Western Flower Thrips, *Frankliniella occidentalis* (Thysanoptera: Thripidae): Evaluation of Potential Attraction to Vanilla Extract under Laboratory and Greenhouse Conditions

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Additional index words. plant essential oils, plant volatiles, insect trapping, plant protection, monitoring

Abstract. Plant-derived essential oils or extracts and their associated volatiles can serve as insect attractants to enhance adult captures when used as whole plants or extracts that are incorporated onto colored sticky traps. In our study, we initially assessed the attractiveness of western flower thrips (WFT) (*Frankliniella occidentalis*) adults to vanilla extract in the laboratory using choice and no-choice experiments by comparing one (0.05 mL) and two (0.10 mL) drops of vanilla extract (0.029% and 0.059%, respectively). In the choice experiments, a drop of water and drop of vanilla extract were placed on opposite sides of a petri dish. One WFT was placed in the center of the petri dish, and observations were made on whether there was preferential movement to the water or vanilla extract. For the no-choice experiments, one petri dish only contained a drop of water, whereas another petri dish only contained a drop of vanilla extract. One WFT was placed into each petri dish and movement was observed to assess whether the WFT moved toward the water or to the vanilla extract. We then determined if yellow sticky cards containing vanilla extract were more attractive to WFT adults than those with water, by using the number of adults captured on yellow sticky cards as an estimate under greenhouse conditions. Western flower thrips adults were not attracted to vanilla extract based on the results associated with the choice and no-choice tests conducted under laboratory conditions with no differences in selection between vanilla extract and water. In addition, there was no evidence that inoculating yellow sticky cards with vanilla extract enhanced the number of adults captured on yellow sticky cards. Overall, the use of vanilla extract in attracting WFT adults to yellow sticky cards is not justifiable under the parameters of our study.

Western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) are one of the most destructive insect pests of horticultural crops (Helyer and Brobyn, 1992; Jensen, 2000; Kirk, 2002; Kirk and Terry, 2003). The destructive attributes of WFT are based on the direct and/or indirect damage they cause to plants (Tommasini and Maini, 1995). Direct plant damage is associated with feeding. Western flower thrips have piercing-sucking mouthparts that are used to obtain nutrients from plant cells (Harrewijn et al., 1996). Their feeding results in cell death and leaf or flower deformation, which can negatively impact marketability due to decreased aesthetic value

(Childers, 1997; Chisholm and Lewis, 1984; Jensen, 2000). Indirect damage is affiliated with transmission of *tosspoviruses* such as *Impatiens necrotic spot* or *Tomato spotted wilt virus* that decreases aesthetic value and marketability (Allen and Broadbent, 1986; Pappu et al., 2009; Wijkamp et al., 1995). Therefore, insecticides are used to suppress WFT populations in greenhouse production systems (Cloyd, 2009; Parrella and Murphy, 1996). However, WFT populations are difficult to suppress due to their ability to inhabit secluded areas on plants, such as, unopened flower buds and terminal buds, which reduces exposure to insecticide applications (Cloyd, 2009; Jensen, 2000; Loughner et al., 2005). The use of colored sticky cards is oftentimes recommended as a means for greenhouse producers to monitor for WFT adults. The information garnered from monitoring helps to determine population changes throughout the growing season, which also assists in the timing of insecticide applications (Binns and Nyrop,

1992; Heinz et al., 1992; Schmidt and Frey, 1995). As such, greenhouse producers regularly seek strategies that will enhance the effectiveness of monitoring techniques for WFT.

Plant-derived essential oils or extracts and the subsequent volatile constituents can serve as insect attractants to enhance adult captures when used together with whole plants or when extracts are incorporated onto trapping devices (Koul et al., 2008; Vargas et al., 2000; Visser, 1986). Enhanced trap captures of insect pests are important for monitoring and developing action thresholds (Binns and Nyrop, 1992). Monitoring programs can be improved by incorporating plant volatiles or extracts onto trapping devices to obtain accurate estimates of population dynamics and population parameters, including, presence or absence and life stage present at a given time. For instance, Frey et al. (1994) found under laboratory conditions, that geraniol was attractive to WFT adults. Similarly, Koschier et al. (2000) demonstrated that WFT adults were attracted to a number of plant-derived floral volatiles including, geraniol, linalool, eugenol, and citronellol. Western flower thrips adults were found to be attractive to volatiles of sweet bay (*Laurus nobilis*) in laboratory bioassays (Chermenskaya et al., 2001), and Manjunatha et al. (1998) reported that WFT adults were attracted to volatiles produced by chrysanthemum (*Dendranthema grandiflora*).

Colored sticky cards (yellow or blue) are commonly used in greenhouse production systems to monitor for insect pests, including WFT because they are effective in capturing adults (Cloyd and Sadof, 2003; Gillespie and Vernon, 1990; Heinz et al., 1992; Pizzol et al., 2010). The use of certain plant volatiles or extracts along with colored sticky cards can increase the number of WFT adults captured (Kirk, 1985). For example, flower volatiles, such as certain aldehydes (e.g., *p*-anisaldehyde), increase the number of adult WFT captured on yellow sticky cards (Teulon et al., 1993). Higher numbers of WFT adults were captured on blue sticky cards treated with a chrysanthemum extract compared with untreated sticky cards (Manjunatha et al., 1988). Several terpenes associated with the essential oils of lemon and geraniol, when applied to blue traps, were shown to be attractive to thrips (Koul et al., 2008). However, not all plant volatiles or extracts act as insect attractants (Katerinopoulos et al., 2005; Picard et al., 2012).

There are anecdotal claims that vanilla extract may be an attractant to WFT; however, there is no evidence to support these claims or even indications why vanilla extract is considered to be attractive to WFT adults. Therefore, laboratory (choice and no-choice experiments) and greenhouse experiments were conducted, using yellow sticky cards to determine whether adult WFT are attracted to vanilla extract and if vanilla extract could be used to improve the accuracy of WFT monitoring programs that use yellow sticky cards. Improved monitoring could enhance management practices in greenhouse production systems.

Received for publication 2 Feb. 2016. Accepted for publication 29 Feb. 2016.

We thank Mary Beth Kirkham of the Department of Agronomy at Kansas State University (Manhattan, KS) and Kun Yan Zhu of the Department of Entomology at Kansas State University for reviewing initial drafts of the manuscript.

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Materials and Methods

WFT colony. A laboratory colony of WFT, *F. occidentalis* (Pergande) (Thysanoptera: Thripidae) was maintained on green beans [*Phaseolus vulgaris* (L.)] and a 10% honey solution under $25 \pm 5^\circ\text{C}$, 50 to 60% relative humidity, and a photoperiod of 24:00 (only light) hours in the Department of Entomology at Kansas State University (Manhattan, KS). Specimens used in this research are deposited as voucher number 237 in the Kansas State University Museum of Entomological and Prairie Arthropod Research (Manhattan, KS).

Laboratory experiments. Choice and no-choice experiments were designed to determine whether 1) same-aged adult WFT are attracted to vanilla extract (59% vanilla bean extract and 41% alcohol; McCormick®: McCormick & Co., Inc., Hunt Valley, MD) and 2) adult WFT age (young or mature) influences attraction to vanilla extract.

Thirty glass petri dishes (100 × 15 mm) were lined with a 9-cm-diameter piece of P8 Fisherbrand® filter paper (Fisher Scientific, Pittsburgh, PA). Ten petri dishes were used for the choice experiment and 20 were used for the no-choice experiment. Each experiment was replicated 10 times. For the choice experiment, one drop (0.05 mL) of vanilla extract (0.029%), using a sterile 1 mL plastic syringe (BD®: Becton, Dickinson and Comp., Franklin Lakes, NJ), was applied to the edge of the filter paper in the petri dish. Care was taken to insure that the drop made a circle, and did not disperse along the edge of the petri dish and filter paper, allowing us to determine (based on observation) if WFT adults were making a selection. An equal volume of water was added to the opposite edge of the filter paper in the same petri dish. The water served as a control. One adult WFT (10 ± 1 d post-emergence) was removed from the colony and subsequently placed into the center of the petri dish using a fine-tipped paintbrush, and then the petri dish lid was immediately replaced. Using a stopwatch, the amount of time (seconds) required for each WFT adult to select either vanilla extract or water was recorded. A selection was defined as any WFT adult that entered into ≥ 1 mm drop of liquid absorbed into the filter paper and paused for at least 1 s. If a WFT adult did not make a selection after 300 s, then a “no selection” was recorded. A similar method was used for the no-choice experiment although two petri dishes were used and contained one drop (0.05 mL) of either vanilla extract (0.029%) or water. The same method was performed again using two drops (0.10 mL) of vanilla extract (0.059%). The quantity of vanilla extract used was chosen because preliminary experiments demonstrated no difference in adult WFT attraction to one, two, four, five, and eight drops of vanilla extract (N.J. Herrick and R.A. Cloyd, unpublished data).

Another series of choice and no-choice experiments was conducted similar to that described above using one drop (0.05 mL) of vanilla extract (0.029%) or water to determine

whether WFT adult age influences attraction to vanilla extract or water. Adult WFT used were either young adults (1 ± 1 d post-emergence) or mature adults (20 ± 1 d postemergence).

Greenhouse experiments. Caged, choice experiments were conducted in a glass-covered greenhouse at the Throckmorton Plant Sciences Center, Kansas State University (Manhattan, KS) to determine whether 1) same-aged adult WFT exhibit similar responses in the greenhouse as in the laboratory associated with attraction to vanilla extract and 2) adult WFT (young or mature) exhibit similar responses in the greenhouse as in the laboratory in terms of attraction to vanilla extract or water.

Twenty, clear plastic cages [$45.7 \times 45.7 \times 60.9$ cm (L × W × H)] were arranged in rows and placed on top of two wire mesh greenhouse benches (4.3×1.1 m). Each cage had a lid with a hole on top and two additional holes on opposite sides (12.7 cm diameter) covered with thrips screening (Green-Tek, Inc., Edgerton, WI). The screened holes allowed for ventilation and prevented movement of WFT adults among cages. Yellow sticky cards [12.7×7.6 cm (L × W)] were creased (before removing the protective coverings) 7.0 mm from the base, creating a fold that retained the vanilla extract or water drop (s). One yellow sticky card was attached to a bamboo stake (30.5 cm in length) using a wooden clothes pin, which kept the base of the sticky card 8.9 cm above the cage bottom. The bamboo stake was placed into a circular plastic container (250 mL) filled with sand, which held the stake upright. One experiment was conducted using one drop (0.05 mL) of vanilla extract (0.029%) or water and subsequently repeated using two drops (0.10 mL) of vanilla extract (0.059%) or water. Two yellow sticky cards, attached to bamboo stakes, were randomly placed in opposite corners of the cages. One yellow sticky card contained vanilla extract and the other yellow sticky card contained water. A 9 dram (33.27 mL) plastic vial containing ≈ 50 adult WFT (10 ± 1 d postemergence) was placed in the center of each cage (26.7 cm from both sticky cards), and the number of adults captured was counted after 7 d. There were 10 replications (cages) for each experiment.

A series of choice experiments was conducted similar to that described above using two drops (0.10 mL) of vanilla extract (0.059%) or water to determine whether age (young or mature) of adult WFT respond similarly in the greenhouse as in the laboratory. Adult WFT were either young (1 ± 1 d postemergence) or mature (20 ± 1 d post-emergence). Two drops were used because preliminary experiments revealed a higher number of adult WFT captured than with one drop (N.J. Herrick and R.A. Cloyd, unpublished data).

Statistical analysis. All experiments were conducted in a completely randomized design, and data were subjected to analysis of variance (ANOVA) (SAS Institute, 2002) at $\alpha = 0.05$. In the laboratory experiments, the

amount of time required to make a selection was used as the response variable and treatment (e.g., vanilla extract or water) and WFT adult age (young or mature) were the main effects. In the greenhouse experiments, percent capture of WFT adults was the response variable and treatment (e.g., vanilla extract or water) and WFT adult age (young or mature) were the main effects. Percent capture was calculated by dividing the total number of WFT captured per sticky card by the total number of WFT adults released per cage.

Results

Laboratory experiments. In the choice tests, using same-aged adult WFT, no selection was made within 300 s in the experiment with one drop (0.05 mL) of vanilla extract (0.029%) and water. However, in the no-choice tests, water was selected 60% of the time compared with 10% for vanilla extract, and selection occurred in 139 ± 25.3 s (mean $\pm$ SE) and 259 s, respectively. Similar results were observed in the experiments using two drops (0.10 mL) of vanilla extract (0.059%) or water; however, in the choice tests, water was selected 40% of the time and vanilla extract only once, or 10% of the time. Selection of water occurred in 149 ± 30.3 s and in 98 s for vanilla extract. In the no-choice tests, water was selected 30% of the time compared with 10% of the time for vanilla extract, and selection occurred in 191 ± 29.7 s and in 48 s, respectively. Data were not analyzed using ANOVA because vanilla extract or water was never selected in the choice tests and the vanilla extract was only selected once in the no-choice tests with one drop (0.05 mL; 0.029%). Similarly, vanilla extract was selected only once in the choice tests and once in the no-choice tests using two drops (0.10 mL; 0.059%).

Experiments designed to determine if age (young or mature) of adult WFT influences the amount of time in selecting vanilla extract or water did not reveal any significant differences in the amount of time associated with 300 s of exposure to vanilla extract and water among young or mature adult WFT in the choice tests ($F = 0.93$, $df = 1, 12$; $P = 0.3422$) or within 300 s of exposure to vanilla extract and water within young and mature adult WFT ($F = 0.84$, $df = 1, 12$; $P = 0.3661$) (Fig. 1). However, in the no-choice tests, mature WFT adults made a selection in significantly less time than young WFT adults ($F = 8.67$, $df = 1, 12$; $P = 0.0066$) although the amount of time in selecting either vanilla extract or water was not significant within adult age (young or mature) ($F = 1.55$, $df = 1, 12$; $P = 0.2243$) (Fig. 2).

Greenhouse experiments. There were significantly more same-aged adult WFT captured on yellow sticky cards with two drops (0.10 mL) of vanilla extract (0.059%) or water than with one drop (0.05 mL) ($F = 7.05$, $df = 1, 12$; $P = 0.0132$) (Fig. 3). However, captures of WFT adults were not significantly different between yellow sticky cards treated with vanilla extract or water ($F = 0.05$, $df = 1, 12$;

Fig. 1. Mean ($\pm$ SE) amount of time (seconds) for young (1 ± 1 d postemergence) and mature (20 ± 1 d postemergence) western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) adults to select either vanilla extract or water in laboratory choice tests. Vertical bars represent the standard error of the mean (SE).

Fig. 2. Mean ($\pm$ SE) amount of time (seconds) for young (1 ± 1 d postemergence) and mature (20 ± 1 d postemergence) western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) adults to select either vanilla extract or water in laboratory no-choice tests. Vertical bars represent the standard error of the mean (SE).

$P = 0.8197$). Furthermore, captures of young or mature adult WFT on yellow sticky cards treated with vanilla extract or water were not significantly different ($F = 0.07$, $df = 1, 12$; $P = 0.7919$) (Fig. 4). The cumulative percent of WFT adults captured on the yellow sticky cards was consistent ($\approx 30\%$ to 40%) after day 2.

Discussion

This is the first study to evaluate quantitatively anecdotal claims regarding the potential attraction of WFT adults to vanilla extract.

We found no evidence that WFT adults were attracted to vanilla extract. Similarly, Katerinopoulos et al. (2005) found that WFT adults were not attracted to extracts of rosemary (*Rosmarinus officinalis*). In the laboratory experiments, when WFT adults were exposed to one drop (0.05 mL) of vanilla extract (0.029%), no selection was made, and, in the no-choice tests, water was selected nearly 60% of the time by same-aged WFT adults. Temporal dynamics associated with life stage and adult age may influence insect motivation for resource acquisition (Boggs, 2009). For example, larvae and even younger adult

insects often search initially for nutrients to survive, whereas older adults are more oriented toward mating, reproduction, or searching for oviposition sites (Pearsall and Myers, 2000). Therefore, if WFT adults were attracted to vanilla extract as a nutrient source, a potential mating cue, or oviposition site then they would be expected to be attracted to vanilla extract whether young or mature. However, the lack of attraction to vanilla extract was apparent in the laboratory tests when exposing young and mature adult WFT to vanilla extract indicating no evidence of attraction under our study parameters or during the exposure period. We did find, however, that mature WFT adults took less time, overall, to make a selection in the no-choice tests, which may be due to their inherent learned ability to orient toward plant volatiles, whereas young WFT adults may not have developed learned orientation behaviors (Terry, 1997).

Field experiments, such as those conducted in the greenhouse, are often more practical (realistic) in assessing insect behavior than laboratory experiments because the laboratory is an artificial environment (Brodsgaard, 1994; Stark et al., 2007). In addition, yellow sticky cards are commonly used in greenhouses to monitor insect pests and, more specifically, act as a visual attractant to WFT (Blumthal et al., 2005). However, there may be issues associated with trap distance where volatiles on baited traps may influence captures on nearby unbaited traps (Teulon et al., 1993), although in our study, the greenhouse experiments verified the laboratory experiments in that WFT were not attracted to vanilla extract. Teulon et al. (1999) also found no differences in adult WFT captured on yellow sticky cards with or without *p*-anisaldehyde in a greenhouse experiment. However, Frey et al. (1994) was not able to duplicate the results obtained in the laboratory under greenhouse conditions.

We do not know why two drops (0.10 mL) of vanilla extract (0.059%) or water yielded higher adult trap catches than one drop (0.05 mL) although attractiveness of plant volatiles or extracts is dependent on concentration (Koschier et al., 2000; van Tol et al., 2006) and the distance that volatiles are emitted (Terry, 1997). In fact, concentrations of volatiles that act as attractants can exert repellent effects at higher concentrations (Visser, 1986). However, the attractiveness of WFT to plant volatiles may not be consistent (Koschier et al., 2000).

Western flower thrips are weak fliers (Hollister et al., 1995), which may impact the number of adults captured. Furthermore, the distance between traps may influence variation in WFT adult numbers captured (Teulon et al., 1993). However, we were successful in recapturing between 40% and 50% of the WFT adults released into our caged experiments; consequently, we were able to determine that the yellow sticky cards treated with vanilla extract were not more attractive to adults than those treated with water.

Fig. 3. Mean percent ($\pm$ SE) of same-aged western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) adults (10 ± 1 d postemergence) captured on yellow sticky cards treated with one drop (0.05 mL) of vanilla extract (0.0295%) and water, or two drops (0.10 mL) of vanilla extract (0.059%) or water in the greenhouse. There were 10 replications per treatment. Vertical bars represent the standard error of the mean (SE).

Fig. 4. Mean percent ($\pm$ SE) of young (1 ± 1 d postemergence) and mature (20 ± 1 d postemergence) adult western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) captured on yellow sticky cards treated with two drops (0.10 mL) of vanilla extract (0.059%) or water in the greenhouse. There were 10 replications per treatment. Vertical bars represent the standard error of the mean (SE).

Although plant-derived essential oils or extracts and their associated volatiles can be important in managing insect pests, based on the parameters and results of our study, vanilla extract does not appear to be useful in increasing monitoring efforts or detection of WFT adult populations in greenhouse crop production systems. Similar investigations, under greenhouse conditions using other plant extracts or volatiles may be useful in determining potential attraction

or even deterrence, which could contribute to better management of WFT populations.

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