Population Dynamics of Western Flower Thrips (Thysanoptera: Thripidae) in Nectarine Orchards in British Columbia

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ABSTRACT Development of a control strategy for thrips attacking nectarine trees depends on an understanding of their phenology, distribution, and life history as related to characteristics of nectarine orchards. To this end, we compared the overwintering behavior, distribution, and abundance of western flower thrips, *Frankliniella occidentalis* (Pergande), among 11 nectarine orchards located in the dry central interior of British Columbia, Canada, during 1993 and 1994. Western flower thrips emerged from areas not previously used for agriculture (wild areas) and from within orchards before trees were out of dormancy. Flight of thrips within and around orchards peaked during early bud development, with a second major peak several weeks later after husk fall as the next generation emerged. Orchards protected from wild areas by other orchards had the lowest densities of thrips in buds. Density estimates of western flower thrips on trees were not affected by location of trees within orchards or buds within trees, but most thrips were found in the most developed buds on a tree at any one time. Thrips were not found within buds until petal was first visible on the buds. Larval feeding on buds at early petal fall resulted in serious surface russetting of fruit.

KEY WORDS *Frankliniella occidentalis,* nectarine, orchard, distribution, abundance, overwintering

PRODUCTION OF NECTARINES, *Prunus persica* (L.) Batsch, in the Okanagan and Similkameen Valleys of British Columbia, has recently grown from being a minor specialty crop to having a regular commodity status. However, this developing industry is threatened by the damage done by thrips, generally assumed to be the western flower thrips, *Frankliniella occidentalis* (Pergande), to the fruit in early spring. Appropriate integrated pest management strategies for this insect have not been developed because information on its population dynamics in this region is lacking. The species composition of thrips within nectarine orchards, the identity of the species responsible for damage, spatial and temporal patterns of abundance of western flower thrips, as well as details of their overwintering and emergence have not been previously identified.

Western flower thrips are believed to overwinter as sexually mature females in soil, curled leaves, evergreen plants, and protected places, such as under bark (Bailey 1938). In the Okanagan and Similkameen Valleys, western flower thrips are likely to overwinter without reproduction in areas of sagebrush, *Artemisia tridentata* Nutt., and areas not previously used for agriculture (wild areas) bordering orchards (Venables 1925, Madsen and Jack 1966).

For design of sampling procedures, information on factors that may affect the density of thrips such as orchard, tree, or within-tree location; time of day; time of year; and the stage of development of nectarine buds must be obtained. Lewis (1973) reported considerable seasonal variation in thrips populations and injury levels, and densities of western flower thrips may vary spatially both within and among plants in a field (Salguero-Navas et al. 1991).

The main objectives of this study were to obtain information on location of overwintering sites, population dynamics, and phenology of western flower thrips both within and around orchards. The influence of time of day, position of buds/leaves on the tree, and position of trees within an orchard were examined for their effect on density estimates by sampling.

Materials and Methods

Study Sites. Studies were conducted in 10 orchards in 1993 (A–J) and 11 orchards in 1994 (A–F, H–L) all located in valleys of the dry central interior of British Columbia. The characteristic climax vegetation on hillsides in these valleys is bluebunch wheatgrass, *Agrypon spicatum* Pursh, together with big sagebrush, brittle prickly pear cactus, *Opuntia fragilis* (Nutt.), and rabbitbrush, *Chrysothamnus nauseosus* (Pallas). Orchards, vineyards, and alfalfa are grown here with the aid of irrigation.

Ten of the orchards were located in the Similkameen Valley near Keremeos and of these, six operated conventionally (A, B, D, F, G, H), two were in the first year (in 1994) of a 3-yr conversion to organic production (C, E), and two were fully organic (K, L). The other two orchards were in the Okanagan Valley near

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Table 1. Characteristics of the various study orchards used for the population dynamics studies 1993–1994

Orchard	Varieties of nectarine	Age in 1993	Location	Surrounding wild land[a]
		Organic		
K	Earliscarlet Early Sungrand Redgold Crimsongold	5	Similkameen	1
L	Redgold	3	Similkameen	2
		Transitional in 1994		
C	Redgold Early Sungrand	8–10	Similkameen	2
E	Redgold Early Sungrand	3	Similkameen	2
		Conventional		
A	Fantasia Redgold	6	Similkameen	1
B	Redgold	5	Similkameen	1
D	Fantasia Redgold	8 3	Similkameen	3
F	Crimsongold Redgold	10–15	Similkameen	1
G	Redgold 60 Independence	2–4	Similkameen	2
H	Flavourtop 60 Independence	7	Similkameen	3
I	Redgold Fantasia	3	Okanagan	2
J	Harko Harblaze Earliscarlet Early Sungrand	4	Okanagan	2

[a] 1, located adjacent to huge area (>20 ha) of wild land on hillside; 2, located adjacent to small patch of wild land (<20 ha); 3, in protected location; surrounded by no wild land.

Summerland and were in conventional production (I, J). Conventional orchards received various herbicide, pesticide, and other chemical sprays throughout the growing season. The fruit varieties and ages of the nectarine orchards are shown in Table 1.

Spring Emergence. *Traps.* In 1993, potential overwintering sites of thrips were sampled in March with emergence traps in orchards A, B, C, and in wild areas close to orchards A and B, and by extraction of thrips with Berlese funnels from leaf litter and soil samples (estimated as ≈125 cm^3), in orchards A, C, I, and J. Emergence traps for adults (Tanigoshi and Moreno 1981) were positioned beneath plants and trees within and bordering the orchards. Thrips were trapped on the undersides of petri dishes coated with tanglefoot glue that were placed on the top of PVC piping (for trap design see Pearsall 1998). Fifty traps were placed in the five locations on 27 March and retrieved on 15 April. Subsamples of thrips collected from the Berlese funnels were mounted on microscope slides and sent to Sueo Nakahara (USDA, Beltsville, MD) for identification.

In 1994, emergence of thrips in nectarine orchards was monitored in orchards B, E, F, and J using emergence traps and bark traps (bands of parafilm around a branch coated with stickum). On 1 March, 15 emergence traps were set up in each orchard and 15 were set up in each of the three wild areas adjacent to orchards B, F, and J. In addition, two sticky bands were wrapped on each of five trees in all four orchards. These bark traps were collected and replaced every few days until 30 March. Thrips on the petri dish tops of emergence traps were counted every few days until zero counts within the orchards occurred (between 19 and 26 April).

Flight in Wild Areas. In addition, yellow sticky cards were placed in pairs on each of four posts (each 1 m high) in wild areas located within 10–15 m of both orchards A and B in 1993 and 1994 to determine when thrips began to fly into orchards, and how abundance varied over the season. In 1993, cards were placed out on 7 April and replaced every few days until the final collection on 1 June. In 1994, the sticky cards were placed out on 23 April and monitored every few days until 30 May. After 30 May, sticky cards were placed out in orchards once per month and collected 12 d later until 20 November.

Distribution and Abundance. The changes in abundance of thrips in both years within all 11 orchards was monitored between 7 April and 17 May in 1993 and between 28 March and 7 May in 1994, from dormant bud to husk-fall stage by sampling 8–12 nectarine buds from each of six to eight trees within each sample orchard. Sample trees were selected randomly after stratifying the orchards into four quarters. The same trees were used both years. Two to three buds were picked arbitrarily from each of the four cardinal quarters (N, E, S, W) of each tree and were placed immediately into selfsealing plastic bags for later analysis. Stage of bloom and the density and species of adult thrips found were recorded at collection. Approximately 50% of the larval samples were placed into vials of 70% ethanol, stained with 1 ml of Rose Bengal stain, and counted as time permitted. The buds were teased apart with forceps and the vial contents and bud washings were poured through a Nytex (85-μm mesh, BSH Thompson, Montreal, QC) filter. Stained larvae collected on the filter were counted under 120× power (Pearsall 1998). In 1993, three bud counts were made between petal fall and husk fall, and the larval stage and number of larvae per bud were recorded. In 1994, three to five larval counts were made, depending on the rate of bud development of the orchard.

In 1994, bud sampling was carried out on an almost daily basis in orchard E. In 1993 and 1994, we also examined 50 randomly chosen nectarine buds directly from each orchard to determine the absolute number of larvae per bud. In 1994, flowers from the ground cover within orchards B and J was sampled at the same times as the nectarine buds and the density of western flower thrips per flower recorded. Sampling of ground cover blooms was continued in these orchards until 20 November.

In 1993 only, the density of larval thrips falling into the ground to pupate was assessed using drop traps (20 by 20-cm^2 stickum-coated coroplast on four long nails) in two orchards (A and H). Four traps were placed under each of six randomly chosen trees in orchard A, and under each of five randomly chosen trees in orchard H from 15 May 1993, petal fall, to 21

May (A) and 22 May (H), husk fall. Tree area was estimated from a mean of the largest and smallest radii from the base of the trunk to the outside edge of the canopy. Abundance of thrips on the nectarine trees was monitored twice in 1993, to determine whether thrips were reproducing on nectarine leaves or fruit.

In 1994 only, trends of aerial populations were monitored from 23 April until 31 May using yellow sticky cards. Later, sticky cards in orchards were collected at the same times as the cards in wild areas as described above.

Damage Assessment. In both years, fruit was rated for injury by thrips shortly after husk-drop using a numerical scale from 1 being no damage, 2 as slight scarring (russetting), 3 as deformation and light scarring, 4 as moderate scarring, 5 as deformation and moderate scarring, 6 as severe scarring, and 7 as severe scarring and severe deformation. In 1993, damage assessments took place on 3 June, southern orchards, and 28 June, northern orchards, and in 1994, on 18/19 May, southern and 10 June, northern orchards.

Factors Affecting Abundance. *Relationship Between Tree Location within Orchards and Density of Adult and Larval Thrips and Subsequent Fruit Damage.* In 1993, density of adult and larval thrips was determined every 3 d between 7 April and petal fall from 12 buds per tree, and fruit damage was assessed from 15 fruit per tree from each of 15 trees in orchards B, I, and J. The orchards were stratified into five sections and three trees were chosen randomly from each of the four outside sections of the orchards, and three trees from the inside section of the orchards. Data were analyzed using analysis of variance (ANOVA).

Relationship Between Position within a Tree and the Density of Adult and Larval Thrips. Counts of adult thrips were made from eight trees in orchards C and E twice in 1993. On four of the trees, 12 buds were taken from both the *inside* (area closer to the trunk) and *outside* (area distal from the trunk) portions of the tree (total of 24 buds); and on the other four trees, four buds were taken from each of the four cardinal directions (N, E, S, W) within both the upper half and lower half of the canopy (total of 32 buds). In 1994, adult and larval thrips were sampled in the same two orchards from 16 buds taken from each of the inner/outer (IN/OUT) portions of eight trees and from 16 buds taken from each of the upper/lower (UP/DOWN) portions of a further eight trees to determine whether there was a preferred location for residence or egg-laying. Paired *t*-tests were used to compare densities of western flower thrips between locations. On a second occasion, larval thrips were collected from 12 buds taken from each of four areas of a tree: Up-In, Up-out, Down-In, and Down-Out for a total of 48 buds per tree. Data were analyzed using ANOVA.

Relationship Between the Stage of Development of Nectarine Buds and the Density of Adult Thrips. At various times throughout bud development, between 12 and 24 buds of two different developmental stages were arbitrarily removed from a total of 8–12 randomly chosen trees, and the number of adult thrips were counted. The eight developmental stages of nectarine buds are described as follows: (1) silver tip: dormant; (2) white swell: breaking dormancy; (3) pink color: dark pink, no petals; (4) early/middle/late petal show: petals increasingly apparent; (5) full pink: 'popcorn stage;' (6) early/middle/late bloom; (7) petal fall; and (8) husk fall. Comparisons were made of the density of thrips per bud at the silver tip/white swell versus pink color, pink color versus early petal show, early petal show versus pink stage and the pink versus bloom stage for each of several orchards for both years using paired *t*-tests.

Relationship Between Tree Size and Density of Thrips and Fruit Damage. The relationship between the total number of adult and larval thrips per nectarine bud per tree between silver tip and petal fall in each orchard in 1993 and the subsequent mean fruit damage per tree (assessed on 10–25 fruit per tree) and the height and canopy radius of the trees was investigated using simple linear regression.

Effect of Time of Day on Adult Thrips Density Estimates. On two occasions in 1993, adult thrips were collected from 12 buds from each of eight randomly chosen trees in orchard B at 0700, 1200, and 1800 hours to determine whether the time of sampling is a critical factor in determining thrips density. On 21 April 1994, adult thrips were collected from 12 buds from eight randomly chosen trees from orchards A, C, and K at 0830, 1330, and 1800 hours. Data were analyzed with one-way ANOVA.

Thrips Association with Fruit Damage. To determine which species of thrips (western flower thrips or *Thrips fallaciosus* or both [see *Species* section under *Results*]) were responsible for the damage to fruit, and whether either western flower thrips morph may be causing more damage, larvae were collected both years from petal fall buds and reared through to adults from orchards C and J. Rearing took place on leaves of Pinto beans (*Phaseolus vulgaris*) placed in pots of water inside mason jars inside an incubator at 25°C with a 2.5-cm layer of peat moss for pupation. Species of thrips emerging were sent to Sueo Nakahara for identification.

Larval Movement. Larval movement was monitored in 1994 on sticky bands of Tanglefoot-coated (BioQuip, Gardena, CA) parafilm (American National Can, Menasha, WI) wound tightly around branches both close to and far from buds, as well as around the tree trunks of each of three trees in orchards A, F, I, J, and K. A total of 18 bands was placed on each tree before larval hatch, and three bands per tree were retrieved every day for 6 d after petal fall and examined under a dissecting microscope.

Data Analysis. Significance was $P < 0.05$ for all statistical comparisons. Comparison of abundance of adult and larval thrips and fruit damage among orchard types (northern valleys versus southern valleys; hillside locations versus valley locations) was carried out using nested ANOVA. For posthoc testing among groups, means followed by the same letter grade were not significantly different (Tukey honestly significant difference [HSD] test, $P > 0.05$). Where heteroscedasticity precluded the use of ANOVA, and where

numbers could not be adequately transformed, the nonparametric Kruskal–Wallis test was used. The Tukey HSD test was used for all posthoc comparisons of ANOVA results. A Mann–Whitney *U* test was used for posthoc comparisons of all Kruskal–Wallis results with a Bonferroni adjustment to control the experiment-wise probability of a type I error to 5%. Averages are presented in the text as mean ± SE.

Results

Species. The species of thrips found within nectarine blossoms were *Frankliniella occidentalis* (pale and dark forms), a new species of thrips, *Thrips fallaciosus* Nakahara, and *Haplothrips kurdjumovi* Karny. The latter, although predatory, is not known to feed on thrips. On all dates, the western flower thrips was the most abundant species found within blossoms, and apart from aphids, there were very few other species of arthropods present on the trees at the time that the adult female thrips were laying eggs.

These three species were also the most common species of thrips captured on sticky cards during the period of nectarine flower development. Other commonly captured thrips species found flying into orchards were *Thrips treherni* Priesner, *Frankliniella fusca* (Hinds), *F. minuta* (Moulton), *T. tabaci* Lindeman, *Aeolothrips fasciatus* (L.), *T. vulgatissimus* Haliday, *Odontothrips loti* (Haliday), *Haplothrips verbasci* (Osborn), *H. halophilus* Hood, *Neohydatothrips* sp., and various *Aeolothrips* spp, but none of these were found within nectarine blossoms. Of these species, only the *Haplothrips* spp. and the *Aeolothrips* spp. are predacious. The other species are phytophagous and belong in the family Thripidae. The *Haplothrips* spp. belong in the family Phlaeothripidae.

Spring Emergence. *Traps.* Few or no thrips were caught in emergence traps, leaf litter, or soils samples in 1993 in orchards or wild areas, making statistical comparisons impossible. In both years, only adult females were caught. In 1993 the first western flower thrips were caught in traps on 11 March, yet trees did not come out of dormancy in these orchards until the first week of April. By 15 April, each trap contained 0–4 thrips. Each leaf litter and soil sample also yielded one–two thrips. In 1994, thrips first emerged on 9 March in the south and 11 March in the north. Trees came out of dormancy this year between 28 and 31 March. Mean trap catches translated to densities of 127–220 thrips per square meter for orchards and 17–89 thrips per square meter for wild areas. Catches varied with temperature and emergence did not occur until maximum daily temperatures exceeded 10°C. (Fig. 1a). Thrips were also caught on sticky bands, suggesting some overwintering on trees (Fig. 1b). More details are provided in Pearsall (1998).

Flight in Wild Areas. In 1993, counts from the sticky cards in wild areas adjacent to southern orchards A and B showed that flight of thrips into orchards began in early to mid-April, and then gradually built up with the emergence of offspring in the beginning of May (Fig. 2A). In 1994 a large peak of female thrips occurred around 29 March, and a second flight of offspring began around nine May (Fig. 2B). Numbers were low through summer and peaked again in autumn. Numbers of western flower thrips within wild areas were low during the summer but peaked in the autumn, probably associated with sagebrush bloom (unpublished data).

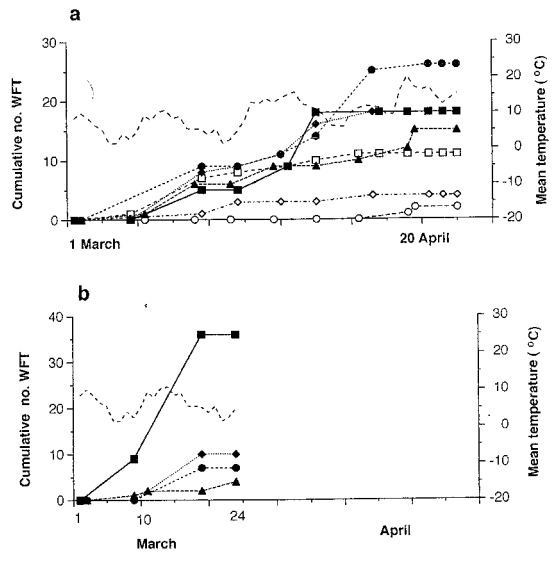

Fig. 1. Emergence of western flower thrips (WFT) (a) from the ground in orchards B, E, F, and J (solid shapes) and from wild areas (open shapes) adjacent to orchards B, F, and J, and daily air temperatures (dotted line) from 1 to 23 April 1994 in Keremeos; and (b) Emergence of western flower thrips from sticky bands wrapped on bark of nectarine trees from orchards B, E, F, and J from 1 to 24 March 1994.

Bud Development. In both years, bud development occurred slightly earlier and more rapidly in the south than the north. In the south, development was earliest in orchard A, and latest in orchard H. In 1993, bloom began 23–26 April and petal fall began 3–5 May in the south; bloom began on 1 May and petal fall on 10 May in the north. In 1994, bloom was earlier, 2–9 April, for southern orchards and 15–20 April for northern orchards, with petal fall beginning 8–12 April in the south and 21 April in the North.

Distribution and Abundance. *Life Cycle of Western Flower Thrips in Nectarine Orchards.* Female adult western flower thrips were noted on buds starting on 11 April in 1993 and 28 March in 1994, while trees were still dormant (Figs. 3 and 4), but did not enter buds until they had reached the early pink stage. The mean numbers of adults were <0.8 per bud in 1993 and less than one per bud in 1994. In 1993, peaks in adult numbers occurred around 22/23 April in several orchards and 1–4 May in all orchards, coincident with full pink and bloom states, respectively. In 1994, peaks in adult numbers occurred in early April in a few orchards, coincident with full pink and around 12–15 April in all orchards at late bloom.

In 1993, first instars appeared in the flowers on 8 May and in 1994 during mid-April at the time of petal

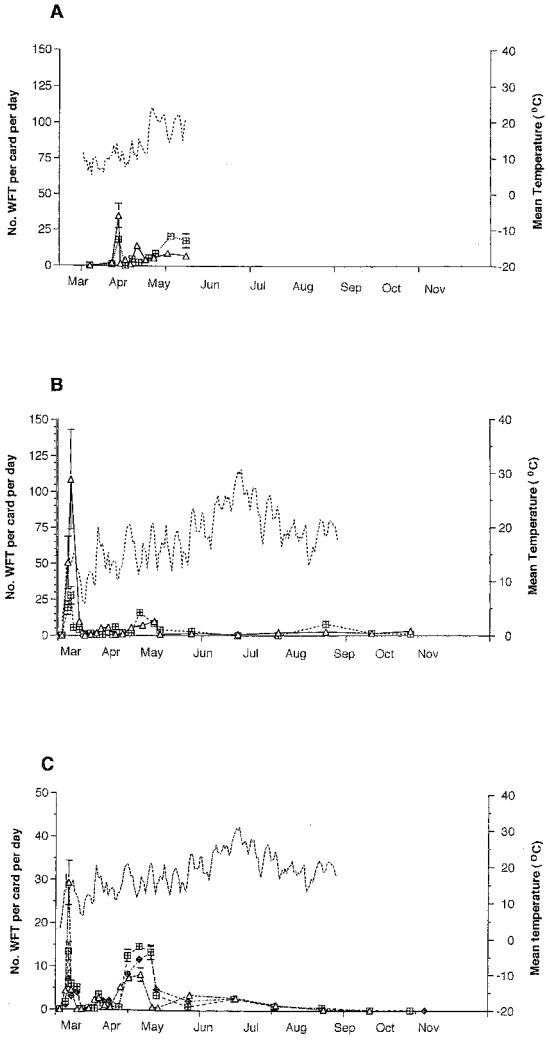

Fig. 2. (a) Mean number of western flower thrips (WFT) caught per card per day from a total of 16 cards (eight posts * two orientations [In and Out]) for areas of wild areas located next to orchards A (triangle) and B (square) between 7 April and 1 June 1993 and concomitant mean daily air temperatures in Keremeos (°C) (dotted line) [B and C]; mean number of western flower thrips caught per card per day from a total of eight cards (four posts * two orientations [In and Out]) from 23 March to 20 November 1994 for (B) wild areas located next to orchards A (triangle) and B (square) and concomitant mean daily air temperatures in Keremeos (°C) (dotted line), and (C) within orchards A (triangle), B (square), and E (diamond) from 23 March to 20 November 1994 and concomitant mean daily air temperatures in Keremeos (°C) (dotted line).

fall (Figs. 3 and 4). Using field examinations of buds we determined that in 1993 there were between zero and five larvae in a flower, with a mode of one; whereas in 1994, with the inclusion of more orchards into the study, some with very high damage levels, there were between zero and nine larvae per flower, also with a mode of one. All larvae collected from buds in both years and reared to adults were western flower thrips.

Temperatures were cooler over the period of bud development in 1993 than 1994, and thus the period during which thrips are believed to lay eggs within buds (pink color to bloom) was generally longer in 1993 than 1994. In 1993, this period was 15.3 ± 2.3 d for southern, and 18.0 ± 0 d for northern orchards; whereas in 1994, these figures were 11.9 ± 0.9 and 14.5 ± 0.5 d for the southern and northern orchards, respectively. Conversely, in southern orchards in 1993, the time from first larval appearance and the time of emergence of the new adult generation was only ≈13 d; whereas in 1994, development from larva to adult occurred over 27 d. Thus, the period for egg laying was longer, but the period for larval feeding was shorter in 1993 than in 1994.

During 1994, the density of adults and larvae per bud was monitored almost daily on four trees in orchard E. Adults peaked on 7 April, when the buds were at ≈20% full pink (Fig. 5), and larvae appeared in buds on 14 April while the trees were still at late bloom and petal fall had barely begun. Numbers of larvae peaked on 25 April. After husk fall no larvae were seen on the fruit surface. In 1993, the second instars dropped to the ground from mid-May onward where they developed through the propupal and pupal stages into adults. Mean densities ± SE of larvae falling to the ground were 76 ± 11.1/m^2 in orchard A and 25 ± 5.2/m^2 in orchard H. Of the orchards examined in 1993, orchard A had the most fruit damage, whereas orchard H had the lowest fruit damage (Table 2).

The new adult generation emerged around 21 May in 1993 and 9 May in 1994, as indicated by large increases in thrips densities on sticky cards placed within orchards (Fig. 2C). This first generation was made up of a mixture of male and female thrips. Western flower thrips of the first (and further) generations were found on a variety of flowering weeds and wildflowers around and within the orchards. Between 21 and 23 May 1993, low numbers of male and female thrips also were found on nectarine leaf clusters. A few of these adult thrips laid eggs on young nectarine leaf tissue (≈6% of leaves had larvae feeding on them by 29 May). Thrips were seen on fruit close to harvest time in August, but growers did not report any damage in the form of silvering at that time.

Flight in Orchards: 1994. Catches of adult western flower thrips on orchard sticky cards were very similar to those seen on the sticky cards in wild areas for the same dates, with a clear peak in late March/early April at the time of emergence of the overwintering generation and a second large peak at emergence of the first generation in May, although peaks were higher in wild areas (Fig. 2 B and C). Western flower thrips populations were at higher levels during the summer in irrigated orchards than in wild areas, but did not exhibit the same peak in the autumn as was seen in wild areas when sage brush bloomed.

Ground Cover. All orchards had a ground cover of orchard grass, *Dactylis glomerata* L., with various wildflowers and weed species occurring over the season.

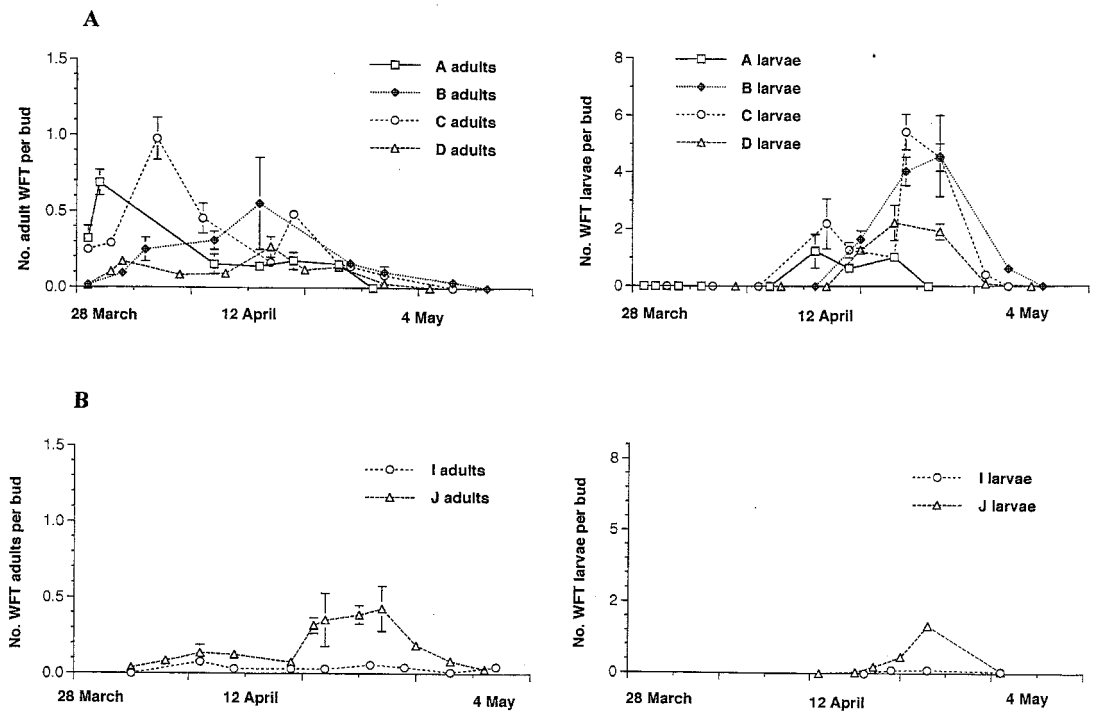

Fig. 3. Numbers of adult and larval western flower thrips (WFT) per bud in (A) four of the southern orchards (A, B, C, and D), and (B) the northern orchards I and J from 7 April to 7 May 1993.

Western flower thrips were found within almost all wild flower, weed, and flowering plant species sampled, both within and bordering orchards, namely: dandelion, *Taraxacum officinale* Weber; alfalfa, *Medicago sativa* L.; Menzie's campion, *Silene cucubalus* Wibel; red clover, *Trifolium pratense* L.; white clover, *Trifolium repens* L.; black mustard, *Brassica nigra* (L.); blue mustard, *Chorispora tenella* (Pallas); chickweed, *Stellaria media* (L.); Canada goldenrod, *Solidago canadensis* L.; common groundsel, *Senecio vulgaris* L.; shepherd's purse, *Capsella bursa-pastoris* (L.); fireweed, *Epilobium angustifolium* L.; wild rose, *Rosa nutkana* K. Presl; big sagebrush; yellow sweet clover, *Melilotus officinalis* (L.); white sweet clover, *Melilotus alba* Medikus; hairy vetch, *Vicia villosa* Roth; pennycress, *Thlaspi arvense* L; and saskatoon, *Amelanchier cusickii* Fern. The only species sampled that did not contain any thrips was yellow salsify, *Tragopogon dubius* Scop. Densities of thrips per bloom are shown for the collections taken during June 1994 during which we saw the greatest diversity of ground cover species and highest densities of western flower thrips (Table 3). Clover and alfalfa appeared to support the largest densities of western flower thrips throughout the season. Larvae were found within blooms of wild rose, dandelion, alfalfa, shepherd's purse, groundsel, and clover.

Density Estimates from Bud Sampling. In 1993 the mean numbers of adult and larval thrips caught over the whole period of bud development in the Similkameen Valley varied significantly among orchards dependent on their location (nested ANOVA: adults, $F = 10.81$; df = 2, 54; $P < 0.001$; larvae, $F = 4.29$; df = 2, 94; $P = 0.02$), with orchards on the hillside adjacent to vast tracts of wild areas (A, B, F: mean = 0.08a), and orchards in the valley adjacent to small sections of wild areas (C, E, G: mean = 0.05a) having more adults than orchards in the valley separated from wild areas (D, H: mean = 0.007b), where means followed by the same letter grade are not significantly different (Tukey HSD test: $P > 0.05$). The hillside orchards (A, B, F: mean = 2.20a) had significantly more larval thrips than all other orchards (means = 1.16b [C, E, G] and 0.92b [D, H]).

Adult western flower thrips were more common in orchards in the Okanagan Valley (I, J) than in the Similkameen Valley (nested ANOVA: $F = 35.33$; df = 1, 75; $P < 0.001$), orchard J having particularly high numbers. Orchards in the north and south had similar numbers of larvae (nested ANOVA: $F = 0.53$; df = 1, 75; $P = 0.67$). In 1994, both the densities of adult and larval thrips caught per sampling date varied significantly among orchards in the Similkameen Valley (nested ANOVA: adults, $F = 29.98$; df = 2, 47; $P < 0.001$; larvae, $F = 15.99$; df = 2, 52; $P < 0.001$) with similarly high densities of adults occurring in orchards located on the hillsides adjacent to vast tracts of wild areas (A, B, F: mean = 0.33a) and in orchards that did not receive any chemical sprays this year (C, E: mean = 0.30a). Lowest densities of adults occurred in those orchards located lower in the valley away from areas of wild areas (D, H: mean = 0.07b). Orchard L

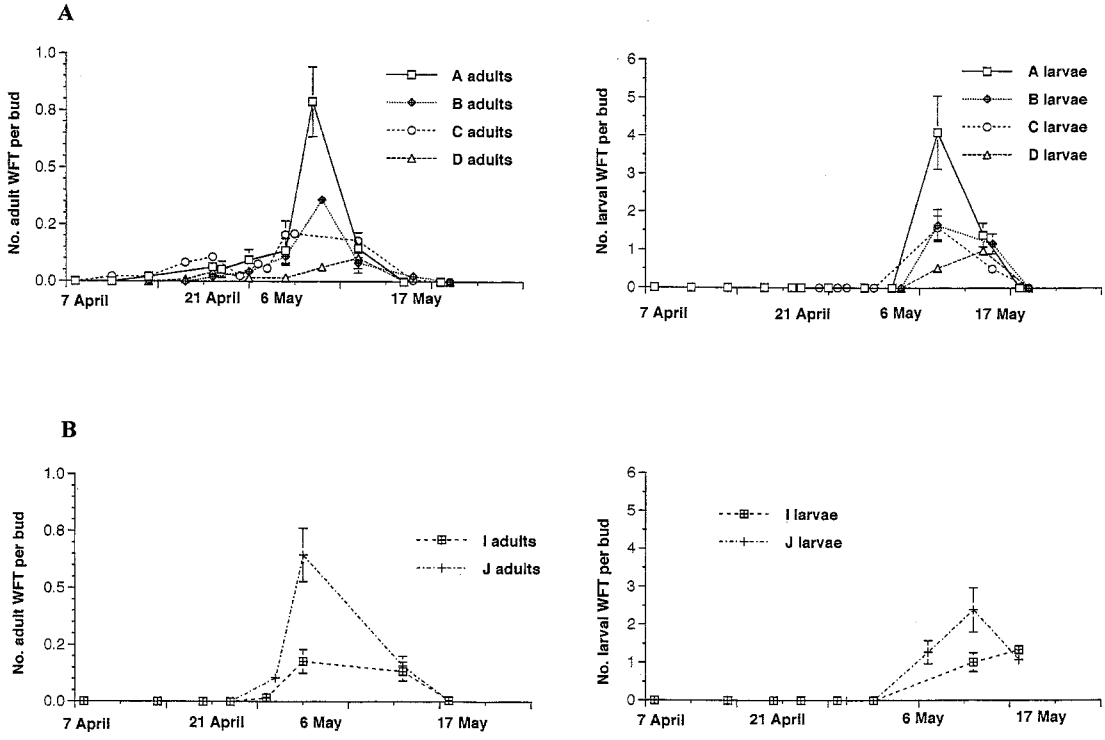

Fig. 4. Numbers of adult and larval western flower thrips (WFT) per bud in (A) four of the southern orchards (A, B, C, and D), and (B) the northern orchards I and J from 28 March to 18 May 1994.

was excluded from this analysis because sampling of adults was irregular. Larvae occurred at similarly high densities in organic orchards (C, E, L: mean = 2.78a) and orchards on the hillside (A, B, F: mean = 2.41a) with lowest densities occurring in valley orchards, D and H (mean = 0.87b). In 1994, unlike in 1993, orchards in the Okanagan Valley had significantly lower levels of adults and larvae than the orchards in the Similkameen Valley (nested ANOVA: adults, $F = 29.98$; df = 2, 47; $P < 0.001$; larvae, $F = 25.31$; df = 2, 66; $P < 0.001$).

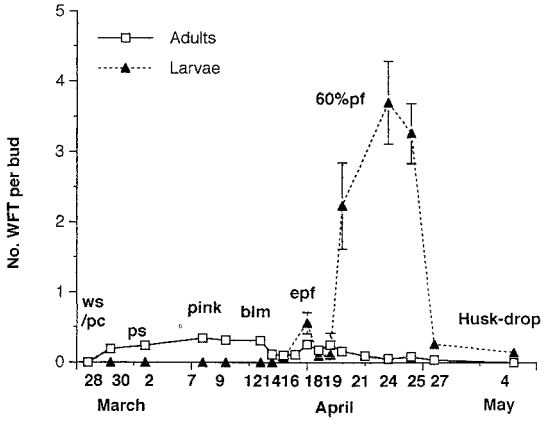

Fig. 5. Intensive sampling of nectarine buds in orchard E for adult and larval western flower thrips (WFT) from 28 March to 4 May 1994. Abbreviations for stages of bud and flower development: ws, white swell; pc, pink color; ps, petal show; pink, (petal nearly developed); blm, bloom; epf, early petal fall; pf, petal fall.

Table 2. Mean damage per tree for each orchard sampled during 1993 and 1994 and statistics for paired *t*-tests for comparison of damage between the 2 yr

Orchard	Mean damage		*t*	df	*P*
	1993	1994			
		Organic			
K	NA	6.30(0.21)	—	—	—
L	NA	3.67(0.25)	—	—	—
		Transitional in 1994			
C	3.28(0.25)	6.44(0.19)	9.869	7	<0.001
E	3.90(0.29)	5.67(0.31)	4.922	7	0.002
		Conventional			
A	5.10(0.25)	2.14(0.13)	10.18	7	<0.001
B	3.56(0.24)	4.17(0.35)	1.269	7	0.245
D	2.80(0.20)	3.93(0.24)	4.703	6	0.003
F	3.07(0.30)	2.90(0.130)	0.295	5	0.780
G	3.53(0.38)	NA	—	—	—
H	2.67(0.11)	1.66(0.16)	6.063	6	0.001
I	4.17(0.36)	1.81(0.25)	4.844	7	0.002
J	4.52(0.29)	2.380.29)	3.779	11	0.003

SEM is given in parentheses. Sample size, 15 fruit from each of eight sample trees per orchard, for orchards A–E, G, H, I, six sample trees for orchard F, and 15 sample trees for orchards J and K. NA, not available.

Table 3. Densities of western flower thrips (WFT) per bloom for ground cover species available in orchard B and J during the month of June, 1994

Flower species	WFT (mean ± SE) per flower head
Orchard B	
White clover	0.96 ± 0.21
Red clover	11.21 ± 0.23
Dandelion	1.07 ± 0.21
Black mustard	1.36 ± 0.15
White sweet clover	0.1 ± 0.15
Purple alfalfa	1.78 ± 0.28
Orchard J	
White clover	3.59 ± 1.59
Red clover	1.46 ± 0.47
Menzie's campion	0.58 ± 0.22
Dark purple alfalfa	1.05 ± 0.28
Pale purple alfalfa	5.30 ± 1.63
Shepherd's Purse	0.61 ± 0.15
Vetch	0.67 ± 0.5
Common groundsel	0.61 ± 0.15
Sweet white clover	0.39 ± 0.14
Yellow salsify	0

For shepherd's purse, black mustard, and sweet white clover, the number of white flower thrips are expressed per stem (a collection of tiny flowers) and for alfalfa, per flower head (an inflorescence of tiny flowers) for a total of 36 stems and flower heads, respectively. For all other species, density of white flower thrips is assessed per bloom from 36 flowers. Flower species are listed in the order of abundance in which they were present in each orchard. See text for scientific names.

Damage Assessment. In both years, fruit damage was visible at husk-fall, which occurred around the end of May in 1993 and around the end of April in 1994. The russetting of fruit, attributable to thrips, was clearly visible when the fruit was only about 1 cm long. Mean damage levels varied between 2.67 and 5.10 in 1993, and between 1.81 and 6.44 in 1994 (Table 2). Mean damage levels of ≈2 and below were considered acceptable by growers in this region, and thus only 10% of orchards in 1993, and 30% of orchards in 1994 showed acceptable damage ratings.

There was significantly greater damage in 1993 than 1994 in orchards A, H, I, and J, and greater damage levels in 1994 than 1993 in orchards C, D, and E (paired t-test, all $P < 0.05$) (Table 2). There was no difference in damage between years in orchards B or F (paired t-test, both $P > 0.05$). In all cases, except orchard H, there were higher densities of larvae in the year coincident with most damage (Pearsall 1998).

In both years, damage levels varied significantly among orchards in the Similkameen Valley (nested ANOVA: 1993, $F = 17.76$; df = 2, 54; $P < 0.001$; 1994, $F = 53.74$; df = 2, 50; $P < 0.001$). In 1993, damage levels were greatest in orchards located on the hillside next to wild areas (A, B, F: mean = 3.97a), with lower and similar levels of damage in orchards lower in the valley (C, E, G: mean = 2.70b) and those in protected locations (D, H: mean = 2.73b). In 1994, damage was highest in the organic orchards (C, E, L: mean = 5.40a), followed by orchards located on the hillside next to wild areas (A, B, F: mean = 3.07a) with lowest levels of damage in the protected orchards, D and H (mean = 2.80b). Northern orchards had significantly higher damage levels in 1993, whereas the opposite was true in 1994 (nested ANOVA: 1993, $F = 34.52$; df = 1, 73; $P < 0.001$; 1994, $F = 54.2$; df = 1, 82; $P < 0.001$).

Factors Affecting Abundance. *Position of Tree in Orchard.* In 1993, there were no apparent relationships between density of adult thrips, density of larval thrips (from the early or late counts), or fruit damage with the position of a tree within the orchard (ANOVA, all $P > 0.1$; Pearsall 1998).

Position of Buds in a Tree. In 1993, thrips numbers per nectarine bud were too low to enable statistical comparisons to detect any differences in the densities of thrips with position within a tree (data not shown). In 1994, there were no significant effects of position within a tree and the density of either adults or larvae for orchards C and E (paired t-tests, df = 7; all $P > 0.1$; ANOVA for larvae in orchard C: $(x + 0.5)^2$ -transformed data, $F = 0.53$; df = 3, 28; $P = 0.66$), except in the case of adults in orchard C, where we found more adults up than down (paired t-test, $t = 3.989$, df = 7, $P = 0.005$) (Pearsall 1998).

Bud Development Stage. In 1993, numbers of adult thrips per nectarine bud did not differ significantly between the full pink and bloom stages in orchard C (paired t-test, $P > 0.05$) (Table 4). In 1994, the abundance of adult western flower thrips per bud was compared for several different bud developmental stages: densities of thrips were equally low between white swell and pink color and also between pink color and early petal show bud stages; for comparisons of full

Table 4. Comparison of western flower thrips (WFT) densities among buds of different developmental stages

Year	Orchard	Bud stages compared	WFT/tree stage (1)	WFT/tree stage (2)	t	P
1994	C	Pink color vs full pink	1.63(0.46)	11.75(1.67)	6.43	<0.001
1994	E	Pink color vs pink	0.25(0.26)	2.88(0.69)	3.12	0.017
1994	K	Early petal show vs pink	0.98(0.52)	4.13(0.95)	3.42	0.016
1993	C	Pink vs bloom	0.63(0.26)	1.75(0.70)	−1.35	0.219
1994	C	Pink vs bloom	3.75(0.98)	5.50(1.18)	2.70	0.031
1994	E	Pink vs bloom	4.25(1.91)	2.63(0.63)	1.30	0.236
1994	K	Pink vs bloom	6.00(1.23)	4.00(0.96)	1.74	0.231
1994	E	Bloom vs petal fall	4.38(0.84)	1.63(0.57)	2.73	0.050

Densities are expressed on a per tree basis (for a total of 12 buds per tree) with associated standard errors in parentheses. White flower thrips per tree (1) and white flower thrips per tree (2) give the density of white flower thrips for the first life stage and second life stage for each paired comparison. Developmental stages are defined in *Materials and Methods.* Statistics given are for degrees of freedom, in each case.

Table 5. Numbers of adult western flower thrips per bud by early, mid- and late bloom stages in 3 orchards in 1994

Orchard	Adults (±SE) per bud			*F*	*P*
	Early bloom	Mid-bloom	Late bloom		
B	7.00 (1.27)	7.00 (1.28)	11 (1.91)	3.210	0.123
E	7.75 (1.41)	4.75 (1.13)	6.00 (1.14)	1.691	0.209
F	9.00 (1.07)	5.00 (1.58)	6.00 (1.51)	2.161	0.140

Statistics given are for 2, 21 degrees of freedom; sample of 24 buds per tree.

pink versus bloom stages, the abundances of thrips per bud did not vary significantly among buds ($P > 0.1$) for orchards E and K, but in orchard C, numbers of western flower thrips per bud were significantly higher in the bloom stage; for pink color versus pink and early petal show versus pink there were significantly greater numbers of adult thrips per bud in the pink stages for all orchards tested ($P < 0.05$ for orchards C, F, and K) (Table 4A). Number of thrips per bud did not vary significantly with bloom stage among the early bloom, mid-bloom and late-bloom stages in orchards B, E, or F (Table 5). Finally, numbers of thrips per bloom bud were higher than per petal fall bud in orchard E (Table 4).

Tree Size. Fruit damage per tree and tree size were not related in any orchard in 1993 (linear regression: all $P > 0.05$). Fruit damage per orchard was not related to the mean tree height or mean tree radius per orchard (linear regression: for radius, $r^2 = 0.161$; df = 1, 6; $F = 1.15$; $P = 0.32$; for height, $r^2 = 0.19$; df = 1, 6; $F = 0.74$; $P = 0.42$).

Time of Day. In 1993, the abundance of thrips per bud was too low to permit statistical analysis, but in general there appeared to be no effect of time of sampling on thrips density estimates. In 1994 in orchard A, there were significantly more thrips per bloom bud in the late afternoon than the noon count; whereas in orchard C, there were significantly fewer thrips per bud for the early morning count than either of the counts later in the day (both $P < 0.05$). For orchard K, no significant differences were detected among the different times of day, but again the late afternoon sample was the highest (Table 6).

Thrips Association with Fruit Damage. In both years, all larvae reared to adults were western flower thrips, suggesting that although there were adults of two other species within blossoms during sampling (*T. fallaciosus* and *H. kurdjumovi*), these species were not laying eggs that develop to viable larvae within the buds, at least during the period of sampling that lasted from dormancy to after petal fall.

Larval Movement. No larvae of any stage were caught on the sticky bands at any of the dates sampled in all of the orchards.

Discussion

The life cycle of western flower thrips in the Okanagan and Similkameen Valleys, British Columbia, begins with emergence of adult female thrips in the early spring from overwintering locations both in areas of wild areas and within orchards. This emergence occurs not only from soil and leaf litter, but also from protected places in the bark of the nectarine trees. Western flower thrips overwinter as adults in the soil, in protected locations such as under leaves, and in crevices in the tree bark (Cranshaw 1988). Felland et al. (1995) recovered overwintering adult western flower thrips in emergence traps placed over leaf litter, dead grass, and bare soil in a nectarine orchard in Pennsylvania. In some areas, for example North Carolina, western flower thrips also overwinter as larvae (Cho et al. 1995). Chamberlin et al. (1992) and Buntin and Beshear (1995) suggested that western flower thrips may reproduce on winter and spring hosts. It is highly unlikely that this occurs in either the Okanagan or Similkameen Valleys where winter temperatures are often well below freezing. Only female western flower thrips appear to overwinter in British Columbia, although males are present in high numbers in the late autumn (unpublished data). Emerging females produced both sons and daughters in both 1993 and 1994 in laboratory studies, which indicates that they had been mated before overwintering (I.A.P., unpublished data). Unmated females would produce only male offspring (Higgins and Myers 1992).

Information on overwintering behavior is critical for pest management decision making. Emergence from the ground did not occur to any great extent until air temperatures reached a daily maximum of 10°C. However, temperature variation in soil, bark, and leaf litter would likely influence the time to emergence of thrips. Adult emergence occurred gradually over a fairly extended period, which makes accurate timing of insecticide application to coincide with emergence impossible. Emergence in both years began before bud burst thus insects are active on trees and may be laying eggs long before buds have developed. Although we found low numbers of thrips in emergence

Table 6. Comparison of adult western flower thrips densities at three different times of day of bud collection

Orchard	Adults (± SE) per bloom at			F/KW	df	*P*
	0830 hours	1330 hours	1800 hours			
A	5.33 (0.76)	4.58 (0.73)	7.42 (1.27)	F = 3.60	2, 23	0.038
C	7.88 (1.51)	12.83 (0.85)	13.83 (1.27)	KW = 14.02	2	0.001
K	7.42 (0.79)	7.25 (0.78)	9.33 (0.88)	F = 1.99	2, 23	0.152

Numbers given are densities of western flower thrips for a pooled sample of 12 buds per tree for a total of 12 trees per orchard. Data for A were $\sqrt{(x + 0.5)}$ transformed, whereas data for orchard C could not be adequately transformed. Statistics given are for ANOVA or Kruskal–Wallis test if the former test was not appropriate.

traps in wild areas as compared with the orchards, the total numbers of western flower thrips overwintering within wild areas may be huge because these areas are expansive.

Adult females were found on dormant buds, but they did not enter buds until the early petal show stage. Adults and first-generation larvae were only found on flowers when these were present, although a few occurred on the young leaf tissue after petal fall. Higgins (1992) found that most larvae were located on leaves, whereas most adult females were associated with flowers of bell peppers, *Capsicum annuum* L., and long English cucumbers, *Cucumis sativus* L. She attributed this niche separation to the temporary nature of the flowers in these crops. The flowers of nectarine are also temporary; however, the buds provide optimal protection for larvae, and the larval development seems to be well synchronized with bud development.

Changes in abundance of thrips were related to changes in crop phenology. At any one time we found the highest densities of western flower thrips in those orchards that were most developmentally advanced, with notable peaks in adults coincident with the full pink and bloom stages of the trees. These thrips also appear to prefer the most developmentally advanced blooms on a tree at any one time, with the exception of the period when trees have a mixture of either pink buds and blooms or blooms and petal fall buds present. In the case of the former, generally equal densities occurred in the two bud types; whereas for the latter, thrips concentrated in the open blooms. Terry and DeGrandi-Hoffman (1988) similarly found that western flower thrips prefer open apple blossoms, *Malus domestica* (Borkh.), to unopened buds or blossoms without petals.

We found no consistent effect on thrips density of location of trees within orchards or buds within a tree. We also found no consistent effect of the time of day on estimates of thrips abundance, although there was a tendency for greater abundance in the early evening. This is in contrast to the results of Yonce et al. (1990) who found that the best time of day to sample for thrips in nectarine was the early morning, because this is the time that they are apparently least active. However, Salguero-Navas et al. (1991) found that the time of day of sampling had no effect on abundance estimates of western flower thrips on tomato, *Lycopersicon esculentum* Mill.

Only one generation of thrips occurs on the nectarine buds, but a few larvae were found on leaves later in the summer, which suggests that there may be limited reproduction by further generations on the leaves of the trees. However, these later generations of thrips did not appear to be causing any damage to the nectarine crop. The bulk of reproduction in orchards after nectarine bloom is probably taking place on the flowers of the ground cover. All ground cover species sampled yielded adult and sometimes larval western flower thrips throughout the summer and autumn. Clover and alfalfa appeared to be the most 'attractive' to the thrips. Felland et al. (1995) also found western flower thrips in clover blooms on the orchard floor in Pennsylvanian nectarine orchards. The presence of larvae in a number of the ground cover species suggested that they were appropriate oviposition sites. The population of thrips overwintering within orchards is most likely derived in part from the ground cover blooms present in the fall. Presence of a ground cover may result in increased densities of western flower thrips in orchards because the flowers (clover, dandelions, and mustards) provided alternate food and oviposition sites for thrips when most other vegetation in this region was parched.

Fruit exhibited varying levels of damage: from no blemishing to severe surface scarring. A separate study found that damage to nectarines by thrips is caused by feeding larvae rather than by oviposition activity or feeding by adult females (Pearsall 1999). The relationship between adult and larval densities and subsequent fruit damage in each orchard was also examined during that study. The minute scars that larvae caused on the tiny developing nectarine ovary grew into large areas of scarred and russetted tissue as the nectarines grew in size. Once the husk dried up, the larvae under the tight husk were protected from any spraying. Larvae did not appear to move about on trees but remained protected within the fruit husk throughout the course of their development until they were ready to fall to the ground to pupate.

Western flower thrips also were found in nectarine blooms in Georgia (Yonce et al. 1990). The relative abundance of thrips varied from year to year in that study, and it was the most injurious species found, causing both russetting injury from feeding larvae and silvering injury from adult feeding near to final fruit swell. The presence of western flower thrips also is associated with injury in nectarine orchards in California, Italy, and France (Bournier 1970, LaRue et al. 1972, Cravedi et al. 1983, Cravedi and Molinari 1984, Grasselly et al. 1993). Injury to nectarines also occurred in Greece (Kourmadas et al. 1982), but this was mainly attributed to *Frankliniella intonsa* (Trybom) and *Taeniothrips meridionalis* Priesner. Because the emergence of western flower thrips in Pennsylvania is well synchronized with petal fall, fruit injury there is mainly in the form of silvering rather than larval scarring (Felland et al. 1995).

Comparisons of thrips densities or damage levels across orchards were complicated by the fact that some orchards were organic, whereas others received pesticide sprays. However, all the orchards sampled in 1993 received some pesticide applications. In 1994, orchards C, E, K, and L received no applications of pesticides and were thus grouped separately for statistical comparison purposes. In general, organic orchards had higher densities of larvae and higher levels of damage than pesticide-treated orchards. However, pesticide sprays of diazinon (Ciba, Greenville, NC) carried out at pink or petal fall in 1993 did not generally result in low levels of damage in orchards A–E. Application of the pesticide endosulfan (Hoechst AG, Frankfurt, Germany) in orchards B and F at the late bloom stage in 1994 also did not appear to achieve

satisfactory damage levels. However, application of endosulfan during the pink stage in 1994 resulted in low numbers of adults within buds and in low levels of damage in orchards A, I, and J (unpublished data). Further studies may resolve whether application of this chemical is effective when applied at the pink stage.

In addition to pesticide use, there was variability among orchards in terms of their location within valleys. In both years, orchards bordering patches of wild areas (A, B, and F) had higher densities of buds infested both by adult and larval western flower thrips, and higher levels of fruit scarring than orchards surrounded entirely by other blocks of trees (D, H). Factors other than location, such as orchard exposure to wind flow, which carries dispersing thrips, also may play a role. Orchards D and H were the least exposed orchards, both almost fully surrounded by other orchards and thus highly protected from wind. Orchards A, C, I, J, and K are the most highly exposed with more than two sides open to wind, with orchards B, E, F, G, and L open on more than one side to wind. Other sources of variability among orchards are the varieties of nectarine grown and the rate of development of the fruit buds. This latter factor appeared to vary because of microclimate effects, with similar varieties of nectarines exhibiting differences of up to a week or more in rate of development dependent on the location of an orchard within the valley (unpublished data). Although the early stages of nectarine development were delayed in the northern orchards relative to the southern orchards, with lower mean and maximum temperatures in the former orchards, these climatic differences did not appear to result in any consistent effects on western flower thrips densities or damage levels.

Although the period between buds coming out of dormancy and full bloom was longer in 1993 than 1994 because of cool and wet conditions, the opposite situation was apparent for the period between the occurrence of larvae in petal fall bud to the emergence of the first generation adults, which was shorter in 1993 than 1994. The bloom progression data for orchard E showed that the period between petal fall and huskfall was very long in 1994, because temperatures fell at this time. Thus, although the period for egg laying was likely longer in 1993, the period for larval feeding activity was longer in 1994. This extended period of larval residence within buds, together with generally higher adult and larval densities in 1994, may account for the increased damage seen in 1994 as compared with 1993 in those orchards not sprayed with endosulfan at pink (B, C, D, E).

In conclusion, the western flower thrips was the most abundant and only injurious species of thrips found in nectarine orchards in the dry central interior of British Columbia, although densities were variable among orchards and in the 2 yr of study. The emergence period in the spring is not likely to be a stage at which pest control options would be effective. Field scouts do not have to be concerned with the location of a tree within an orchard or buds within a tree when sampling for thrips in these orchards but should always choose buds of the same developmental stage if they wish to compare thrips densities among orchards. Orchards located in protected locations had consistently lower densities of western flower thrips than orchards located adjacent to wild areas, which provided a large source area for emerging thrips in the early spring. It would be very useful to further study the differences in immigration of western flower thrips among orchards located close to and far from wild areas.

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References Cited

Bailey, S. F. 1938. Thrips of economic importance in California. Univ. Calif. Agric. Exp. Stn. Circ. 346: 24.

Bournier, A. 1970. Degats des thrips sur nectarines. Phytoma 22: 26–29.

Buntin, G. D., and R. J. Beshear. 1995. Seasonal abundance of thrips (Thysanoptera) on small grains in Georgia. Environ. Entomol. 24: 1216–1223.

Chamberlin, J. R., J. W. Todd, R. J. Beshear, A. K. Culbreath, and J. W. Demski. 1992. Overwintering hosts and wingform of thrips, *Frankliniella* spp., in Georgia (Thysanoptera: Thripidae): Implications for management of spotted wilt disease. Environ. Entomol 21: 121–128.

Cho, K., C. S. Eckel, J. F. Walgenbach, and G. C. Kennedy. 1995. Spatial distribution and sampling procedures for *Frankliniella* spp. (Thysanoptera: Thripidae) in staked tomato. J. Econ. Entomol. 88: 1658–1665.

Cranshaw, W. 1988. Western flower thrips. Colo. State Univ. Coop. Ext. Greenhouse Insect Pest Manage. Sheet No. 3.

Cravedi, P., and F. Molinari. 1984. Tisanotteri dannosi alle nettarine. Inf. Fitopatal. 34: 12–16.

Cravedi, P., F. Molinari, and G. Spada. 1983. Controllo del *Taeniothrips meridionalis* Preisn. (Thysanoptera: Terebrantia: Thripidae) dannoso alle nettarine. Redia 66: 37–46.

Felland, C. M., D.A.J. Teulon, L. A. Hull, and D. K. Polk. 1995. Distribution and management of thrips (Thysanoptera: Thripidae) on nectarine in the mid-Atlantic region. J. Econ. Entomol. 88: 1004–1011.

Grasselly, D., G. Perron, E. Navarro, and E. Delnord. 1993. Thrips du pecher et du nectarinier *Frankliniella occidentalis* observe en verger dans le sud de la France. Infos-Ctifl 90: 25–30.

Higgins, C. J. 1992. Western flower thrips (Thysanoptera: Thripidae) in greenhouses: Population dynamics, distribution on plants and associations with predators. J. Econ. Entomol. 85: 1891–1903.

Higgins, C. J., and J. H. Myers. 1992. Sex ratio patterns and population dynamics of western flower thrips (Thysanoptera: Thripidae). Environ. Entomol. 21: 322–330.

Kourmadas, A. L., T. Zestas, and L. C. Agyriou. 1982. Timing of spraying for control of thrips in nectarine trees. Ann. Inst. Phytophathol. Benaki 13: 120–129.

LaRue, J. H., J. E. Dibble, and G. Obenau. 1972. Thrips in nectarines. Blue Anchor: 21–25.

Lewis, T. 1973. Thrips, their biology, ecology and economic importance. Academic, New York.

Madsen, H. F., and I. D. Jack. 1966. The relation of thrips to pansy spot on apples. Can. Entomol. 98: 903–908.

Pearsall, I. A. 1998. Life history and population dynamics of the western flower thrips in the dry central interior, British Columbia, Canada. Ph.D. dissertation, University of British Columbia, Vancouver.

Pearsall, I. A. 1999. Damage to Nectarines by the Western Flower Thrips (Thysanoptera: Thripidae) in the interior of British Columbia, Canada. J. Econ. Entomol. (in press).

Salguero-Navas, V. E., J. E. Funderburk, R. J. Beshear, S. M. Obon, and T. P. Mack. 1991. Seasonal patterns of *Frankliniella* spp. (Thysanoptera: Thripidae) in tomato flowers. J. Econ. Entomol. 84: 1818–1822.

Tanigoshi, L. K., and D. S. Moreno. 1981. Traps for monitoring populations of the citrus aphid, *Scirtothrips citri* (Thysanoptera: Thripidae). Can. Entomol. 113: 9–12.

Terry, L. I., and G. DeGrandi-Hoffman. 1988. Monitoring western flower thrips (Thysanoptera: Thripidae) in 'Granny Smith' apple blossom clusters. Can. Entomol. 120: 1003–1016.

Venables, E. P. 1925. Pansy spot on apple (a peculiar form of thrips injury). Proc. Entomol. Soc. B.C. 22: 9–12.

Yonce, C. E., R. J. Beshear, J. A. Payne, and D. L. Horton. 1990. Population distribution of flower thrips and the western flower thrips (Thysanoptera: Thripidae) in nectarines and their relative association with injury to fruit in the southeastern United States. J. Entomol. Sci. 25: 427–438.

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