COMPARISON OF SCIRTOTHRIPS PERSEAE (Thysanoptera: Thripidae) Infestation Levels on Avocado Fruit and Leaves

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COMPARISON OF *SCIRTOTHRIPS PERSEAE* (THYSANOPTERA: THRIPIDAE) INFESTATION LEVELS ON AVOCADO FRUIT AND LEAVES

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ABSTRACT

Avocado fruit can be severely damaged by *Scirtothrips perseae* (Thysanoptera: Thripidae) in southern California. *Scirtothrips perseae* is found on leaves and fruit, but its prevalence on one versus the other substrate has not been documented. In this study, the occurrence and infestation levels of *S. perseae* on avocado leaves and fruit during late spring and summer were compared at three sites in Ventura and Santa Barbara Counties, California, from 1998-2000. In all sites and years, adult and larval *S. perseae* were more abundant on young leaves than on small fruit from early to mid June. After leaves matured and hardened with increasing temperatures from late June through August, overall *S. perseae* populations generally declined. However, populations became proportionally higher on fruit than on leaves compared with earlier in the season. This usually resulted in equal numbers on the two substrates and sometimes in higher numbers on fruit late in the season. The change in relative *S. perseae* abundance on leaves and fruit between pre- and post-leaf hardening indicates control efforts need to be made shortly before leaves harden and become unsuitable for *S. perseae* feeding and oviposition or shortly after the first thrips move onto fruit.

Key Words: *Scirtothrips perseae* populations, avocado leaves, fruit, leaf development, fruit development

RESUMEN

La fruta del aguacate puede ser dañada severemente por *Scirtothrips perseae* (Thysanoptera: Thripidae) en el sur de California. *Scirtothrips perseae* se encuentra sobre las hojas y las frutas, pero la prevalencia de substrato sobre el otro no ha sida documentada. En este estudio, los niveles de ocurrencia e infestación de *S. perseae* en las hojas y en la fruta de aguacate durante el final de la primavera y el verano fueron comparadas en tres sitios en los condados de Ventura y de Santa Barbara, California desde 1998 hasta 2000. En todos los sitios y todos los años, los adultos y las larvas de *S. perseae* fueron más abundantes en las hojas tiernas que en las frutas pequeñas desde el principio hasta la mitad de junio. Después que las hojas maduraron y endurecieron con el aumento de la temperatura desde el final de junio hasta el final de agosto, la población de total de *S. perseae* declinó generalmente. No obstante, la población se convertió proporcionalmente más alta en las frutas que en las hojas comparada con al principio de la estación. Esto usualmente resultó en números iguales sobre los dos substratos y a veces números mas altas sobre la fruta en la época posterior de la estación. El cambio en la abundancia relativa de *S. perseae* sobre las hojas y las frutas entre el pre-endurecimento y el pos-endurecimiento de las hojas indica que las medidas de control deben ser realizadas un poco antes de cuando las hojas se endurecen y se vuelven no apropiadas para la alimentación y la oviposición de *S. perseae* o un poco después de que los trips se movieron encima de la fruta.

Scirtothrips perseae Nakahara (Thysanoptera: Thripidae) is a serious pest of avocado, *Persea americana* Miller, in southern California, USA (Hoddle et al. 1998). Discovered in 1996 in Ventura County, CA (Hoddle & Morse 1997), and described in 1997 (Nakahara 1997), *S. perseae* has been responsible for millions of dollars in damage as a result of its feeding on and scarring of avocado fruit (Hoddle et al. 1998), with losses to the California avocado industry in 2000-2001 estimated at $8.65 million (Hoddle et al. 2003). Even though our understanding of *S. perseae* biology is increasing (Hoddle et al. 2000, 2001; Hoddle 2002), little is known about the relationship between *S. perseae* populations on avocado leaves and fruit, and the factors influencing their prevalence on one versus the other substrate. Factors related to infestation on fruit are of particular interest because economic damage caused by thrips feeding primarily occurs on fruit. The feeding results in scarring and downgrading or rejection of fruit in packinghouses. To better understand *S. perseae* field ecology and to develop less insecticide-oriented pest control strategies, it is necessary to investigate patterns of substrate use by *S. perseae* and to relate them to patterns of leaf and fruit development.

Feeding on leaves and fruit of various hosts by other thrips species is well documented. The citrus thrips, *Scirtothrips citri* (Moulton), feeds on leaves and fruit of citrus (Metcalf & Flint 1962). The pear thrips, *Taeniothrips inconsequens* (Uzel) (Felland et al. 1995), bean thrips, *Hercothrips fasciatus* (Pergande) (Metcalf & Flint 1962), and the flower thrips, *Frankliniella occidentalis* (Pergande) (which is well known to feed in flowers) (Salguero-Navas et al. 1991), also feed on foliage and fruit of their hosts. On avocado, the greenhouse thrips, *Heliothrips haemorrhoidalis* Bouché, feeds on mature leaves and fruit (Smith 1929; Bekey 1986).

In this study, infestation levels of *S. perseae* on avocado leaves and fruit are compared and their relationships with periods of leaf and fruit development are described. We hypothesized that *S. perseae* stays on leaves that are young, but moves onto fruit as leaves mature and harden during late spring and early summer, accounting for high populations and damage observed on fruit during this time.

Materials and Methods

Study Sites

Data were collected from three orchards that were untreated with insecticides (with one exception, see below) and that had 'Hass' avocado trees in Santa Barbara and Ventura Counties, CA, from 1998-2000. Trees were 10-18 years old and 4.6-6.2 m tall. Orchards were located in the cities of Carpinteria (Santa Barbara County), Somis, and Moorpark (both Ventura County). These sites represented coastal (cool temperature), intermediate (moderate temperature), and inland (warm temperature) (Kimball & Brooks 1959) distributions of *S. perseae*, respectively. Moorpark was treated once with an insecticide (abamectin) in June 2000.

Temperatures were determined within the three sites throughout the season using StowAway XT1 temperature loggers (Onset Computer Corp, Pocasset, MA). Loggers were hung from branches in the canopy. Data were recorded daily every 30 min.

Sampling for *S. perseae* on Leaves and Fruit

Numbers of adult and larval *S. perseae* were recorded by visually examining 100 leaves and 100 fruit on the trees at the three sites from June through August 1998 and 1999 and from June through July 2000 when fruit first appeared. Adults and larvae were large enough so that a hand lens was not required. Flowers were not examined because they last only about 24 h (Bergh 1973) and because the western flower thrips, *F. occidentalis*, is the predominant species in them, not *S. perseae* (Hoddle 1999). Younger, three-quarters expanded leaves (Hoddle 2002) were sampled, but when these were unavailable, older, hardened leaves had to be sampled. Upper and lower surfaces of leaves were examined, although the majority of thrips was found on lower surfaces. Lengths of all leaves and fruit were measured. Dates when the majority of leaves began to harden were recorded. Hardening of leaves was determined visually. The youngest leaves were mostly reddish brown; older but still young, three-quarters expanded leaves were light green and flexible. Hardened old leaves were dark green, shinier, and rigid.

In 1998, 20 leaves and 20 fruit from five trees were randomly sampled. In the case of leaves, random sampling occurred within young leaves (unless absent) and not among all leaves. Thrips were congregated on young leaves, so whether the thrips were dispersed or aggregated in the tree depended on the amount of leaf flush present. In 1999 and 2000, 10 leaves and 10 fruit from 10 trees were randomly sampled. Sampled leaves and fruit were located 1.5-2.0 m above ground, a height chosen for practicality. In all years, sampling was conducted approximately every one or two weeks.

Exceptions to the above protocol in 1998 were as follows. On 10 June in Somis, 20 leaves and 20 fruit from only three trees were sampled. In three cases, there were no fruit present in two or three out of the five trees designated for sampling. Thus, on 25 June in Somis, 20 leaves on each of two trees were matched with 20 fruit from two neighboring trees. On 11 and 29 June in Moorpark, 20 leaves on each of three trees were matched with 20 fruit from three neighboring trees.

Statistics

To compare *S. perseae* infestation levels on fruit and leaves, the Mann-Whitney U-test was conducted on data within individual dates. The hypothesis tested was that the medians of thrips populations on fruit and leaves were the same (i.e., populations had the same statistics of location [Sokal and Rohlf 1981]). Numbers on fruit and leaves from the same tree were paired and considered replicated observations (n = 5 and 10 trees/date and 10 and 20 leaves or fruit/date, except n = 3 on 10 June 1998 in Somis). When there were many or all zero data on fruit or leaves, the t-test was used to compare the paired samples after counts were transformed (square root + 1). Statgraphics Plus (1997) was used for all analyses.

Results

Temperatures

Mean weekly temperatures at Carpinteria, Somis, and Moorpark from 1998-2000 are shown in Fig. 1. Carpinteria was the coolest site, Somis was

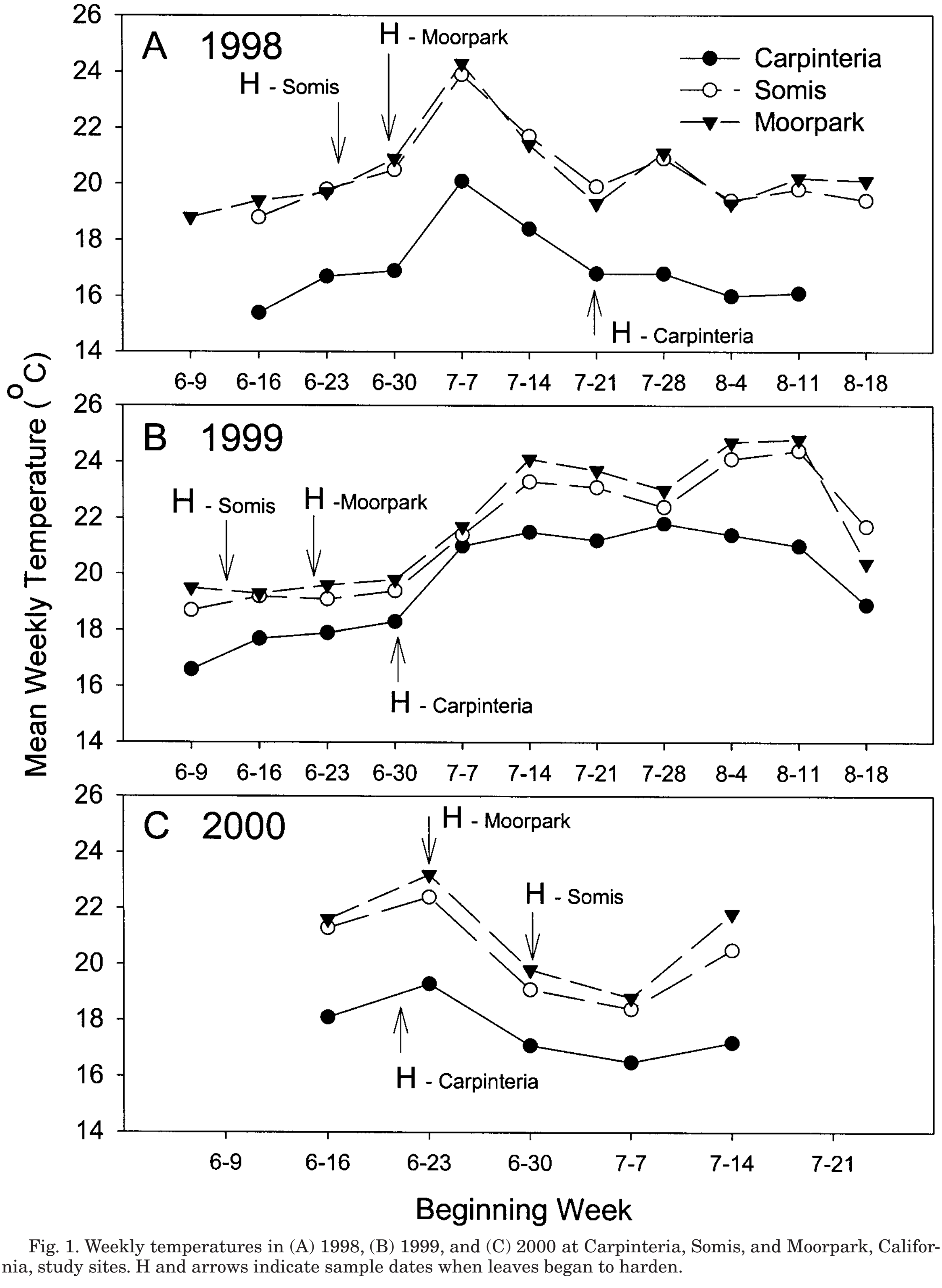

Fig. 1. Weekly temperatures in (A) 1998, (B) 1999, and (C) 2000 at Carpinteria, Somis, and Moorpark, California, study sites. H and arrows indicate sample dates when leaves began to harden.

intermediate, and Moorpark was the warmest. Gradually increasing temperatures in late June were associated with initial leaf hardening, which occurred the latest at Carpinteria, except during 2000 (Fig. 1). Mean high temperatures at Carpinteria in June, July, and August in 1998-2000 were

22.2, 24.3, and 24.6°C, respectively (no data for August 2000). At Somis, mean high temperatures were 27.7, 29.4, and 30.6°C, respectively, and at Moorpark, they were 28.9, 30.6, and 31.8°C, respectively. Sustained high temperatures in early and mid July were generally followed by overall declines in adult (Figs. 2-4) and larval (Figs. 5-7) *S. perseae* populations during late July and August.

Infestation Levels on Leaves and Fruit

In general, for all sites and years, adult *S. perseae* were found in significantly higher numbers on leaves than fruit when fruit were first seen in early June (Figs. 2-4). However, as leaves hardened from June into July, differences were usually not seen between substrates. This trend was also generally true of larvae, although larval abundance was significantly higher on fruit than on leaves after leaves hardened during late season in several cases (Figs. 5-7). Noteworthy significant site-specific patterns were as follows.

Carpinteria

At Carpinteria in 1999, a protracted period of sporadic leaf flush following initial leaf hardening coincided with higher populations of adults (Fig. 2B) and larvae (Fig. 5B) on leaves than fruit from 22 June to 10 August. This period with higher thrips numbers on leaves was longer than for the other two years.

Somis

At Somis in 2000, adult numbers were higher on leaves than on fruit for all but one sample date (Fig. 3C). However, in 1998 and 1999, larval numbers were higher on fruit than leaves on three dates in July and August of each year (Figs. 6A and 6B, respectively).

Moorpark

At Moorpark in 1999, adult numbers were higher on fruit than leaves on one date (Fig. 4B). In 1998, larval numbers were also higher on fruit than leaves on two dates in August (Fig. 7A) and in 1999 on three dates in August (Fig. 7B).

Relationships Between Infestation Levels and Leaf and Fruit Lengths

Younger leaves were approximately the same lengths from June to August. There was no correlation between adult and larval infestation levels and leaf lengths ($P > 0.05$). Thus declines in *S. perseae* abundance on leaves were not related to leaf lengths, but were associated with when leaves hardened at Somis in 1998 and 2000, Moorpark in 2000, and Carpinteria in 1998 and 1999.

Fruit lengths increased from 0.5-6 cm during June to August. Increases in *S. perseae* abundance on fruit were positively correlated with fruit lengths up to mid July, but they were not positively correlated over the season ($P > 0.05$). Thrips were first seen on 0.5-1.4 cm long fruit. Numbers were highest on 3-4 cm long fruit, but numbers declined on fruit >5 cm long (Figs. 2-7).

Discussion

The results support our hypothesis that *S. perseae* tends to stay on young leaves until they mature and harden during early summer. Despite the later onset of leaf hardening at the coolest site, the sequence of events that resulted in infestation on fruit was the same at all three sites. Growth flush was followed by simultaneous hardening of leaves and fruit appearance (and absence of flowers), which seemed responsible for *S. perseae* movement onto developing fruit. In general, these events were also associated with gradually increasing temperatures that probably caused rapid leaf development and hardening.

Our results suggest adult *S. perseae* prefer young leaves that are 15-17 cm long over small fruit that are <1.5 cm, at least as resting or feeding sites. However, larger fruit 3-4 cm long may be more preferred than smaller fruit, and perhaps more than young leaves. Within fruit, those 2.5-5.4 cm in diameter are preferred over those smaller or larger for oviposition (Hoddle 2002), and immature fruit 2.85 cm in diameter (2.87 larvae/fruit) apparently are preferred for oviposition over undersides of three-quarters expanded immature leaves (1.53 larvae/leaf) (Hoddle 2002). In our study, however, it was unclear if the higher adult and larval numbers on the 3-4 cm long fruit compared with the smaller fruit were caused by an actual preference for larger fruit or a lack of suitable leaves. In other thrips, *T. palmi* Karny and *F. occidentalis*, there is an apparent preference for foliage and flowers over fruit of cucumber (Rosenheim et al. 1990).

Leaves clearly are larval developmental sites for *S. perseae* (Hoddle & Morse 1998; Hoddle 2002). However, adults probably cannot feed on or oviposit into mature leaves and this may force them onto fruit. We have also observed larvae congregating on leaf stems when populations on leaves are high. This suggests larvae can also move from leaves to fruit after leaf resources are depleted by high feeding activity.

Interestingly, in its native subtropics, where 'Hass' avocado tree phenology is different than in the United States (Teliz 2000), *S. perseae* seems to rarely infest fruit (Phillips 2003). In Mexico, fruit appear in February during leaf flush (Phillips 2003) rather than at or near the end of leaf flush, as it usually did at our study sites. In Mexico, thrips are also found feeding on and scarring foli-

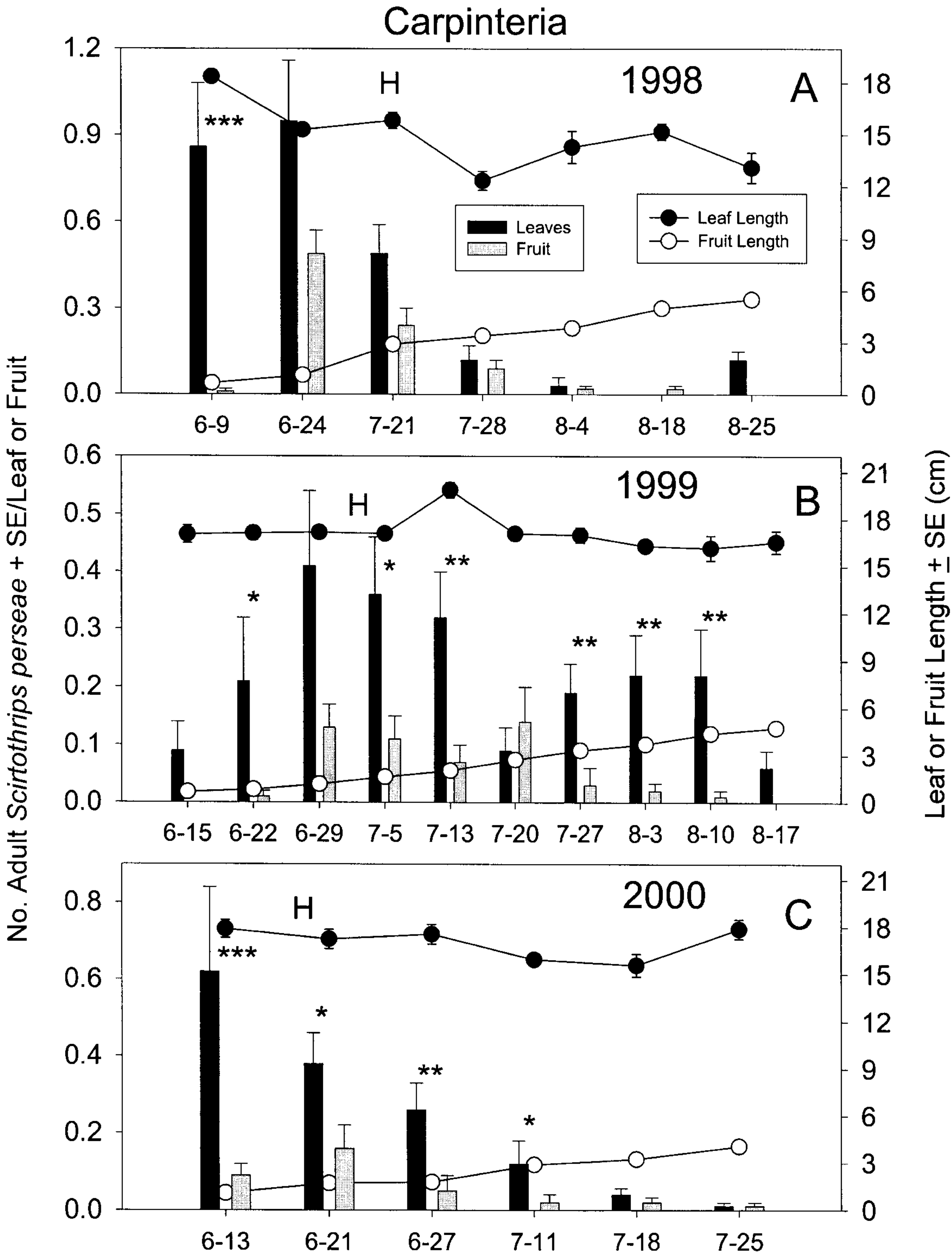

Fig. 2. Numbers of adult *S. perseae* + SE on leaves and fruit at Carpinteria, California in (A) 1998, (B) 1999, and (C) 2000 related to leaf and fruit lengths. H = leaves began to harden. Asterisks indicate significance detected by the Mann-Whitney U-test or t-test (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

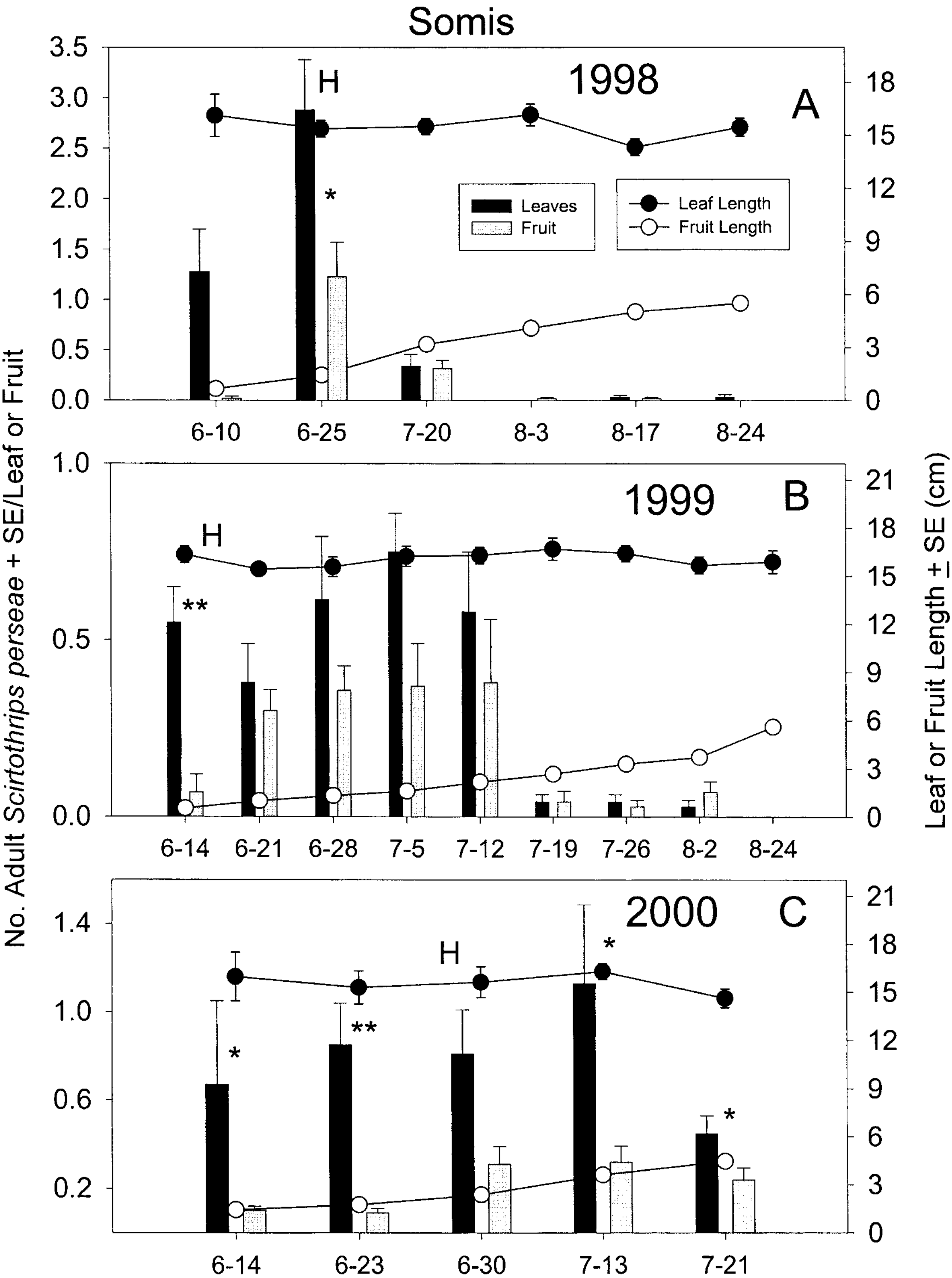

Fig. 3. Numbers of adult *S. perseae* + SE on leaves and fruit at Somis, California in (A) 1998, (B) 1999, and (C) 2000 related to leaf and fruit lengths. H = leaves began to harden. Asterisks indicate significance detected by the Mann-Whitney U-test or t-test (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

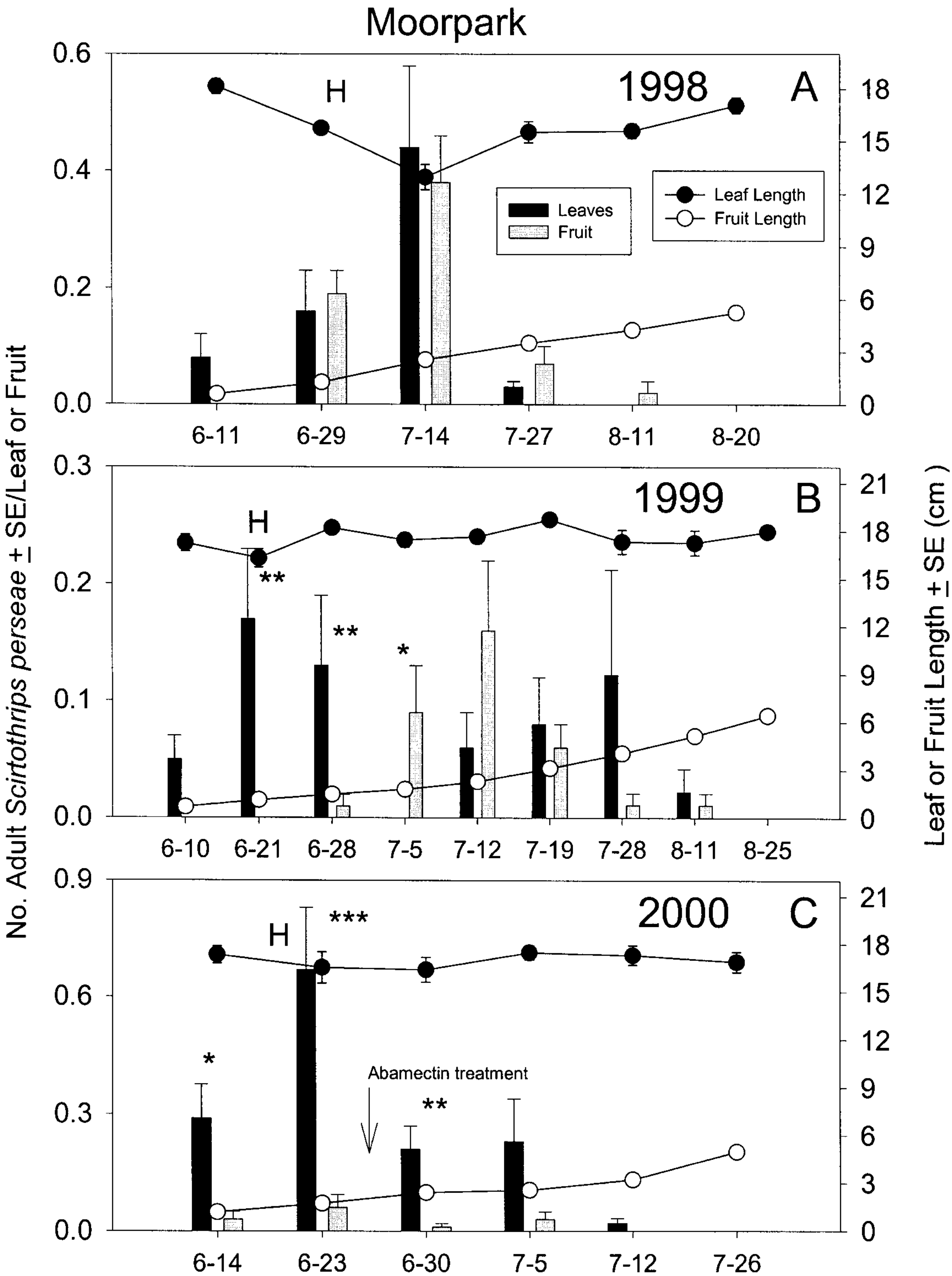

Fig. 4. Numbers of adult *S. perseae* + SE on leaves and fruit at Moorpark, California in (A) 1998, (B) 1999, and (C) 2000 related to leaf and fruit lengths. H = leaves began to harden. Asterisks indicate significance detected by the Mann-Whitney U-test or t-test (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

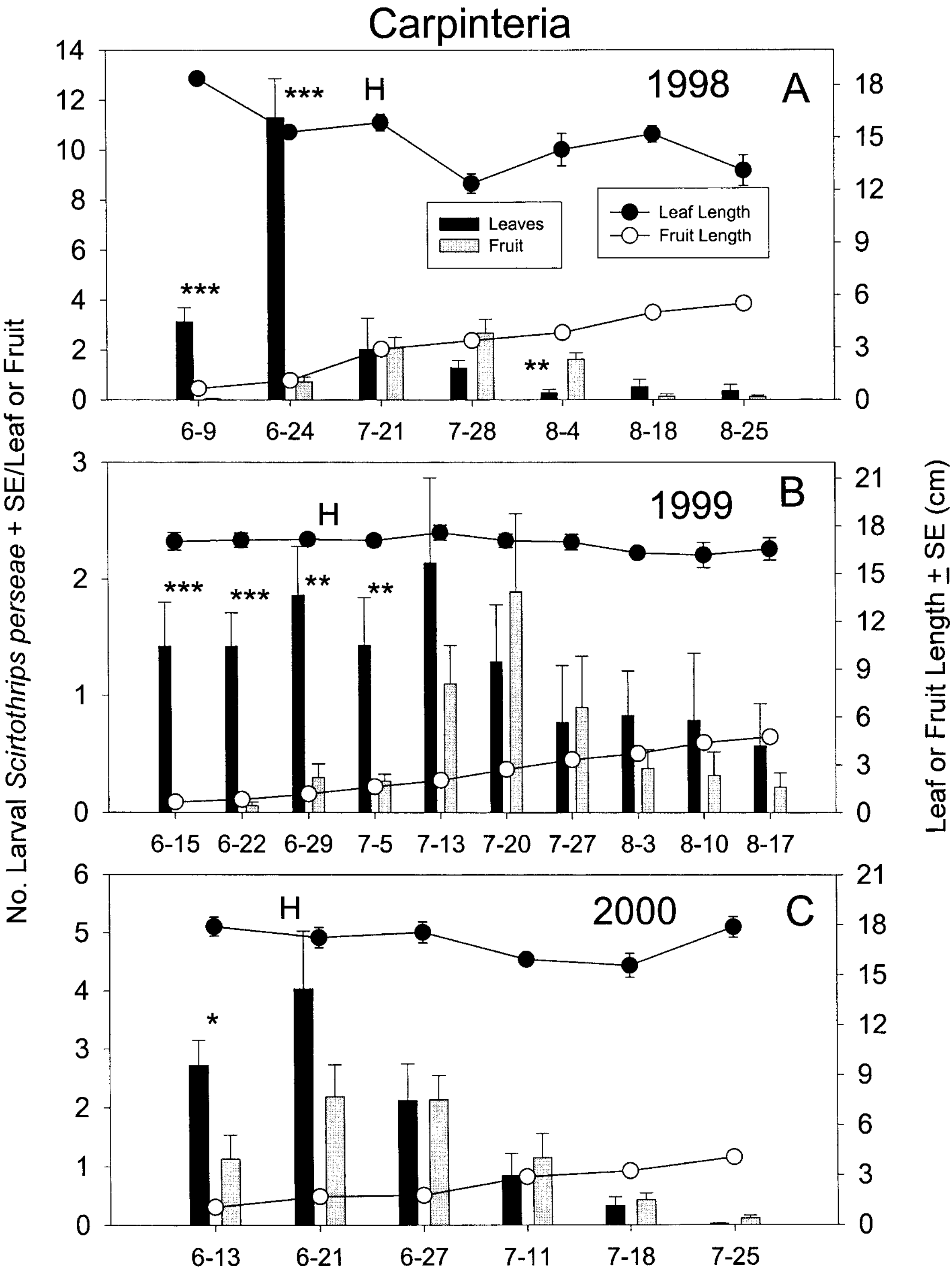

Fig. 5. Numbers of larval *S. perseae* + SE on leaves and fruit at Carpinteria, California in (A) 1998, (B) 1999, and (C) 2000 related to leaf and fruit lengths. H = leaves began to harden. Asterisks indicate significance detected by the Mann-Whitney U-test or t-test (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

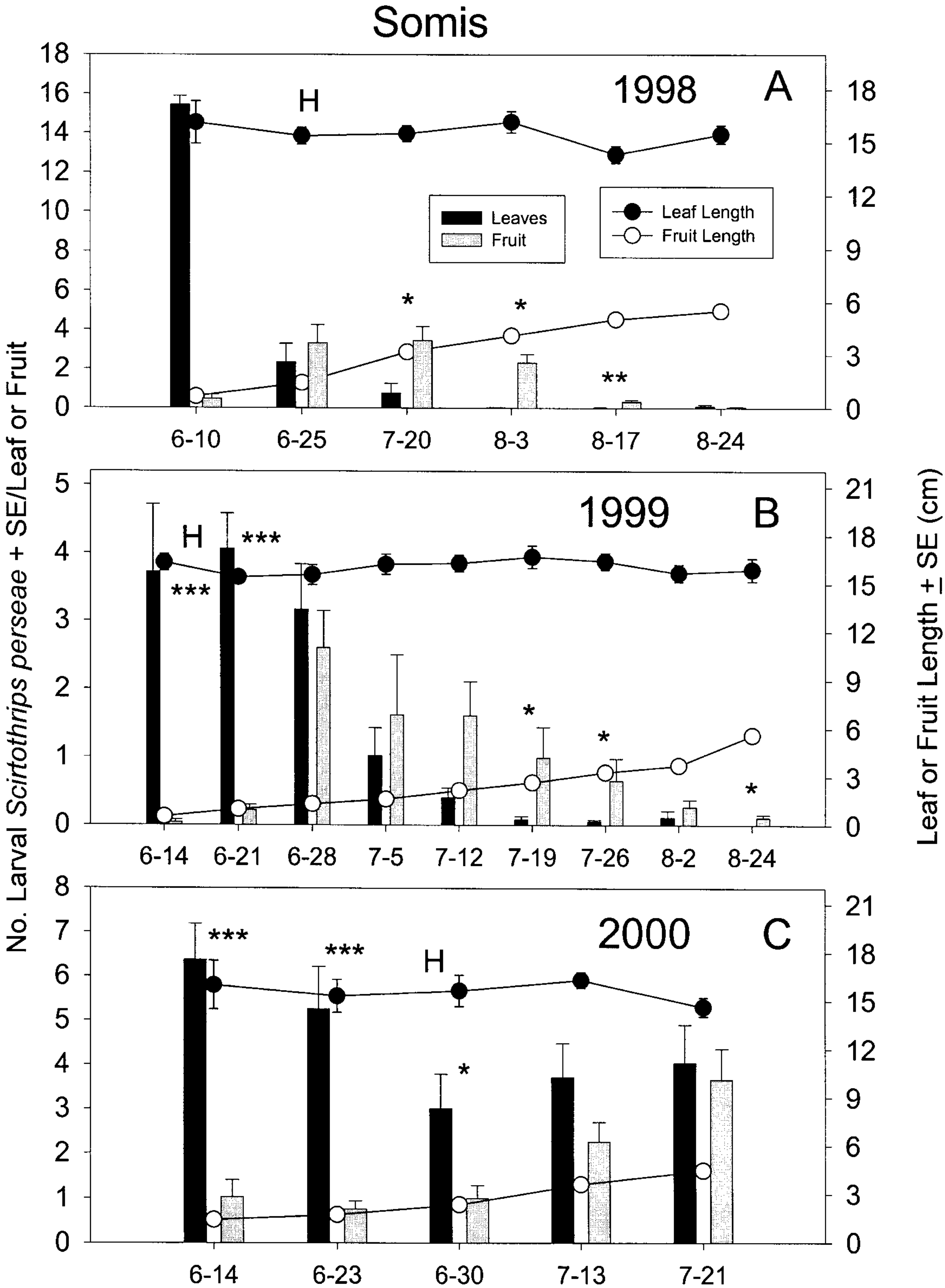

Fig. 6. Numbers of larval *S. perseae* + SE on leaves and fruit at Somis, California in (A) 1998, (B) 1999, and (C) 2000 related to leaf and fruit lengths. H = leaves began to harden. Asterisks indicate significance detected by the Mann-Whitney U-test or t-test (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

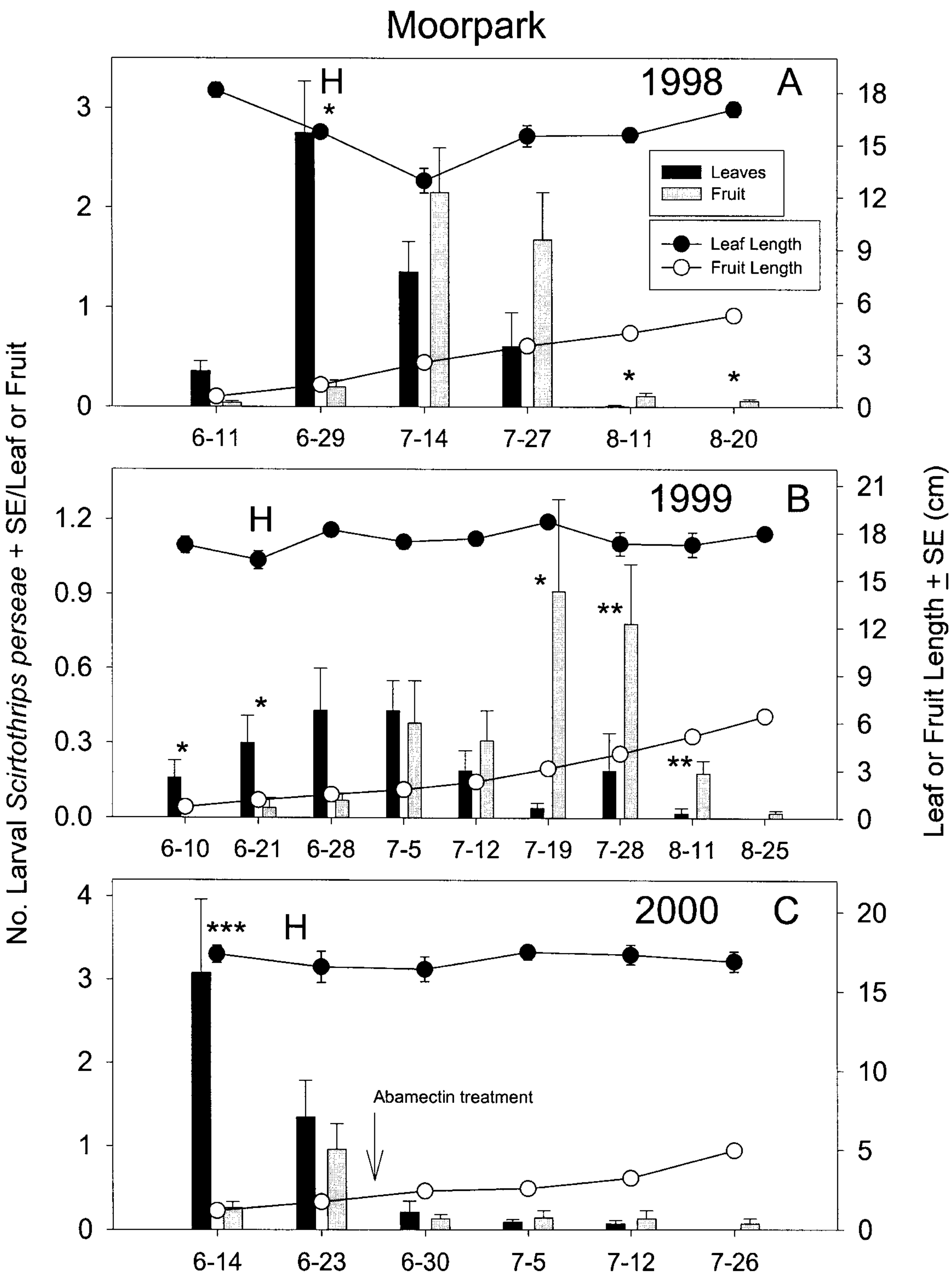

Fig. 7. Numbers of larval *S. perseae* + SE on leaves and fruit at Moorpark, California in (A) 1998, (B) 1999, and (C) 2000 related to leaf and fruit lengths. H = leaves began to harden. Asterisks indicate significance detected by the Mann-Whitney U-test or t-test (**P* < 0.05, ***P* < 0.01, ****P* < 0.001).

age early in the season prior to fruit set. In addition, thrips populations are low by the time of fruit set, when temperatures are often well above 29°C (P. A. Phillips, unpublished). Laboratory data show that *S. perseae* develops poorly at high temperatures. When held at 30°C, 61% fewer larvae emerged from leaves than at 25°C (Hoddle & Morse 1998). Temperatures were still relatively cool and thrips populations were high at the beginning of fruit set at our three study sites. The combined evidence suggests southern California avocado growing conditions have contributed to the current pest status of *S. perseae*. It must be noted, however, that the phenology of leaf flush and hardening even within southern California varies from year to year. Thus leaves and fruit may not always be present at the same time, which may alter the patterns seen in this study.

The change in relative *S. perseae* abundance on leaves and fruit between pre- and post-leaf hardening indicates control efforts need to be made shortly before leaves harden and become unsuitable for *S. perseae* feeding and oviposition or shortly after the first thrips move into fruit. Insecticide treatments may need to be considered when a threshold of 3-5 thrips larvae per leaf is reached, as this corresponds later to 6-15% economic damage of fruit when treatments are not applied (Yee et al. 2001). Future studies need to determine more precisely how the timing of leaf growth flush in relation to fruit set can be used to predict potential movement of *S. perseae* from leaves onto fruit and to prevent scarring damage.

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