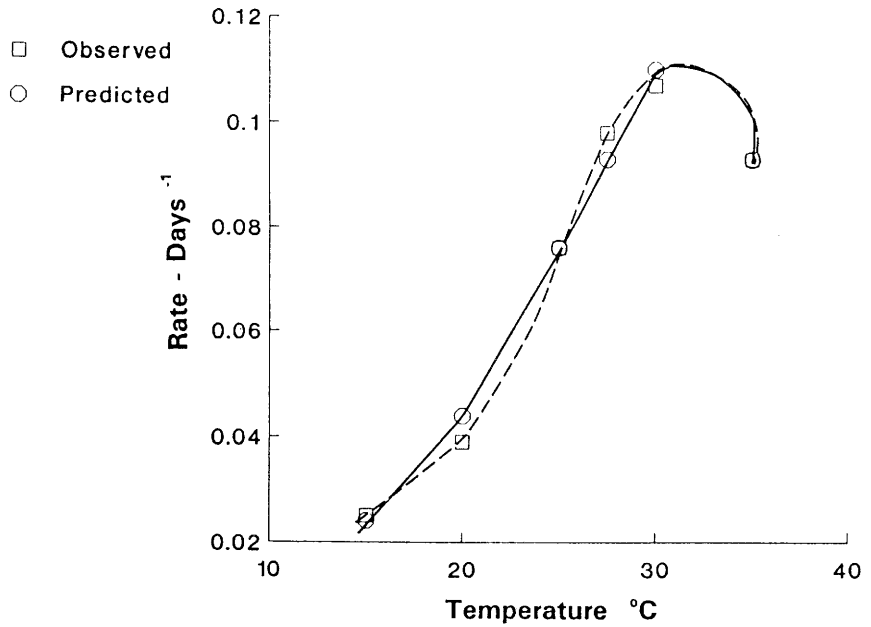

Figure 1. Development rates of *Frankliniella occidentalis* (Pergande) at selected temperatures and nonlinear regression fit by biophysical model.

The development rates observed in this study differ from those reported by Bryan & Smith (1956) on wild radish and by Lublinkhof & Foster (1977) on green bean sections. These differences probably reflect responses of this thrips species to the different host plants utilized in each trial. Dintenfass et al. (1987) observed an exponential increase in western flower thrips populations in onion fields up to temperatures of 35°C whereas above 35°C, development was considerably reduced. Their results were based on ambient field temperatures, however the temperature in the microenvironment of the thrips was probably lower, being modified by the crop canopy. Thus, the results of Dintenfass et al. (1987) generally agree with the findings of this study.

Longevity and Fecundity of Adult Female Western Flower Thrips

Adult male and female pairs were confined to chrysanthemum leaves at the temperature regimes described previously. Adult mortality was assessed daily to determine age specific survival (l_x). Leaves were changed every other day and subsequently held for seven days at 25°C to ensure emergence of all larvae. Emerging larvae were transferred to fresh leaves and maintained until adult emergence to determine sex ratio and age specific fecundity (m_x). The l_x and m_x data were used to compile life tables for each temperature regime (Carey 1982).

The greatest numbers of progeny per female and progeny per female per day were produced at 27.2°C (Table 2). In addition, mean longevity of females maintained at 27.2°C was almost three times as long as the mean longevity of females at 30°C. Net reproductive rate, R_o, was greatest at 27.2°C and dropped sharply as temperature increased. Intrinsic rate of increase, r_m, was lowest at the temperature extremes and mean generation time decreased with increasing temperature. It is clear from this short generation time and high reproductive rate how quickly large populations of western flower thrips can build up in greenhouses. Other factors, such as migration, also influence the numbers of thrips in greenhouses.

Western Flower Thrips Movement Into and Within Greenhouses

Numerous crops and weeds serve as hosts of western flower thrips outside greenhouses. Adults, after their original host plants senesce or are harvested, search for and move to new hosts. Adult dispersal is initiated with the adults launching themselves into the wind (Lewis 1973). Thrips are not strong fliers, and airspeed is negligible in relation to the speeds of circulating winds (Johnson 1969). Even in relatively calm weather, wind speed is greater than thrips' flight speed (Lewis 1973). Consequently, thrips can be dispersed great distances and can be carried into greenhouses through openings such as open doors and vents.

Table 2. Longevity, fertility and life table parameters of *Frankliniella occidentalis* (Pergande) at selected temperatures

Temperature Regime (°C)	n^a	Longevity Days	(±SE)	Mean No. Progeny/ Female	(±SE)	$R_0{}^b$	$r_m{}^c$	T (days)	t_2 (days)
15	9	46.33	(9.735)	50.51	(18.771)	42.25	0.0563	66.523	12.311
20	9	75.17	(10.131)	125.88	(34.676)	86.49	0.0941	47.186	7.366
25	10	31.40	(3.776)	135.60	(46.550)	99.51	0.1713	26.856	4.046
27.2	9	34.00	(4.120)	228.60	(34.502)	124.92	0.2545	18.969	2.724
30	11	12.67	(2.833)	42.00	(14.292)	35.39	0.2054	17.366	3.381
35	10	9.50	(2.604)	5.10	(3.567)	2.69	0.0563	17.565	12.312

[a] Total number of individuals evaluated, trials replicated at least three times for each temperature regime.

[b] Net reproductive rate.

[c] Intrinsic rate of increase.

Colored sticky traps were used to evaluate thrips movement within greenhouses. Yellow sticky traps are attractive to many pests of ornamental crops, including whiteflies, aphids and leafminers (Roach & Agee 1972, Parrella & Jones 1985, Jones & Parrella 1986). White and blue traps have been reported to be as attractive, or more, to western flower thrips than to other common ornamental pests (Moffitt 1964, Beavers et al. 1971, Yudin et al. 1987, Brødsgaard 1989).

The attractancy of white, yellow, blue and green traps to western flower thrips was determined in a chrysanthemum greenhouse. Colored acrylic panels (12.8 X 17.8 cm) were used for traps. The panels were placed inside a polyacetate envelope which was covered with a very thin layer of Tanglefoot®, which traps insects as they alight without affecting the attractancy of the trap (Prokopy 1968, Gregory 1985). Traps were suspended over benches of chrysanthemums. Four traps, one of each color, were placed over four benches in a Latin square design. The traps were left in place for 48 hours and then the thrips were counted. Traps were rearranged and the trial was repeated four times. Data were analyzed using analysis of variance procedures. Treatment means were separated using Duncan's multiple range test.

Blue and yellow were the most attractive colors to western flower thrips (Table 3). Yellow traps were chosen for all subsequent trials since yellow is attractive to other pests of ornamental crops (Roach & Agee 1972, Parrella & Jones 1985, Jones & Parrella 1986).

Evaluations in rose, carnation, chrysanthemum and poinsettia greenhouses indicated that several factors affected western flower thrips movement. These factors include movement into greenhouses, crop type and cultivar composition. Mark-recapture studies demonstrated that adult thrips were trapped at greater distances from the release point in greenhouses containing poinsettias, a non-preferred host, than in greenhouses with roses, a preferred host. In the rose greenhouse, 72.2% of the thrips were recaptured within 20 m of the release point. No thrips were captured near the release point in the poinsettia greenhouse and more than half were caught 96 m from the release point (Robb 1989).

Table 3. Effects of trap colors on attractancy to *Frankliniella occidentalis* (Pergande)

Trap Color	n^a	Mean No. (±SE) thrips/trap[b]
Green	16	40.00 (5.038)a
White	16	86.88 (10.396)b
Yellow	16	125.50 (14.609)c
Blue	16	150.50 (19.519)c

[a] Total number of traps evaluated per color. Traps were changed and rearranged every 48 hours. Trial was replicated four times.

[b] Means followed by the same letter do not differ significantly ($P > 0.05$) Duncan's multiple range test.

Significant differences were also observed in the attractancy of different cultivars of carnations and roses to western flower thrips. The spectral reflectance of different cultivars probably accounted for some of the differences observed with cultivar composition (Robb 1989). Other factors are also important, however. In roses, for example, flower development and time of sepal splitting also affected the number of thrips in the flowers. Early splitting cultivars had a longer exposure time to adult females and a greater percentage of larvae were present at harvest (Robb 1989). It is clear from these results that an understanding thrips biology and behavior is crucial to the development of integrated control strategies for this pest.

Western Flower Thrips Control Strategies

Chemical control of western flower thrips can be extremely difficult for many reasons. Good contact of thrips with pesticides is hard to achieve due to the thigmotactic behavior of this insect. Its propensity to develop insecticide resistance is another factor which complicates control. Reinfesting populations through migration of thrips into greenhouses further complicates the problem.

Based on our knowledge of the biology and behavior of this pest, several management strategies have been developed. An integrated approach incorporates strategies for the reduction/prevention of western flower thrips in the greenhouse, without relying solely on insecticides for control. While all these strategies may not be appropriate for every situation, many can be used by almost every grower.

Physical Controls

Thrips exclusion. The most effective strategy for thrips control is prevention (Robb 1990). Many greenhouse structures have open sides or vents for increased ventilation. However, this offers no impediment to thrips movement into these greenhouses. Therefore, screening over vents and doorways can greatly reduce this movement into greenhouses and reduce or eliminate the need for insecticides.

Isolation of propagation areas. One of the most important factors in managing thrips populations is to start with clean plant material. However, this is virtually impossible if thrips move from production areas to stock and rooting areas.

Therefore, isolation of stock and propagation areas is crucial. Physical barriers, such as screening or distance from production areas can serve to isolate propagation areas.

Cultural Controls

Weed control around greenhouse. As mentioned previously, western flower thrips have a broad host range, including weeds as well as flowering plants. Weeds, however, are not usually targeted for pesticide applications and can serve as a refuge during pesticide applications. Moreover, weeds can act as a reservoir for tomato spotted wilt virus.

Avoidance of continuous cropping. Many flower crops are grown in very large, contiguous greenhouses. All stages of production may be present under one roof. As crops are harvested, mobile adult

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