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Research

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Mature Larval Dispersal and Adult Emergence of the Economically Significant Pest, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae), in Commercial Citrus

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Abstract

Scirtothrips aurantii Faure (Thysanoptera: Thripidae) is a major pest of citrus fruit in subtropical southern Africa. Population monitoring is an important aspect of *S. aurantii* control, but additional information is required on its phenology. Dispersal of mature larvae onto the soil surface from the tree canopy, and emergence of adults, were assessed using dispersal/emergence (D/E) traps in an untreated citrus orchard in South Africa. Overall, 90.7% of adult Thysanoptera emerging from soil / leaf litter beneath the citrus trees were *S. aurantii*, of which 35.7% were males, and 64.3% were females. Female *S. aurantii* having survived winter as adults oviposited on the early spring flush. This resulted in the first population peak of larvae dropping to the ground to pupate and adults emerging in spring, September to early October, as the first vegetative flush of the citrus-growing season hardened, and fruit was set as blossoming ended. Initial infestation of young fruit occurred after a build-up of larval numbers on the soft citrus flush late July to early August. The second generation larval and adult peak occurred late November to early December, whether there was new flush or not, as young fruit could support the *S. aurantii* population. A third peak occurred mid-December to late January, depending on year. Thus, there were three generations of *S. aurantii* during the period of citrus fruit susceptibility to thrips damage (September–January). After the autumn flush in April, another peak of larvae and adults occurred before the population declined to a minimum from May to July.

Key words: Thripidae, citrus, survey, dispersal/emergence trap, abundance

The South African citrus thrips, *Scirtothrips aurantii* Faure (Thysanoptera: Thripidae), is widespread across Africa and has many host plants of economic importance (Faure 1929, Mound and Palmer 1981, Rafter and Walter 2012). In South Africa, it causes significant economic cosmetic damage to citrus, rendering fruit undesirable for the export market (Samways 1986; Samways et al. 1986, 1987; Gilbert and Bedford 1998). It has become more significant from a global perspective as it has established in Australia, but so far only on the alien pasture weed *Bryophyllum delagoense* (Eckl. & Zeyh.) Schi nz, (Saxifragales: Crassulaceae) (Mound & Stiller 2011; Rafter et al. 2011, 2013; Garms et al. 2013).

The natural enemy complex of *S. aurantii* is generally ineffective, although a parasitoid and predacious mites play a valuable role in some production areas (Grout and Richards 1992, Grout and Stephen 1995). This means that chemical control is essential in most citrus production areas. When there is no chemical control, damage levels can be high in some major production areas (Samways 1986), and in some seasons it poses a serious threat, especially in the northern lowveld production areas of South Africa (Gilbert and Bedford 1998), with the cost of control >50% of the total pest control budget. *S. aurantii* is also a species with phytosanitary implications, making it of global concern (Wang et al. 2015).

Monitoring of *S. aurantii* is vital so as to determine when to apply chemical control to prevent economic damage. This involves precise spray application following petal fall. The timing of sprays can be aided by monitoring of flying phototactic adults using yellow traps with a peak reflectance of 525 nm (Samways 1986, Samways et al. 1986). The timing of thrips peaks can vary with latitude (Samways et al. 1987). Scouting of fruitlets for *S. aurantii* population levels at the end of petal fall until fruit is old enough to no longer be susceptible to damage is also important. Fruit scarring, which begins after petal-fall, can vary in appearance depending upon the timing and severity of infestation as well as fruit size.

S. aurantii is abundant and has a contagious dispersion pattern in citrus orchards while, in indigenous vegetation, its population is low and variable (Samways 1986, Samways et al. 1987, Gilbert 1990). What this means is that the orchard is a reservoir for the insect in comparison with the surrounding natural vegetation. Although thysanopteran larvae remain above ground during development on their host plant, pupation in certain species may occur in the soil beneath (Varatharajan and Daniel 1984, Lewis 1997). In the United States, dispersal/emergence (D/E) traps, which sample mature larvae falling to, and emerging adults rising from, the soil have been used for the detection of the Californian citrus thrips, S*cirtothrips citri* (Moulton) (Reed and Rich 1975, Tanigoshi and Moreno 1981). Between 33% (Grout et al. 1986) and 49–90% (Schweizer and Morse 1996) of *S. citri* adults in young citrus orchards have been estimated to have emerged from pupae on the orchard floor.

In the case of *S. aurantii*, Bedford (1943) demonstrated that mature larvae drop to the soil to pupate, although it is not known whether every individual exhibits this behavior. Nevertheless, D/E traps have proved to be useful when sampling Thysanoptera spp., including *S. aurantii*, in South African mango orchards (Grové et al. 2000, 2001).

The object of this study was to determine whether meaningful citrus thrips population peaks could be detected using D/E traps and to relate these to the flushing rythmn of citrus and to the period during which fruit is vulnerable to thrips damage in southern Africa. More information on this species is required, as *S. aurantii* is assuming greater importance globally (Mound and Stiller 2011, Garms et al. 2013, Rafter and Walter 2013). We explore here the use of the D/E trap to fine focus the phenology of *S. aurantii* in relation to both the larvae and the adults on citrus in South Africa, which has not been done before. We also compare results with those that have been found for *S. citri* in the U.S. citrus (Reed and Rich 1975, Grout et al. 1986) to seek generalizations.

Materials and Methods

Our studies were carried out in a small (200 mature 25-yr old trees with 2.5 m wide canopy per tree) Washington Navel orange (*Citrus* x *sinensis* (L.) Osbeck) orchard (plot 371, section L), on the property known as Letaba Estates (co-ordinates 23° 51′ 46″ S, 30° 19′ 09″ E), a large citrus farm in the Lowveld region of Limpopo Province, South Africa. Irrigation in the experimental orchard was by way of microsprinklers (Netafim SA, Nelspruit, South Africa). Fertilization was achieved through a program of applied granular limestone ammonium nitrate (Kynoch Fertilizers, Johannesburg, South Africa) supplemented by foliar feeds of urea. The orchard received no insecticidal applications during our study from 1986 to 1988 so that the natural population fluctuations of *S. aurantii* in the citrus orchard could be monitored.

Each D/E trap consisted of a PVC cylinder (internal diameter 190 × 200 mm tall). A clear square of poly(methyl methacrylate) sheet (Perspex), 220 × 220 × 2 mm was covered on both sides with a transparent film of sticky polybutene, and was placed on top of the cylinder to form the trapping surface on both sides of the plate, catching emerging adults below and falling larvae above (Lewis 1997).

As D/E traps have not been used previously to sample *S. aurantii* on citrus, the trap position for maximizing the numbers of thrips individuals caught needed to be determined. Traps were placed at the cardinal compass points (N, E, S and W) around three citrus trees at varying distances from the trunk (30, 60, 90, 120 cm), making a total of 16 traps per tree. The traps were left in place for 1 wk, after which the Perspex squares were covered on both sides with cling film wrap and taken to the laboratory for examination under a microscope. The layer of cling film wrap was replaced each week. The position of the PVC pipe was changed weekly to avoid re-sampling an already sampled area. Each trap was moved to an adjacent patch of ground every week (within the same quadrant) and then returned to its original position the following week. This was repeated for three separate weeks in May–June, the time when many *S. aurantii* individuals were present on an out-of-season growth flush and fruit set. A total of nine single-tree replicates and 144 individual trap counts were made.

Having established the optimal position for trap placement in relation to the tree trunk, the major assessment began. Four D/E traps per tree were placed 30 cm from the trunk under each of six citrus trees within the orchard. The horizontal trapping surface was replaced weekly and the trap moved to allow the monitoring of emerging adults to continue, as mentioned above. The occurrence of vegetative growth periods (flushes) was also recorded throughout the duration of the study. Monitoring for thrips took place weekly, September Year 1 to January Year 3, and also June to December Year 3.

All thysanopteran larvae and adults caught on the upper or lower sides, respectively of the traps were recorded. Emergence rate was estimated as the number of adult *S. aurantii* caught on the bottom surface of the traps divided by the number of larvae caught on the top surface and expressed as a percentage.

Identification of Larval and Adult Thysanoptera

Trapped dead larvae of thrips species swell or shrink according to weather conditions. Wet weather causes larvae to swell and become paler in color, whereas dry weather has the opposite effect. In certain species, this affects the ease of larval identification. Live larvae of *Thrips tenellu*s Trybom are yellowish-white in color and only a little larger than those of *S. aurantii*. In order to become more familiar with the thrips larvae to be encountered, sampling was carried out beforehand by beating citrus and other vegetation to dislodge insects onto white paper. Thrips larvae and adults were mounted on slides for detailed examination using the method of Mound & Pitkin (1972). Characteristic setal patterns on the head and abdomen of *S. aurantii* second instar larvae were identified and documented (Gilbert 1986). To further confirm the identity of larvae, specimens were confined in acrylic cages (Tashiro 1967). Mature larvae pupated within the cages and the identity of the emerging adults could be ascertained (Gilbert 1990). Larvae of *Haplothrips* spp., which possess red transverse bands across the body (Bedford 1943, Zur Strassen 1960), were readily distinguished from those of *S. aurantii*. Using these methods, the thysanopteran larvae encountered could be identified.

The color of emerged adults of *S. aurantii* caught on the trap undersurface did not differ from those sampled from citrus foliage. The abdominal stripes of both sexes were visible as was the black comb of setae on the hind femur of the males (Faure 1929, Hoddle and Mound 2003). Adults of *S. aurantii* could be readily distinguished from those of other species, and the sexes could also be easily told apart (Gilbert 1986, 1990).

Results

Trap Logistics

During the citrus blossom period, the top surface of the transparent plate received falling petals and stamens. Nevertheless, all the larvae could still be counted. Heavy rain caused mud to splash, resulting in some fine silt collecting on the trap upper surface, requiring extra care to count the larvae. During these challenging times for larval counts, there were no problems with adult thrips counts on the underside of the plate.

Trap Positioning

The effect of trap orientation on the numbers of *S. aurantii* caught was analyzed by combining the observed trap counts at different distances from the tree trunk and comparing them to an expected even distribution around the cardinal compass points. No clear picture emerged using X^2 analysis, with four of the comparisons significant, and five showing no significance. Given this variation, it was not surprising that the combined totals of the nine replicates gave no indication of a significant directional bias according to the cardinal compass points ($X^2 = 4.97$, $P = 0.17$). However, with regards to the distance of the trap from the tree trunk, there was a significant trend for greater numbers of thrips to be caught the closer the traps were to the tree trunk ($X^2 = 12.75$, $P \leq 0.001$).

Population Monitoring

For convenience, the results of the long-term monitoring experiment are divided into three parts: September Year 1 to May Year 2, June Year 2 to January Year 3, and June to December Year 3 to encompass three citrus fruit-bearing seasons.

September Year 1 to May Year 2

During this time, a total of 2,587 larval and 1,154 adult *S. aurantii*, 11 adult *T. tenellus*, 195 *Haplothrips* spp. larvae and 53 adults (mainly *Haplothrips bedfordi* Jacot-Guillarmod), and 19 adults of other species were caught on the D/E traps (presented in Table 1 as thrips per trap). A mean emergence rate of 44.6% was recorded for *S. aurantii* (Table 2).

During the most economically critical months September to December, four peaks of *S. aurantii* larvae dropping to the ground and adults emerging were recorded (Fig. 1). The first peak occurred as the first flush of the growing season was hardening. The second peak, late October, was at a time when the trees were not flushing, and the larvae must therefore have fed on young fruit. The second flush of the season was early November to early December. The third peak of thrips was late November, and the fourth early December. Numbers of both life stages declined from late December and remained relatively low January to March. At the end of the autumn flush in April, a further peak of larvae and adults was recorded before the population declined to a minimum in May.

June Year 2 to January Year 3

During this time, 1,025 larval and 497 adult *S. aurantii* were caught, as well as 42 adult *T. tenellus*, 75 larval and 17 adult *Haplothrips* spp., and 19 adults of other species (presented in

Table 1. Monthly numbers of different Thysanoptera species caught per 'Dispersal / Emergence' trap in an unsprayed Navel orange orchard at Letaba Estates, South Africa

September Year 1 – May Year 2

	Month									
	S	O	N	D	J	F	M	A	M	Total
S. aurantii larvae	14.5	14.4	17.8	28.0	7.6	4.6	4.4	13.7	2.7	107.8
Adults	3.4	8.8	6.2	17.2	3.0	3.3	1.8	3.6	0.7	48.1
Thrips tenellus										
Adults	0.4	0.04	0	0	0	0	0	0	0	0.5
Haplothrips larvae	0	0	0.1	1.9	2.8	2.1	0.7	0.4	0.1	8.1
Adults	0.04	0	0	0.2	0.3	1.4	0.2	0.1	0.04	2.2
Other adults	0.3	0	0	0.2	0	0.1	0.1	0.04	0.01	0.8

June Year 2 – January Year 3

	Month								
	J	J	A	S	O	N	D	J	Total
S. aurantii larvae	0.3	0.3	0.5	9.9	7.1	5.5	1.4	17.7	42.7
Adults	0.3	0.04	0.2	3.0	4.9	3.2	1.8	7.3	20.7
Thrips tenellus									
Adults	0	0	0	0.4	0.2	1.1	0	0	1.8
Haplothrips larvae	0.2	0	0.1	0.2	0.3	0.2	0.3	1.8	3.1
Adults	0	0.04	0	0	0.04	0.1	0.1	0.5	0.7
Other adults	0	0.1	0	0.1	0.3	0.1	0.1	0.04	0.8

June – December Year 3

	Month							
	J	J	A	S	O	N	D	Total
S. aurantii larvae	0.1	0	0.9	17.0	1.7	8.4	6.0	34.0
Adults	0.1	0.1	0.1	4.6	2.7	1.0	3.2	11.8
Thrips tenellus								
Adults	0	0	0	0.8	0	0	0.04	0.8
Haplothrips larvae	0	0	0	0.1	0	0.2	0.3	0.5
Adults	0	0	0.04	0.04	0.3	0	0	0.4
Other adults	0.1	0	0.1	0.04	0	0.1	0.1	0.4

Table 2. Monthly summary of larval and adult *S. aurantii* caught per Dispersal / Emergence trap in an unsprayed Navel orange orchard at Letaba Estates, South Africa

September Year 1 – May Year 2

	Month									
	S	O	N	D	J	F	M	A	M	Total
S. aurantii larvae	14.5	14.4	17.8	28.0	7.6	4.6	4.4	13.7	2.7	107.8
Adults	3.4	8.8	6.2	17.2	3.0	3.3	1.8	3.6	0 .7	48.1
S. aurantii males	1.5	3.3	2.8	6.1	1.1	0.9	0.5	0.9	0.1	17.3
Females	1.9	5.5	3.4	11.1	1.9	2.4	1.3	2.7	0.6	30.8
% Males	44.4	37.7	45.3	35.4	37.0	27.5	29.5	25.6	17.6	36.0
% Females	55.6	62.3	54.7	64.6	63.0	72.5	70.5	74.4	82.4	64.0
χ^2	1.00	12.75	1.32	35.45	4.95	16.2	7.36	20.51	7.11	89.6
P	0.32	<0.001	0.25	<0.001	0.03	<0.001	<0.001	<0.001	<0.001	<0.001
	N.S.	***	N.S.	***	N.S.	***	***	***	***	***
Emergence rate (%)	23.2	61.3	34.7	61.4	40.1	72.1	41.5	26.2	26.2	44.6

June Year 2 – January Year 3

	Month								
	J	J	A	S	O	N	D	J	Total
S. aurantii larvae	0.3	0.3	0.5	9.9	7.1	5.5	1.4	17.7	42.7
Adults	0.3	0.04	0.2	3.0	4.9	3.2	1.8	7.3	20.7
S. aurantii males	0.1	0	0.1	0.9	1.9	1.4	0.6	2.5	7.3
Females	0.2	0.04	0.1	2.1	3.2	1.8	1.2	4.8	13.4
% males	33.3	0.0	40.0	30.6	35.6	42.9	33.3	34.1	35.2
% females	66.7	100.0	60.0	69.4	64.4	57.1	66.7	65.9	64.8
χ^2	0.67	-	0.2	10.5	9.8	1.57	4.67	17.82	142.88
P	0.4	-	0.65	<0.001	<0.001	0.21	0.03	<0.001	<0.001
	N.S.	N.S.	N.S.	***	***	N.S.	N.S.	***	***
Emergence rate (%)	85.7	14.3	38.5	30.4	69.0	57.9	127.3	41.5	48.5

June – December Year 3

	Month							
	J	J	A	S	O	N	D	Total
S. aurantii larvae	0.1	0	0.9	17.0	1.7	8.4	6.0	34.1
Adults	0.1	0.1	0.1	4.6	2.7	1.0	3.2	11.8
S. aurantii males	0.04	0	0.04	1.3	1.3	0.4	1.1	4.2
Females	0.04	0.1	0.04	3.3	1.4	0.6	2.1	183
% Males	50.0	0.0	50.0	28.8	46.9	40.0	33.8	35.3
% Females	50.0	0.0	50.0	71.2	53.1	60.0	66.2	64.7
χ^2	0.0	-	0.0	19.9	0.25	1.00	8.11	24.3
P	0.0	-	0.0	<0.001	0.62	0.32	<0.001	<0.001
	N.S.	N.S.	N.S.	***	N.S.	N.S.	***	***
Emergence rate (%)	100.0	-	9.5	27.2	156.1	12.4	53.1	34.6

Mann-Whitney paired test on the months with more than a total of 10 adult thrips from all traps emerging showed that significantly more females than males were emerging from the soil, $n = 19$, $Z = 6.07$, P (two-tailed) < 0.001. ***$P < 0.001$. N.S., not significant.

Table 1 as thrips per trap). A few blossoms persisted in the orchard late October, and probably accounted for the comparatively late trapping of some *T. tenellus* adults in November. This is in contrast to the previous year when the *T. tenellus* population was very low after September. With *Haplothrips* spp. the pattern of Year 1 was repeated in that the population was very low during the most critical months for citrus thrips damage and only started to increase in January. A mean emergence rate of 48.5% was recorded for *S. aurantii* (Table 2).

Only 14 larvae and seven adult *S. aurantii* were trapped from June to July during which time the citrus trees were dormant. There was little movement of thrips to and from the soil, indicative of a low overwintering population (Fig. 2). The onset of the first flush of the growing season in early August produced little change. However, from mid-September, when the flush was hardening and blossoming was nearly over, the number of larvae trapped increased greatly, with a peak at the end of this month as was also the case with adults. The second peak was late November. As in Year 1, no new vegetative growth was present at this time, with fruitlets supporting this generation of larvae. A second growth flush late December to mid-January saw large larvae and adult *S. aurantii* population peaks as leaves were hardening.

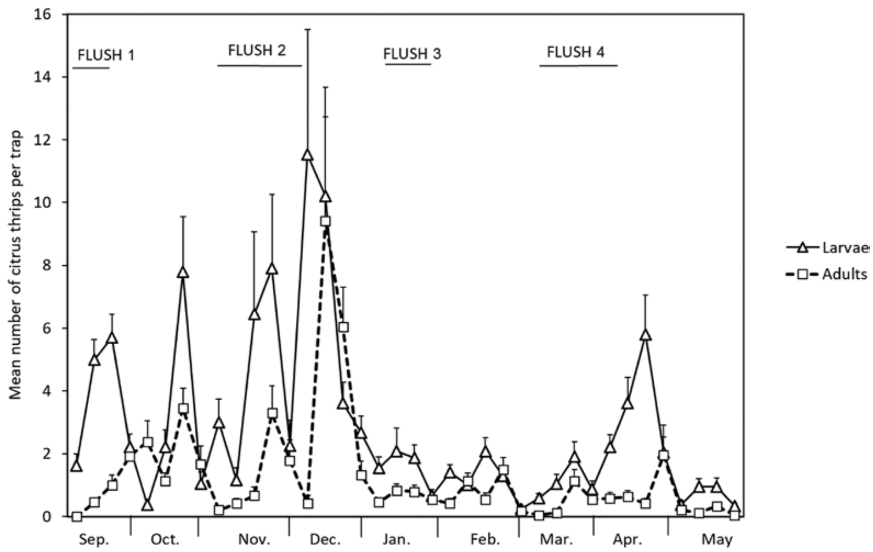

Fig. 1. Mean (+ Standard Error bar) weekly numbers of *S. aurantii* larvae and adults caught on Dispersal / Emergence traps, September Year 1 – May Year 2.

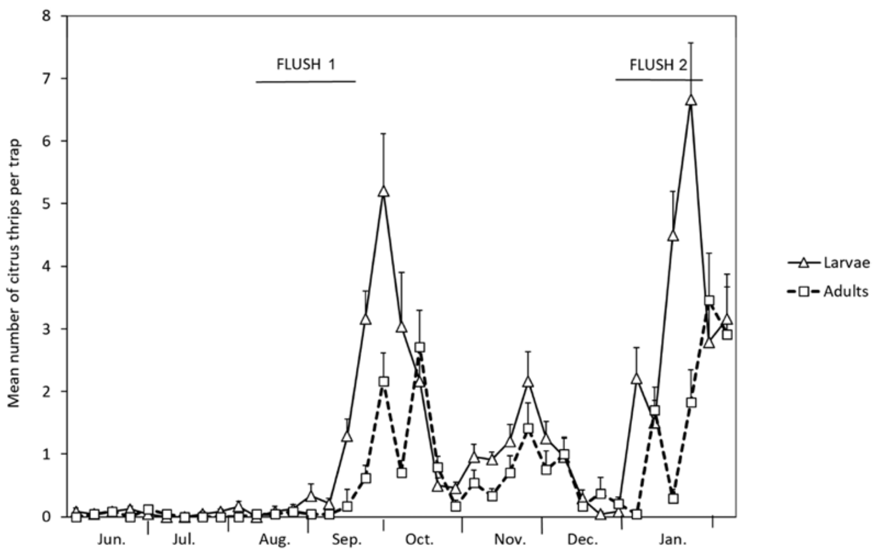

Fig. 2. Mean (+ Standard Error bar) weekly numbers of *S. aurantii* larvae and adults caught on Dispersal / Emergence traps, June Year 2 – January Year 3.

June Year 3 to December Year 3

A total of 818 larval and 283 adult *S. aurantii*, 19 adult *T. tenellus*, 12 larval and 9 adult *Haplothrips* spp., and 9 adults of other thysanopteran species were recorded (presented in Table 1 as thrips per trap). As in Year 2, there was a very low overwintering population of *S. aurantii* in Year 3 (Fig. 3) and, for June to July, only two larvae and four adults were trapped. The first sign of trapped larvae was in week 3 of September, at the end of blossoming as the growth flush hardened. A corresponding peak of adults emerging occurred in the following week 4 of September. During November, there was a second larval peak in week 4 of the month as the second flush was hardening. There was no clear peak of adults at this time, seemingly due to high mortality in the soil. A mean emergence rate of 34.6% was recorded (Table 2).

In summary, the species composition of all the adult Thysanoptera caught emerging from the soil during the long-term monitoring phase (n = 2,132) was as follows: 90.7% were *S. aurantii*, 3.4% were *T. tenellus*, 3.7% were *Haplothrips* spp., and 2.2% were of other species. Regarding Thysanoptera as a group, this illustrates the dominance of *S. aurantii* on citrus in this geographical area.

Discussion

The D/E traps were effective for monitoring *S. aurantii*, notwithstanding the problems experienced mainly from petal fall affecting the trap top surface. Identification of adult *S. aurantii* was not difficult, but the larval counts may have included a very small proportion of other species, mainly *T. tenellus*. The rarity of *T. tenellus*, whose adults featured in extremely low numbers compared to *S. aurantii* (Table 1), indicates that this does not have any major consequences for estimation of *S. aurantii* population levels.

We found that larvae and adults of *Haplothrips* spp. were distinguishable from other genera of Thysanoptera. *H. bedfordi*, a known citrus thrips predator (Jacot-Guillarmod 1941), was only common on *S. aurantii*-infested fruit from January to April (Bedford 1943), after the most critical months for *S. aurantii* damage to fruit. We also

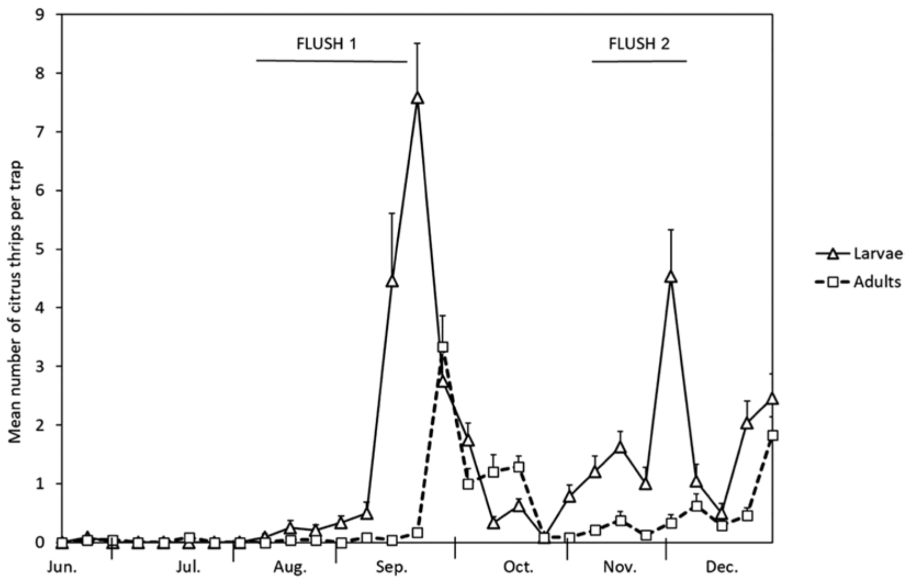

Fig. 3. Mean (+ Standard Error bar) weekly numbers of *S. aurantii* larvae and adults caught on Dispersal / Emergence traps, June – December Year 3.

found population peaks of *Haplothrips* spp. late in the season, and this, combined with their low population levels, would make them ineffective biocontrol agents of *S. aurantii*.

Numbers of *S. aurantii* larvae decreased farther away from the tree trunk, as was the case for *S. citri*, which move towards the darker centre of the tree before dropping to the ground (Reed and Rich 1975, Grout et al. 1986), and which also appears to be the case for *S. aurantii*. We found that compass orientation of the traps was not significant, perhaps due to the low latitude of our site (approximately 24° S) with its relatively even distribution of sunlight, in contrast to Grout et al. (1986), with *S. citri* at the higher latitude of 36° N where there was a significant effect of compass orientation.

We found clearly-defined peaks in the population levels of both larvae and adults of *S. aurantii*, which were almost co-incident, as might be expected from the short pupation period of this species (Bedford 1943). Peak emergence of adults occurred either in the same week or in the week following each peak of larvae dropping to the ground. Our work covered two winters, when out-of-season fruit was not present, and so this potential food source was unavailable mid-winter when very little thrips activity was recorded. In spring, the first peaks of larvae and adults occurred at the end of the first flush (late September), indicating that there was only sufficient time for a single generation to develop on this particular food resource. This suggests that the life-cycle of *S. aurantii* is well synchronized with the phenology of citrus at this time of year, there being sufficient time for egg-laying by overwintering females, hatching and full development of larvae before the flush hardens when it is unsuitable for further feeding and oviposition.

In all 3 yr, the first and economically important peak of adult citrus thrips emergence in September was always accompanied, or was just preceded, by many larvae dropping to the ground as the flush hardened. After 100% petal-fall, the first infestation on fruitlets (Reed and Rich 1975, Grout et al. 1986) would therefore not be the result of mass emergence of adults from pupae which had remained dormant over winter. Such a pattern would have been typified by the trapping of adults first, and only after a number of weeks would larvae be trapped as the offspring of the original adults dispersed to the ground. Initial infestation of fruit therefore took place after a build-up of larval numbers on the soft citrus flush which appeared late July to early August at our site. The citrus flush hardened as flowering finished, and the whole population of newly-emerged adults was then concentrated upon the vulnerable small fruitlets. In the absence of control measures, this would occur immediately after petal-fall, with risk of high levels of economic damage.

In Years 2 and 3, the second generation peak after the onset of the growing season occurred late November, well within the critical period for *S. aurantii* damage. During Year 1, the second peak was earlier (late October), possibly from overlapping generations following a winter in which comparatively large numbers of individuals overwintered on out-of-season fruit and an extra flush being promoted by heavy late rainfall in April. It is unlikely that this peak represents a true second generation, as the third peak of Year 1 coincided with the second peak in the other 2 yr (late November). The timing of citrus flush periods and presence of small fruit is therefore very important for population build-up. In the Lowveld, new flush can be stimulated during winter by unseasonal rainfall due to the mild temperatures prevalent in this region.

The trapping surfaces of the D/E trap are transparent and only intercept moving larvae and adults without any attraction. Any emerging adults, whether male or female, would have an equal chance of being caught due to the enclosed nature of the underside of the trap, and an unbiased estimate of the adult emergence sex ratio is obtained. Over the 2-yr trapping period, 35.7% of emerging adults were males and 64.3% females, a greater proportion of males than the 23.6 and 23% recorded by Faure (1929) and Bedford (1943), respectively. The greater activity and willingness to fly of males observed by Bedford (1943) is probably the reason for the lower proportions of males in their samples, which were gathered by beating foliage.

The number of emerging adult *S. aurantii* relative to the number of larvae dropping to the ground can be used as a measure of mortality during pupation. For *S. citri*, Reed and Rich (1975) recorded emergence rates of 31–62% in orange orchards, but much higher levels of emergence in lemons. Our mean emergence rate for *S. aurantii* on oranges was 43.7%. However, considering the biology of *S. aurantii* and the construction of the D/E trap, this figure is probably an underestimation. Hall (1930) estimated the combined length of the propupal and pupal stages as 3.92 d, October to November, in Southern Rhodesia (now Zimbabwe), while Bedford

(1943) estimated 4–7 d at the same time of year at the lower latitude of South Africa. It is therefore likely, particularly during the hotter months of the year, that the time taken between a larva dropping to the ground and its emergence as an adult is <7 d, with the peaks of larvae and adults being closely associated, (Figs. 1–3), here supporting this time frame. However, as the traps prevent larvae from reaching the ground and pupating, they prevent those adults that would have emerged from these pupae within the same week from being counted. As the traps can therefore only record adults which developed from larvae that dropped in the previous week, the mean emergence rate of 43.7% must therefore be viewed as an underestimate.

In spring, post-blossom, *S. aurantii* immediately infests citrus fruitlets. But the ending of blossom can vary in time from tree to tree (so-called uneven blossoming) which makes it difficult to gauge the *S. aurantii* total population, as not all fruitlets are exposed at the same time. The D/E traps were able to determine when citrus thrips larvae fell to the ground and adults emerged with precision, giving a timely warning with well-defined peaks of activity. The first (spring) growth flush (emerging in late July to August) provided food for the build-up of thrips larvae that then dropped to the ground as the leaves were hardening. In our area, a 'pre-blossom' thrips treatment is frequently used to prevent *S. aurantii* numbers building up on the new flush, so reducing the likelihood of damage post-bloom. Our results illustrate the value of such an approach for control of this species.

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