UPPER THERMOTOLERANCE OF NEW ZEALAND FLOWER THRIPS *THRIPS OBSCURATUS* (CRAWFORD)

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ABSTRACT

The upper thermotolerance of New Zealand flower thrips was investigated in laboratory bioassays, and from supporting field evidence. The LT_{95} for adults treated at 35ºC in spring 1996 and 1997 was 1.6 hours. However, assessments in autumn 1998, showed the LT_{95} had increased to 19.1 hours in March and 26.4 hours in April. A generation could not be completed if adults had been exposed to 35ºC for 2.5 hours in spring, but by autumn, exposures longer than 18 hours at 35ºC were required to prevent development in the laboratory. Egg viability on fruit was higher in the laboratory than in the field. There is evidence that temperatures above 34ºC reduced either female fertility or egg viability in the field in 1995 and 1998. Some practical implications of these data are discussed.

Keywords: New Zealand flower thrips, *Thrips obscuratus*, thermotolerance, nectarine, peach, female fertility, egg viability.

INTRODUCTION

New Zealand flower thrips, *Thrips obscuratus*, (NZFT) is a quarantine pest on export produce (summerfruit, cut flowers, asparagus). It breeds on the flowers and new foliage of summerfruit in spring, but disappears from orchards during early summer. Adults are attracted to ripening summerfruit, thus presenting problems to growers who wish to meet Australian export standards. Interest in the upper thermotolerance of thrips began when the numbers of larvae hatching from the fruit of nectarine cv. 'Fantasia' declined to negligible levels following a day when the maximum temperature reached 34.5ºC on 26 February 1995 (McLaren unpubl.). In that year, numbers of larvae remained exceptionally low until the end of the season, six weeks later. This raised doubts about the ability of NZFT to establish in warmer climates. Teulon and Penman (1991) reared NZFT at constant temperatures up to 27ºC, but did not investigate its upper thermotolerance. Carpenter *et al*. (1996) tested the survival of adult NZFT at 36 ºC and 48ºC in air for 2-24 hours, but did not record the ability of the survivors to reproduce. In their trials, all adults died within 24 hours at 36ºC, 95.8% died within 4 hours and 97.2% within two hours. The thrips in their trial were collected from flowers but the time of year was not recorded. This could be important since it is possible for insects to adapt to extreme conditions through pre-conditioning (McDonald *et al*. 1997; Hara *et al*. 1997; Lester and Greenwood 1997). Changes in the upper thermotolerance of NZFT over the growing season were investigated.

METHODS

Trials were conducted in spring 1996 and 1997 to test the ability of adults or larvae of *T. obscuratus* to survive treatments at 33±0.5 ºC (range = 3 - 11 hours), 35±0.5 ºC (0.5 - 2.5 hours), 37±0.5 ºC (0.5 -2 hours) and 39±0.5 ºC (0.5 -1.5 hours) at 90-95% RH in a Sanyo MIR 252 incubator. Survivors of these treatments were maintained in the laboratory at 20ºC at 85-90% RH, to determine the exposure at which they were no longer capable of moulting and developing into the next instar, or of completing a generation (adult to adult). Since 35ºC appeared to be a critical temperature in the field, all tests in autumn 1998 were carried out at this temperature (6 -12 hours in March and 10-24 hours in April). In each trial, five time exposures at one temperature were tested,

including zero hours. The times were selected to produce a mortality line; in spring 1996 and 1997, the same times were selected (e.g. at 35ºC and 75-80%RH, treatments were removed after 0.5, 1.5, 2, 2.5 hours) but in autumn, the times needed to be extended (6, 8, 10, 12 hours in March and 10, 14, 18, 22 hours in April). Each exposure time was repeated three times in spring and five times in autumn.

Adult and larval survival in laboratory bioassays

Spring. In October each year, an undetermined number of NZFT were collected from the field on 25 cm lengths of flowering shoots of sweet cherry (*Prunus avium).* Three infested shoots were sealed inside each plastic container (350 x130 x 115 mm, Tupperware celery crisper), lined on the bottom with paper tissue. When cherry flowers were no longer available in November and December each year, naturally-infested flowers of gorse (*Ulex europeaus)* were used as an alternative. Samples were treated at 33, 35, 37 and 39ºC, once on cherry, and twice on gorse (3 replicates). The number of survivors on all treatments, including the untreated, was recorded 18-24 hours after treatment, using either a x10 hand-lens or a binocular microscope. Although the initial number of thrips present inside the flowers could not be recorded, the post-treatment assessments recorded the number alive and dead with 30 - 100 adults and 15 - 40 larvae per sample.

Autumn. Between 12 and 25 March 1998, and 30 March and 9 April 1998, adults and larvae were exposed to heat treatments on naturally-infested peaches (10 fruit per sample). The first samples (referred to as 'March 1998') were collected from the field on various peach and nectarine cultivars growing at the HortResearch Clyde Research Centre. Later samples (referred to as 'April 1998') were collected on peach cv. 'Golden Queen'. The treatment time on fruit commenced when a probe just below the skin reached the target temperature (approximately 30 minutes after the infested fruit was placed in the incubator). Survivors were retained on the fruit at 20ºC (80-90%RH) until their number was recorded 18-24 hours after treatment, using a binocular microscope. There were 15 - 30 adults, and very few larvae, on each sample of 10 fruit. Each exposure time at 35ºC was repeated on five different days.

Ability of survivors to continue development

Adult to egg. Adult survivors from each temperature x time combination were transferred to plastic rearing tubes, 4 x 3 cm, covered at either end with plastic budding tape (Buddy-Tape, Aglis Co. Ltd). At one end, a double layer of tape enclosed a 10% w/v sucrose solution, which provided both diet and an oviposition site for the adults (Teulon and Penman 1986). This method was less successful than using natural rearing media such as flowers or fruit (see below) but it did allow observation of oviposition and could be used when natural media were no longer available. All rearing was conducted at 20ºC. The relative humidity in the different containers at this temperature varied from 65-70% inside the plastic rearing tubes, 85-90% on flowers and foliage and 75-80% on peaches inside their respective containers.

Adult to new larva. In spring, adults which survived the treatments laid eggs on the treated flowers and foliage. Newly hatched larvae were recorded after 4 days at 20ºC. Inspections were repeated at 3-day intervals until no new larvae appeared. In autumn, adults were transferred from field-infested peaches to thrips-free peaches, that had been preheated to the target temperature. They were treated in a 5 litre plastic pottle, which was ventilated through a 100 mm^2 hole in the lid, covered with cloth. Thrips-free peaches were obtained by treating them in water at 50ºC for two minutes, a proven method of disinfestation for NZFT (McLaren *et al*. 1997). Numbers of newly-hatched larvae were recorded as above.

Larva to adult; adult to adult. In the spring, larvae which had survived the heat treatments, were transferred to fresh flowers and foliage inside sealed plastic containers (previously described) and allowed to complete development to the adult stage. In autumn, field-infested peaches were treated at 35ºC in 5 litre plastic pottles and held for a further 20 days at 20ºC until new adults emerged. In both spring and autumn, one change of flowers or fruit was necessary to avoid losses of thrips when rots began on the medium. If fresh plant material was no longer available, the immature stages were transferred to plastic rearing tubes to complete development.

Female fertility or viability of eggs in the field

Eggs of NZFT are laid just under the skin of fruit. Therefore, disruption of oviposition or egg hatch is not recognised until the larvae hatch. A sample of 25 peaches cv. 'White Lady' was picked from trees growing at Clyde Research Centre every day from 2 to 19 February 1998 and at 2-3 day intervals thereafter from nectarine cv. 'Fantasia' until 16 March 1998. In the laboratory, all fruit were inspected for larvae. The larvae were recorded and removed from the fruit before it was packed and held in cardboard trays for 4 days at 20ºC and 75-85%RH, then inspected again under a binocular microscope, for newly hatched larvae. Egg viability under field and laboratory conditions was compared. Egg hatch was also compared over several years, and results presented for 1994, 1995 and 1998, using data from samples of 'Fantasia', collected from the same site at irregular intervals from late February to mid-March each year. Egg hatch was related to maximum temperatures >34ºC, recorded at Clyde Research Centre.

Statistical analyses

Percentage mortality was compared with exposure time in a logistic model (using non-linear least squares in S-Plus (MathSoft 1997)). The time to 50% mortality and 's', the scale parameter (75% mortality approximates t_{50} + s hours) were estimated and compared for the four data sets, spring 1996, spring 1997, March 1998 and April 1998. A single LT_{95} was calculated for 33, 35, 37 and 39ºC in spring and 35ºC on March and April, using complementary log-log transformation ($\log(-\log(1-p)) = a + bt$, where p = expected mortality and t = time in hours) in S-Plus. There were insufficient larvae on the fruit from the field to create a mortality line for the autumn populations. Egg hatch on fruit in the field and in the laboratory was compared on 'White Lady' peach and 'Fantasia' nectarine by *t*-test.

RESULTS

Adult and larval survival in laboratory bioassays

The time to 50% mortality at 35ºC did not differ between the two spring populations (1996, 1997) but the scale parameter 's' did, suggesting that the sets of spring data were different, as were those for March and April 1998 (Table 1).

TABLE 1: Estimates of the parameters LT_{50} and 's' (75% mortality approximates LT_{50} +s) for each data set at 35ºC in hours (standard errors in parenthesis).

Season	LT_{50} (hours)	s (hours)
Spring 1996	0.46 (0.032)	0.36 (0.031)
Spring 1997	0.42 (0.197)	1.90 (0.327)
March 1998	2.24 (0.903)	4.31 (0.919)
April 1998	6.79 (0.721)	7.75 (0.891)

The slopes of the regression lines decreased over the season and were significantly different (Figure 1).

When comparing LT_{95} values, adults and larvae were equally susceptible to exposure to a particular temperature (Table 2). Tolerance of both adults and larvae declined as the temperature increased from 33 to 39ºC. The LT_{95} in spring (both years) was shorter than that in March or April, and the adults collected in April were more heat tolerant than those in March.

Ability of survivors to continue development

Adults which had survived exposure to 35ºC for up to 2 hours in spring and 18 hours in autumn, managed to complete a generation; larvae which had survived 1.5 hours in spring and 18 hours in autumn reached the adult stage. However, adults exposed for 2.5 or 20 hours respectively, failed to complete a generation (Table 3). As in the case of direct mortality (LT_{95}), there was no consistent trend to indicate that one

stage was more susceptible than another. Although development from larva-to-pupa-to-adult appeared to include the most sensitive steps after exposure to 33ºC in spring, the short exposures survived by the adult to egg stage (female fertility) at 35ºC suggested that this process was more heat sensitive than the other development processes at that temperature.

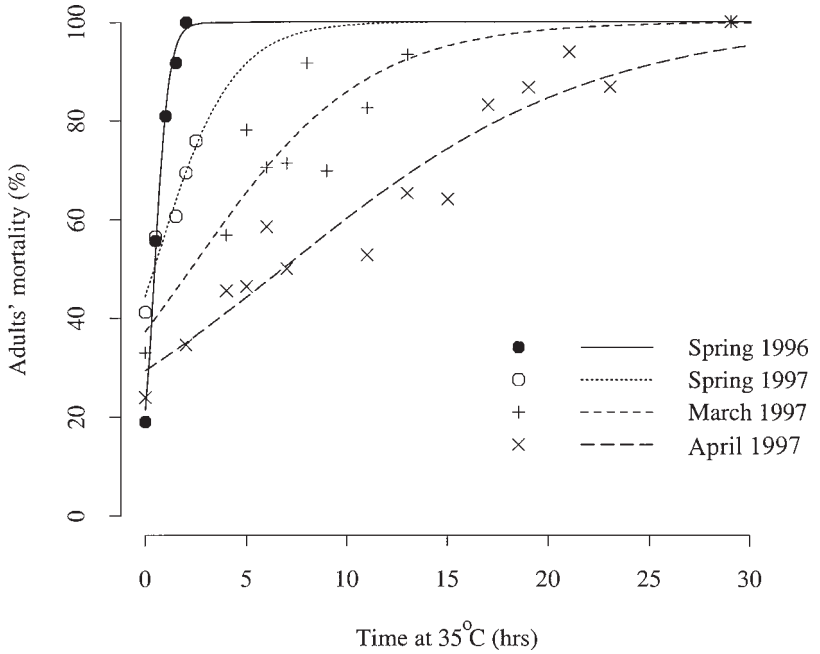

FIGURE 1: Percentage mortality of adults treated at 35ºC in spring 1996 and 1997 and March and April 1998, presenting datapoints and fitted lines using a logistic model.

TABLE 2: LT_{95} (hours) for NZFT adults and larvae in spring 1996 and 1997, and autumn (March and April 1998) after treatment at 33 to 39ºC.

Temperature	Spring adults		Spring larvae		Autumn adults	
	1996	1997	1996	1997	March 1998	April 1998
33 ºC	-[1]	8.12	-	7.78	-	-
35 ºC	1.61	4.66	1.63	2.08	19.08	26.38
37 ºC	1.60	1.44	1.36	1.41	-	-
39 ºC	0.82	1.46	0.64	-	-	-

[1]- = not tested.

TABLE 3: Completion of development after treatment. Time (hours) after which no survivors were found ('none') and longest exposure tolerated ('some').

Temperature	33ºC		35 ºC		37 ºC		39 ºC	
Survival	none	some	none	some	none	some	none	some
Adult to egg (artificial medium)								
spring	5	3	1.5	1.0	1.5	1.0	0.75	0.5
autumn	-[1]	-	18	14	-	-	-	-
Adult to new larvae (natural media)							-	
spring	6	5	2.5	2.0	1.5	1.0	1.25	1.0
autumn	-	-	25	21	-	-	-	-
Larvae to adult							-	
spring	3	2.5	2	1.5	1.5	1.0	0.5	-
autumn	-	-	20	18	-	-	-	-
Adult to adult (one generation)							-	
spring	3	2.5	2.5	2	1.5	1.0	<0.5	-
autumn	-	-	20	18	-	-	-	-

[1]- = not tested.

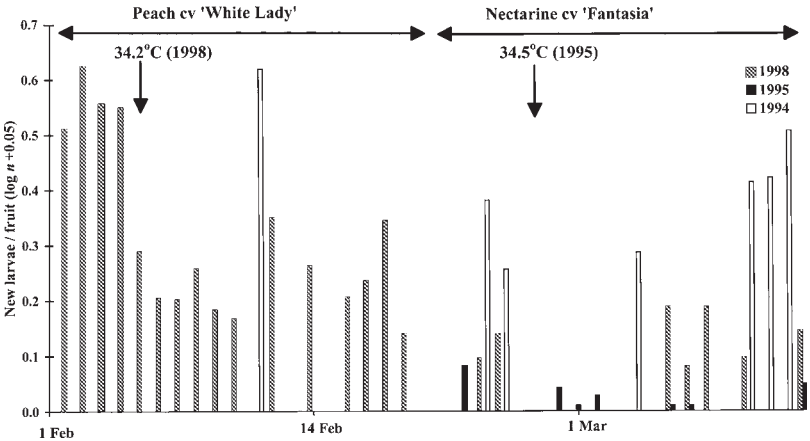

FIGURE 2: Eggs hatched on peaches and nectarines sampled from the field in February and March 1994, 1995 and 1998. Maximum temperatures did not exceed 30ºC in 1994 but reached 34.5ºC on 26 February 1995 and 34.2ºC on 5 February 1998.

Fertility of adults or viability of eggs in the field

Fewer eggs hatched on the fruit under field conditions than in the laboratory. On 'White Lady' peach, 0.39 larvae/fruit were recorded as the fruit was picked and 16.8 larvae/fruit hatched in the laboratory ($P<0.01$; $n=5$; $F = 117.8$). On 'Fantasia' nectarine, 0.14 larvae hatched per fruit in the field but 1.44 larvae per fruit hatched in the laboratory ($P = 0.03$; $n= 5$; $F= 8.7$).

Numbers of new larvae hatching on fruit after 4 days in the laboratory at 20ºC remained high to the end of March in 1994 (Figure 2), in a year when field temperatures never exceeded 30ºC, but in 1995, the numbers declined to negligible levels when the maximum temperature reached 34.5ºC on 26 February. A similar decline was observed in 1998 after a maximum of 34.2ºC on 5 February, but on that occasion numbers recovered within a week.

DISCUSSION AND CONCLUSION

A phenological model (Hayes, unpubl.), partly based on data presented by Teulon and Penman (1991), showed that NZFT could have completed seven generations over the 1997/98 season in Central Otago. The trials described were carried out on generations 1 and 2 (spring 1996 and 1997), and generation 6 (March 1998) and 7 (April 1998). With so many generations happening within a year, it is possible that between spring and autumn, a combination of selection and pre-conditioning could produce populations with higher thermotolerance. However, the increase in thermotolerance between March and April, when temperatures were decreasing, is more difficult to explain, although it is likely that individual variation would be at its maximum at the end of the season, depending as it could on an insect's age, its source of pollen, site and temperature for pupation, and position on the tree during previous high temperatures.

Thrips within a stage (instar) appeared to have a higher upper thermotolerance, measured by $LT_{95,}$ than those trying to pass from one stage to the next. The time to complete development from adult to adult was, therefore, an important measure of the effect of high temperatures in the laboratory. Comparison of egg hatch under field and laboratory conditions suggested that conditions for hatching may be dependent on more than temperature. Field observations indicated that female fertility and egg viability are reduced in the field after relatively short exposures to temperatures exceeding 34ºC (2-3 hours in the field, compared to 18 hours in the laboratory). This difference between laboratory and field results could be attributed to factors such as differences in relative humidity or exposure to light. The laboratory experiments were conducted under conditions of higher relative humidity and lower light than in the field. NZFT, like most thrips (Laughlin 1997; Kirk 1997), is very sensitive to low humidity. The effect of heat exposure on thrips eggs, especially if fully exposed to the sun, the position of the egg on the fruit and the position of the fruit in the tree may all be critical. However, results from both the field and laboratory confirm that temperatures above 34ºC are detrimental to the survival of NZFT, even if the levels of exposure involved vary.

NZFT is currently treated as a quarantine pest in certain export markets. At the time when New Zealand summerfruit is exported, between January and March, NZFT adults and larvae are more heat tolerant than the spring populations, but temperature is probably not the only factor to be considered in establishment. This research has highlighted some of the problems that can be encountered in trying to determine if NZFT could establish in countries which experience higher temperatures than New Zealand. In the meantime, the continued absence of records of NZFT occurring in Australia (L. Mound pers. comm.) supports the suggestion that establishment will be difficult for this insect in that country.

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