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The Effects of Sucrose and Tannin on Oviposition by the Western Flower Thrips

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In no-choice experiments, the addition of sucrose to a diet of water had no effect on oviposition rate whether or not pollen was also present. However, the addition of 1% or 5% tannic acid to a diet of water decreased the oviposition rate by 68% and 86% respectively when pollen was also present. A novel design of U-tube cage allowed thrips to choose between two oviposition and feeding substrates in the presence of pollen. When thrips were offered a choice between 5% tannic acid solution and water, 88% fewer eggs were laid in the tannic acid. However, the total number of eggs laid per U-tube was not significantly different from in control U-tubes with water as the only substrate. It is concluded that tannin acts as a feeding deterrent and/or oviposition deterrent rather than as a toxin.

Keywords: *Frankliniella occidentalis,* deterrent, stimulant, feeding, sugar.

The western flower thrips *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) is a highly polyphagous pest of horticulture. Its original distribution was western North America, but in the 1970s and 1980s it spread rapidly across the USA and Canada and then to Europe and the rest of the world (Kirk, 2002; Kirk and Terry, 2003).

Little is known about the plant factors that influence feeding and oviposition in the western flower thrips. However, a knowledge of stimulant and deterrent factors could help in the selection of resistant cultivars in horticulture or could be used to increase the uptake of insecticides or reduce populations on crops.

Adult female western flower thrips normally lay a few eggs each day (Hulshof et al., 2003). The eggs are large compared to the size of the body, so adult females must feed on protein or amino acids in order to continue to produce eggs. The addition of pollen, which is high in protein, to a leaf or petal diet, which is low in protein, increases oviposition rate (Trichilo and Leigh, 1988; De Jager and Butőt, 1993). Experiments suggest that the aromatic amino acids, phenylalanine and tyrosine, particularly favour larval growth in the western flower thrips (Mollema and Cole, 1996; Brodbeck et al., 2001), and these may also favour oviposition.

Sugar has long been known as a feeding stimulant in thrips and has been added to insecticide sprays to increase mortality of thrips, including the western flower thrips (Parrella, 1995). Since sugar is not a protein source, it is unlikely to increase oviposition rate, but it does appear to increase adult survival and longevity in some thrips (Koyama and Matsui, 1992).

Cysteine protease inhibitors can reduce oviposition rate in the western flower thrips by 55% (Annadana et al., 2002), and some volatile essential oils can reduce oviposition rate by 30% in *Thrips tabaci* Lind. (Koschier and Sedy, 2002). Alpha-tomatine, which occurs in tomato leaves, is a feeding deterrent in *Thrips palmi* Karny (Hirano et al., 1994). These may have potential for use in pest management of the western flower thrips. Tannins are well known as feeding deterrents in many insects (Bernays, 1981), but their effects on thrips do not appear to have been tested.

Feeding and oviposition are closely linked because diet has a rapid effect on oviposition (Kirk, 1997). It is therefore very difficult to separate the effects of a substance on feeding from those directly on egg laying. A substance could reduce oviposition simply by deterring feeding and thus reduce nutrient intake. It could have a toxic effect and so prevent egg production. It could deter feeding so that thrips move to where food is suitable and thus tend to lay elsewhere. Thrips may even test the suitability of an oviposition site by feeding.

The aim of this paper is to test whether sucrose enhances oviposition and whether tannin, in the form of tannic acid, reduces oviposition. A novel oviposition choice experiment is described that separates oviposition preference from overall oviposition rate.

Materials and Methods

A culture of *F. occidentalis* from commercial glasshouses in the UK was maintained on pot chrysanthemums (*Dendranthema grandiflora* Tzvelev) at 25±2 °C and L18: D6. Adult thrips collected from this culture were transferred to 500 ml plastic pots containing French bean pods (*Phaseolus vulgaris* L.) and pine pollen (*Pinus brutia* Tenore) and kept at 25±1 °C and L18: D6. A hole (diam. 70 mm) in the lid allowed moisture exchange through a piece of tissue held in place between the lid and the pot. Emerging adults were collected daily and kept in a similar pot to produce adults of known age.

Straight oviposition tubes, modified from the design of Kirk (1985), were constructed from Perspex tubing (external diam. 12 mm, internal diam. 8 mm, length 30 mm), with a single circular ventilation hole (diam. 5 mm) cut half way along. The hole was covered externally with a small square of tissue, held in place with a length of clear adhesive tape into which a circular hole had been cut. A Parafilm membrane was stretched thinly across the top of each tube, and a collar of flexible clear plastic sheet was attached with more Parafilm. Thrips could feed and oviposit through the membrane into a solution above, allowing eggs to be counted from above. The base of each tube was a glass sheet held on with glycerine jelly.

U-tube cages *(Fig. 1)* provided a choice of two membranes through which thrips could feed and lay eggs. A length of clear Perspex tubing of the same diameter as before was heated and carefully bent into shape. The ends were cut so that the finished tube was 60 mm high and 60 mm wide. Ventilation holes, membranes and collars were constructed at each end of the U-tube, as for the straight tubes. The U-tubes were held upright on a glass sheet with a small amount of wax.

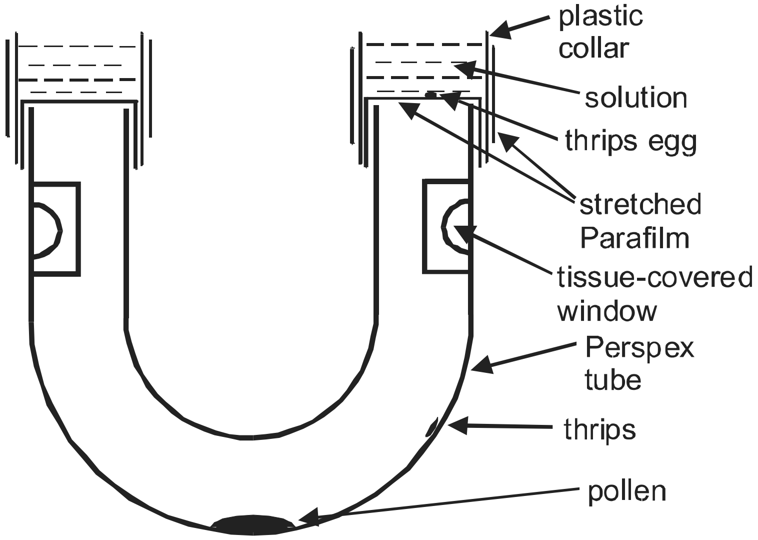

Fig. 1. Diagram of the U-tube used for oviposition choice experiments

Solutions were freshly made up with deionised water and sucrose (Timstar Lab Suppliers Ltd., UK) or tannic acid (Avocado Research Chemicals Ltd., UK). Concentrations are expressed as percentage weight/volume. At the start of each experiment, approximately 1 mg of defrosted pine pollen was placed in the bottom of each tube, and a single 4- to 8-day-old adult female thrips was placed near the pollen. Tubes were maintained at 25±0.3 °C, 75±1% relative humidity and a photoperiod of L18: D6. At the end of experiments, eggs laid through the membrane were counted using a dissecting microscope and fibre-optic illumination. Any tubes in which thrips exhibited moribund behaviour or had escaped or died were excluded from the analyses.

Results for no-choice experiments were analysed by multiple Mann-Whitney tests with P-values adjusted for multiple comparisons by Holm's procedure (Holm, 1979). Two-choice experiments were analysed with paired or unpaired t-tests.

Results

Diets were initially compared in no-choice experiments with straight oviposition tubes. Over 48 h, the addition of pine pollen markedly increased oviposition rate compared with water alone ($P<0.001$), but there was no significant effect of 20% sucrose compared with water ($P=0.08$) *(Fig. 2)*. When pine pollen was present, the addition of 5%, 10% or 20% sucrose also had no significant effect on oviposition rate compared with water over 72 h ($P=0.87$, $P=0.87$, $P=0.68$ respectively) *(Fig. 3)*. In a further no-choice experiment over 48 h, the addition of pine pollen again markedly increased oviposition rate ($P<0.001$), but this was significantly reduced by 1% or 5% tannin solution ($P=0.046$, $P=0.002$ respectively) *(Fig. 4)*. Compared with the 0% tannin + pollen treatment, the removal of pollen reduced the oviposition rate by 91%, whereas the addition of 1% tannin decreased oviposition by 68% and the addition of 5% tannin decreased oviposition by 86%.

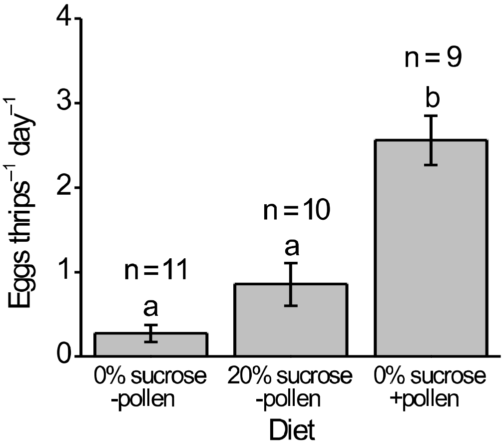

Fig. 2. Graph of the effect of diet on oviposition rate in a no-choice experiment over 48 h. Bars show mean±SEM. Bars with the same letter are not significantly different (*P*>0.05)

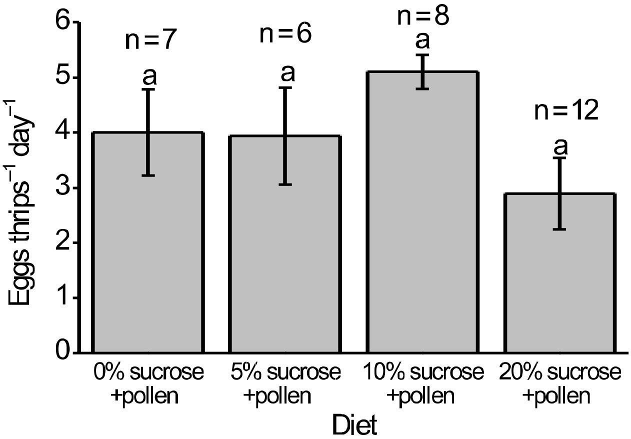

Fig. 3. Graph of the effect of diet on oviposition rate in a no-choice experiment over 72 h. Bars show mean±SEM. Bars with the same letter are not significantly different (*P*>0.05)

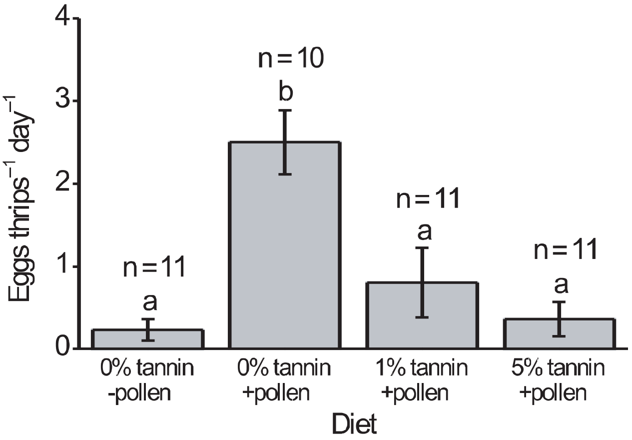

Fig. 4. Graph of the effect of tannic acid solution on oviposition rate in a no-choice experiment over 48 h. Bars show mean±SEM. Bars with the same letter are not significantly different (*P*>0.05)

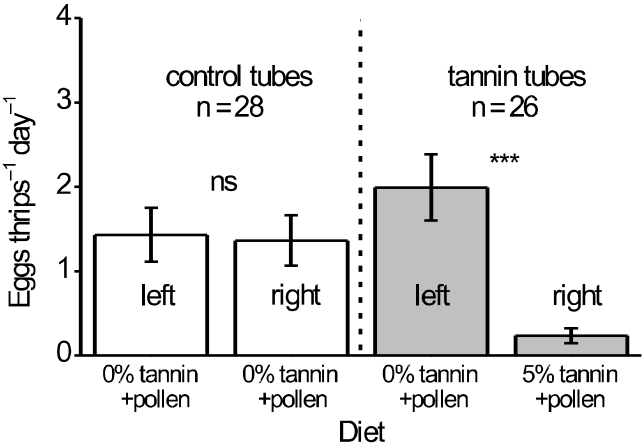

Fig. 5. Graph of the effect of tannic acid solution on oviposition rate in a U-tube choice experiment over 48 h. Bars show mean±SEM. The control tubes (empty bars) had identical solutions with 0% tannin on left and right sides, while the tannin tubes (solid bars) had 5% tannin on the right side only. Key: ns = not significant; *** = *P*<0.001

The effect of tannin on oviposition rate was then investigated with a U-tube choice experiment *(Fig. 5)*. Control tubes were set up with the same solution (0% tannin) on the left and right sides, whereas the tannin tubes had 0% tannin on the left and 5% tannin on the right. As expected, there was no significant difference between the left and right sides of the control tubes, which had identical solutions on each side (paired $t_{(27)}$=0.17, *P*=0.87), but the presence of 5% tannin on the right side of the tannin tubes significantly reduced oviposition rate by 88% compared with the left side (paired $t_{(25)}$=4.48, *P*<0.001). The overall oviposition rate in the U-tubes (left and right sides combined) was 21% lower in the tannin tubes (4.42±0.80 eggs thrips^{-1} d^{-1}) than in the control tubes (5.57±0.90 eggs thrips^{-1} d^{-1}), but the difference was not significant ($t_{(52)}$=0.95, *P*=0.35).

Discussion

The addition of sucrose to diets with or without pollen had no significant effect on oviposition rate. However, the rate increased a little when 20% sucrose was added to a diet without pollen *(Fig. 2),* and since replication was low in this experiment, a repeat with more replication is needed to be certain that sucrose has no effect. Sucrose contains no protein or amino acids, so it is unlikely to promote oviposition directly. In these experiments, the sucrose solution was separate from the nutrients in the pollen. However, if the solution also contained nutrients, sucrose might act as a feeding stimulant and thus increase the intake of nutrients, indirectly increasing oviposition rate.

The addition of tannin to a diet with pollen markedly reduced oviposition in the no-choice experiment, even though the same level of nutrients was available. Some possible explanations are: (1) tannin acts as a toxin and prevents egg production; (2) tannin reduces feeding activity on pollen at the other end of the tube and so reduces oviposition; (3) tannin deters feeding locally and thrips move away to feed and lay eggs elsewhere; (4) thrips are deterred from ovipositing where tannin is present. The first two explanations involve general effects, whereas the latter two have a local effect limited to the vicinity of the tannin. The U-tube choice experiment showed that the reduction in oviposition was local and that the overall oviposition rate was not affected. This suggests that tannin is acting as a feeding deterrent or oviposition deterrent rather than as a toxin. The effects on feeding and oviposition could be further disentangled by means of experiments that measure feeding rate directly, such as those used by Koch (1981) for *Hercinothrips femoralis* (Reuter).

Literature

Annadana, S., Peters, J., Gruden, K., Schipper, A., Outchkourov, N. S., Beekwilder, M. J., Udayakumar, M. and Jongsma, M. A. (2002): Effects of cysteine protease inhibitors on oviposition rate of the western flower thrips, *Frankliniella occidentalis.* Journal of Insect Physiology 48, 701–706.

Bernays, E. A. (1981): Plant tannins and insect herbivores: an appraisal. Ecological Entomology 6, 353–360.

Brodbeck, B. V., Stavisky, J., Funderburk, J. E., Andersen, P. C. and Olson, S. M. (2001): Flower nitrogen status and populations of *Frankliniella occidentalis* feeding on *Lycopersicon esculentum.* Entomologia Experimentalis et Applicata 99, 165–172.

De Jager, C. M. and Butőt, R. P. T. (1993): Thrips *Frankliniella occidentalis* (Pergande) resistance in chrysanthemum; the importance of pollen as nutrition. IOBC/WPRS Bulletin 16, 109–115.

Hirano, C., Yasumi, K., Itoh, E., Kim, C. S. and Horiike, M. (1994): A feeding deterrent for *Thrips palmi* Karny (Thysanoptera, Thripidae) found in tomato leaves – isolation and identification. Japanese Journal of Applied Entomology and Zoology 38, 109–120.

Holm, S. (1979): A simple sequentially rejective multiple test procedure. Scandinavian Journal of Statistics 6, 65–70.

Hulshof, J., Ketoja, E. and Vänninen, I. (2003): Life history characteristics of *Frankliniella occidentalis* on cucumber leaves with and without supplemental food. Entomologia Experimentalis et Applicata 108, 19–32.

Kirk, W. D. J. (1985): Pollen-feeding and the host specificity and fecundity of flower thrips (Thysanoptera). Ecological Entomology 10, 281–289.

Kirk, W. D. J. (1997): Feeding. In: T. Lewis (ed.): Thrips as crop pests. CAB International, Wallingford, pp. 119–174.

Kirk, W. D. J. (2002): The pest and vector from the West: *Frankliniella occidentalis.* In: R. Marullo and L. A. Mound (eds): Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera. Australian National Insect Collection, Canberra, pp. 33–44.

Kirk, W. D. J. and Terry, L. I. (2003): The spread of the western flower thrips *Frankliniella occidentalis* (Pergande). Agricultural and Forest Entomology 5.

Koch, F. (1981): Zum circadianen Verhalten von *Hercinothrips femoralis* (O. M. Reuter) (Thysanoptera, Insecta). Zoologische Jahrbücher. Abteilung für Allgemeine Zoologie und Physiologie der Tiere 85, 462–473.

Koschier, E. and Sedy, K. A. (2002): Effects of plant volatiles on the feeding and oviposition of *Thrips tabaci.* In: R. Marullo and L. A. Mound (eds): Thrips and Tospoviruses: Proceedings of the 7th International Symposium on Thysanoptera. Australian National Insect Collection, Canberra, pp. 185–188.

Koyama, K. and Matsui, M. (1992): Survival of the adult of *Thrips palmi* Karny on various sugar solutions. Proceedings of the Kanto-Tosan Plant Protection Society 39, 205–208. (In Japanese.)

Mollema, C. and Cole, R. A. (1996): Low aromatic amino acid concentrations in leaf proteins determine resistance to *Frankliniella occidentalis* in four vegetable crops. Entomologia Experimentalis et Applicata 78, 325–333.

Parrella, M. P. (1995): IPM – approaches and prospects. In: B. L. Parker, M. Skinner and T. Lewis (eds): Thrips biology and management. Plenum Press, New York, pp. 357–363.

Trichilo, P. J. and Leigh, T. F. (1988): Influence of resource quality on the reproductive fitness of flower thrips (Thysanoptera: Thripidae). Annals of the Entomological Society of America 81, 64–70.