Effect of Sugar-based Compounds in Enhancing the Efficacy of Insecticides against the Western Flower Thrips

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ADDITIONAL INDEX WORDS. *Frankliniella occidentalis*, sugar enhancement, pesticide efficacy, pesticide additives, floriculture, pest management

SUMMARY. **It has been proposed by greenhouse producers that adding sugar to a stomach poison insecticide enhances the efficacy of the insecticide in controlling western flower thrips (*Frankliniella occidentalis*). As such, a series of laboratory, including no-choice and multiple-choice assays, and greenhouse experiments were conducted to determine if adding sugar-based compounds to insecticides enhances efficacy against western flower thrips. The sugar-based compounds evaluated were Mountain Dew, Diet Mountain Dew, white sugar, and brown sugar at two rates [initial (0.18 mL/100 mL and 0.12 g/100 mL) and high (0.36 mL/100 mL and 0.24 g/100 mL)]. A water control was also included in all the assays. In the laboratory experiments, western flower thrips adults and nymphs were not attracted to any of the sugar-based compounds with <60 s (out of 300 s total) spent in any of the treatments, and ≤29 s (out of 300 s total) spent in the treatments when the sugar-based compounds were mixed with three insecticides (tau-fluvalinate, pyridalyl, and spinosad). In the greenhouse experiments, the addition of the high rate of Mountain Dew (0.36 mL/100 mL) and brown sugar (0.24 g/100 mL) did not enhance the efficacy (based on percent mortality) of the insecticides against western flower thrips. There was no significant difference between the individual insecticide treatments and the mixtures with either Mountain Dew or brown sugar. This study is the first to quantitatively demonstrate that western flower thrips adults and nymphs are not attracted to sugar-based compounds and that it is not warranted to add these types of materials to spray solutions targeted for control of western flower thrips.**

Western flower thrips are the most destructive insect pest of greenhouses worldwide, causing both direct and indirect damage to a wide range of horticultural crops (Brodsgaard, 1989; Gerin et al., 1994; Helyer et al., 1995; Tommasini and Maini, 1995). The primary means of dealing with western flower thrips in greenhouse production systems is the use of insecticides (Herron and James, 2005; Lewis, 1997; Parrella and Murphy, 1996). However, greenhouse producers are continually seeking alternative options to manage or regulate western flower thrips populations to alleviate the prospect of resistance (Georghiou, 1986) and thus preserve already existing commercially available insecticides. Furthermore, it is difficult to suppress western flower thrips populations because of their thigmotactic behavior, which means that the body is in constant contact with a surface so they tend to occupy narrow crevices in plant parts (Childers, 1997; Kirk, 1997a,b). This is why western flower thrips tend to reside in tight-enclosed areas including unopened flower buds and terminal buds, which decrease their susceptibility to insecticide sprays (Brodsgaard, 2004; Jensen, 2000; Mound, 1996; Tommasini and Maini, 1995). As such, there has been interest in using materials that lure or attract western flower thrips to increase the efficacy of insecticide spray applications (attract-and-kill strategy).

It has been proposed by greenhouse producers that adding sugar to a stomach poison insecticide enhances the efficacy of the insecticide in controlling western flower thrips (R.A. Cloyd, personal observation). However, there has been no scientific information to support this notion. In fact, a recommendation provided in the 1940s was to use sugar as a feeding stimulant for controlling western flower thrips (Parrella, 1995). This supposedly involved adding sugar (preferably white sugar) with a stomach poison insecticide to enhance the efficacy of the spray solution (Parrella, 1995). In fact, greenhouse producers continually inquire about or suggest that mixing sugar such as white or brown sugar or a sugar-laden soft drink (e.g., Mountain Dew; PepsiCo, Deep Gap, NC) with a contact insecticide (in a spray solution) enhances the efficacy of the spray application against western flower thrips (R.A. Cloyd, unpublished data). Furthermore, it has been suggested that molasses and brown sugar will act as a surfactant or attract thrips from flowers and encourage them to consume or come in contact with insecticide residues (Cloyd, 2009). However, it is difficult to comprehend the basis of this attraction because of the characteristics of sugar and sugar-based compounds.

White sugar is pure sucrose derived from either tropical sugar cane or sugar beets. In contrast, there are two types of brown sugar: sticky and free-flowing. Both types are obtained by adding syrup such as molasses to purified or refined sugar (FitDay-Myth or Fact, 2011). Mountain Dew, which is a sugar-laden soft drink, contains 77 g of sugar (per bottle) and a multitude of ingredients including carbonated water and high-fructose corn syrup. As such,

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
29.5735	fl oz	mL	0.0338
0.0781	fl oz/100 gal	$mL \cdot L^{-1}$	12.8000
0.7813	fl oz/gal	mL/100 mL	1.2800
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
28.3495	oz	g	0.0353
0.0749	oz/100 gal	$g \cdot L^{-1}$	13.3526
0.7489	oz/gal	g/100 mL	1.3353
0.9464	qt	L	1.0567

it is difficult to understand how and why a plant-feeding insect such as western flower thrips, which primarily feeds on pollen and plant tissue (Kirk, 1985, 1987; Trichilo and Leigh, 1988), would be attracted to any type of sugar, particularly if the sugar does not provide any essential nutrients (proteins and amino acids) required for development and reproduction (Kirk, 1987). However, there are no quantitative studies that have actually substantiated claims made regarding using sugar or sugar-based compounds with contact insecticides to enhance efficacy against western flower thrips. Therefore, the objective of this study was to determine if sugar-based compounds are attractive to and improve control of western flower thrips when mixed with insecticides under both laboratory and greenhouse conditions.

Materials and methods

LABORATORY EXPERIMENTS. These experiments involved both no-choice and multiple-choice assays and were designed to determine whether different sugar-based compounds were directly attractive to the adult and nymphal stages of the western flower thrips using two different rates of each compound tested. The compound treatments were white sugar (C&H Sugar Co., Crockett, CA), brown sugar, Mountain Dew, Diet Mountain Dew (PepsiCo), and a water control. The designated compounds were measured to exact quantities and then mixed thoroughly in 100 mL of distilled water. The rates included 0.12 g/100 mL white sugar, 0.12 g/100 mL brown sugar, 0.18 mL/100 mL Mountain Dew, and 0.18 mL/100 mL Diet Mountain Dew. These rates were used based on inquires and feedback from greenhouse producers (R.A. Cloyd, unpublished data). We also conducted similar assays (described below) using higher (2-fold) rates: 0.24 g/100 mL white sugar, 0.24 g/100 mL brown sugar, 0.36 mL/100 mL Mountain Dew, and 0.36 mL/100 mL Diet Mountain Dew. Each treatment was replicated 10 times per each western flower thrips life stage (adult and nymph).

For the no-choice assay, only one compound was used, whereas all four were included in the multiple-choice assays. In addition, a water control was included in all the assays. The experiments were initiated by mixing 10

Table 1. Sugar-based compounds including Mountain Dew (PepsiCo, North Gap, NC), Diet Mountain Dew, white sugar, and brown sugar and insecticides used and rates evaluated against western flower thrips in Expts. 1 and 2.

Treatment	Rate (per quart)[z]
Expt. 1	
Mountain Dew (high rate)	1.70 mL
Diet Mountain Dew (high rate)	1.70 mL
White sugar (high rate)	1.13 g
Brown sugar (high rate)	1.13 g
Mountain Dew (initial rate)	0.85 mL
Diet Mountain Dew (initial rate)	0.85 mL
White sugar (initial rate)	0.56 g
Brown sugar (initial rate)	0.56 g
Untreated control	—
Expt. 2	
Spinosad	0.44 mL
Abamectin	0.59 mL
Azadirachtin	0.59 mL
Sucrose octanoate ester	7.39 mL
Mountain Dew	26.8 mL
Spinosad + Mountain Dew	0.44 mL + 26.8 mL
Abamectin + Mountain Dew	0.59 mL + 26.8 mL
Azadirachtin + Mountain Dew	0.59 mL + 26.8 mL
Untreated control	—

[z]1 mL/qt = 0.1353 fl oz/gal = 1.0567 $mL \cdot L^{-1}$, 1 g/qt = 0.1411 oz/gal = 1.0567 $g \cdot L^{-1}$.

Table 2. Rates of insecticides [tau-fluvalinate at 8.0 fl oz/100 gal (0.625 $mL \cdot L^{-1}$), pyridalyl at 8.0 oz/100 gal (0.599 $g \cdot L^{-1}$), and spinosad at 6.0 fl oz/100 gal (0.468 $mL \cdot L^{-1}$)], and high rate (HR) and initial rate (IR) of Mountain Dew (PepsiCo, Deep Gap, NC) [0.36 mL/100 mL (0.4608 fl oz/gal) and 0.18 mL/100 gal (0.2304 fl oz/gal)] and brown sugar [0.24 g/100 mL (0.3204 oz/gal) and 0.12 g/100 mL (0.1602 oz/gal)] used in Expts. 3 and 4.

Treatment	Rate (per quart)[z]
Expt. 3	
Tau-fluvalinate	0.51 mL
Pyridalyl	0.56 g
Spinosad	0.44 mL
Tau-fluvalinate + Mountain Dew (HR)	0.51 mL + 3.4 mL
Pyridalyl + Mountain Dew (HR)	0.56 g + 3.4 mL
Spinosad + Mountain Dew (HR)	0.44 mL + 3.4 mL
Tau-fluvalinate + Mountain Dew (IR)	0.51 mL + 1.7 mL
Pyridalyl + Mountain Dew (IR)	0.56 g + 1.7 mL
Spinosad + Mountain Dew (IR)	0.44 mL + 1.7 mL
Untreated control	—
Expt. 4	
Tau-fluvalinate	0.51 mL
Pyridalyl	0.56 g
Spinosad	0.44 mL
Tau-fluvalinate + brown sugar (HR)	0.51 mL + 1.1 g
Pyridalyl + brown sugar (HR)	0.56 g + 1.1 g
Spinosad + brown sugar (HR)	0.44 mL + 1.1 g
Tau-fluvalinate + brown sugar (IR)	0.51 mL + 0.56 g
Pyridalyl + brown sugar (IR)	0.56 g + 0.56 g
Spinosad + brown sugar (IR)	0.44 mL + 0.56 g
Untreated control	—

[z]1 mL/qt = 0.1353 fl oz/gal = 1.0567 $mL \cdot L^{-1}$, 1 g/qt = 0.1411 oz/gal = 1.0567 $g \cdot L^{-1}$.

solutions of each compound treatment at the designated rates. There were 10 replications per compound treatment. Then, 10 petri dishes were prepared by excising five circles (2-cm diameter) from filter paper (Whatman No. 1; Whatman, Maidston, England). The five circles of filter paper were placed into each petri dish, where the treatments were to be applied. The circles were placed equidistant from each other into each petri dish. After preparing the solutions and petri dishes, one drop of each treatment, using a micropipette, was placed on the filter paper circle, which was enough to sufficiently moisten the filter paper. Then, an individual western flower thrips adult or nymph, collected from a laboratory-reared colony (≈2 weeks in age) maintained at Kansas State University (Manhattan), was positioned in the center of each petri dish. Similar-aged adults and nymphs (3-d old) were used within 12 h of initiating the experiments. Five-minute (300 s) observations were made of each petri dish (10 replicates total). Thrips movement was monitored throughout the entire length of time, and the amount of time that each life stage visited a treatment was recorded. The experiments were conducted under typical laboratory lighting (overhead ceiling lights).

To avoid positional effects, treatments were rotated so that they were located in different positions within the petri dishes. In addition, we conducted preliminary experiments to compare attraction and retention time of western flower thrips adults and nymphs to water, Mountain Dew, and brown sugar, on filter paper and leaf disks (1-cm diameter) of chrysanthemum (*Tanacetum grandiflora*). We found that there was no difference in either attraction or retention time between the two surfaces associated with the water control and sugar-based compound treatments (data not shown). As such, we were justified in using filter paper in all of the experiments.

The assays were repeated using three different insecticides including tau-fluvalinate at 8.0 fl oz/100 gal (Mavrik Aquaflow®; Wellmark International, Schaumburg, IL), pyridalyl at 8.0 oz/100 gal (Overture®; Valent U.S.A. Corp., Walnut Creek, CA), and spinosad at 6.0 fl oz/100 gal (Conserve®; Dow AgroSciences, Indianapolis, IN). These insecticide treatments were combined with the initial and high rates of all four sugar-based compounds.

Greenhouse experiments. All experiments were conducted in a glass-covered greenhouse, and the procedures were similar for the four experiments. Yellow cut transvaal daisy (*Gerbera jamesonii*) flowers were obtained from a wholesale broker (Koehler & Dramm of Missouri, KS City, MO). No pesticides had been applied to the cut flowers before harvest from the broker, so the possibility of any pesticide residues negatively affecting western flower thrips survival was minimal. Flower stems were excised 2 to 3 inches

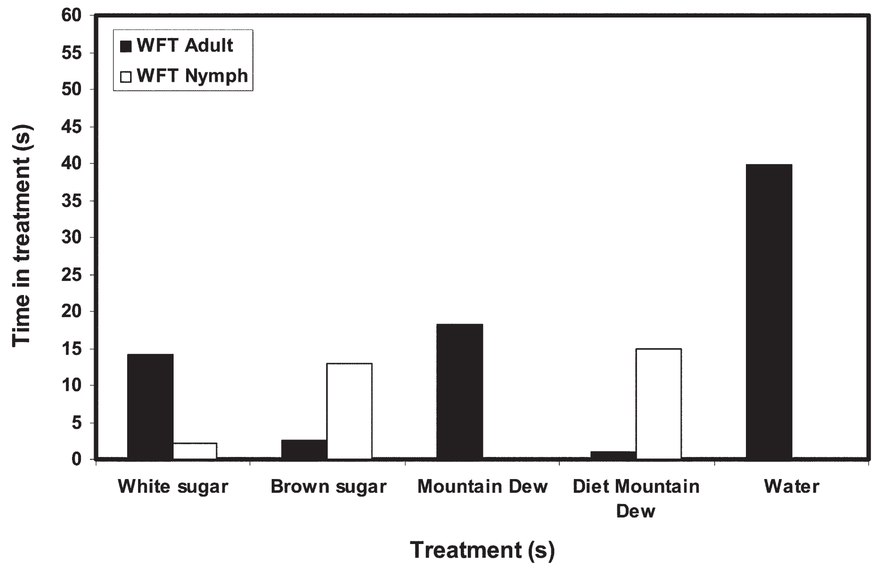

Fig. 1. Time spent (out of 300 s total) by western flower thrips (WFT) adult (black bars) and nymph (white bars) in each of the treatments (at the initial rates) associated with the no-choice bioassays. Rates used were Mountain Dew (PepsiCo, Deep Gap, NC) at 0.18 mL/100 mL (0.2304 fl oz/gal), Diet Mountain Dew at 0.18 mL/100 mL, white sugar at 0.12 g/100 mL (0.1602 oz/gal), and brown sugar at 0.12 g/100 mL.

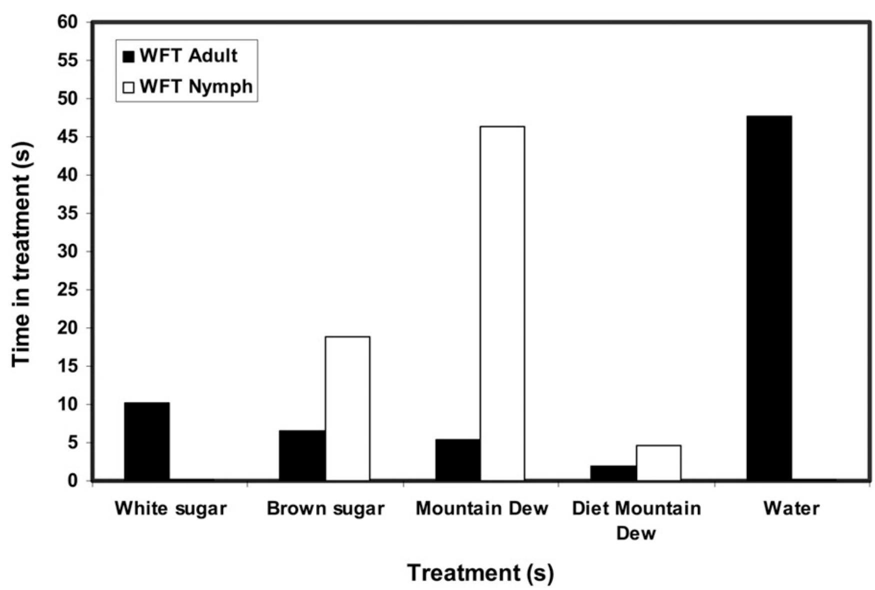

Fig. 2. Time spent (out of 300 s total) by western flower thrips (WFT) adult (black bars) and nymph (white bars) in each of the treatments (at the high rates) associated with the no-choice bioassays. Rates used were Mountain Dew (PepsiCo, Deep Gap, NC) at 0.36 mL/100 mL (0.4608 fl oz/gal), Diet Mountain Dew at 0.36 mL/100 mL, white sugar at 0.24 g/100 mL (0.3204 oz/gal), and brown sugar at 0.24 g/100 mL.

below the base of the flowers and placed into 22-mm, low-background borosilicate glass vials containing tap water. One transvaal daisy cut flower was placed into each glass vial. The glass vials were inserted into plastic containers (250 mL) with sand, which held the glass vial containing the tap water and the cut flower upright during the experiments. One container or cut flower was equal to one experimental unit.

All the plastic containers, with the cut flowers, were positioned in a polyvinyl chloride (PVC) pipe open frame on a wire-mesh bench (16 × 5 ft), and the designated treatment containers, with the cut flowers, were arranged in a completely randomized design. A 50% black knit shadecloth (Hummert International, Earth City, MO) was positioned over the PVC frame to protect the cut flowers from direct sunlight and thus preserve their longevity. Each cut flower was artificially infested with ≈15 to 20 western flower thrips (90% adults and 10% nymphs) obtained from a laboratory-reared colony in the Department of Entomology at Kansas State University (Manhattan).

All flowers were sprayed with the appropriate treatments using a 1-quart plastic spray bottle (The Home Depot, Manhattan, KS) 2 d after postinfestation. Each flower was sprayed to runoff with ≈15 mL of spray solution. This spray volume thoroughly saturated the flower surface and allowed the spray solution to penetrate into the disk portion of the flowers. The glass vials were refilled regularly with tap water to ensure lasting quality of the cut flowers. The temperature inside the greenhouse during all experiments was 21 ± 3 °C with a relative humidity between 50% and 60%.

Four experiments were conducted with different treatment combinations, replicated five times. In Expt. 1 in which we only evaluated the sugar-based compounds, there were a total of nine treatments with five replications per treatment. The treatments and rates are presented in Table 1. In Expt. 2, we evaluated four individual insecticides and combinations with one rate of Mountain Dew (26.8 mL/100 mL). There were five replications per treatment. The insecticides used were spinosad, abamectin (Avid®; Syngenta Crop Protection, Greensboro, NC), azadirachtin (Ornazin®; SePRO Corp., Carmel, IN), and sucrose octanoate ester (SucraShield™; Natural Forces, Davidson, NC). Table 1 presents the materials and rates used in Expt. 2.

Expts. 3 and 4 used three different insecticides: tau-fluvalinate at 8.0 fl oz/100 gal (Mavrik Aquaflow®), pyridalyl at 8.0 oz/100 gal (Overture®), and spinosad at 6.0 fl oz/100 gal (Conserve®). There were five replications per treatment. The insecticides were applied individually and combined with the initial or high rate of either Mountain Dew (1.7 or 3.4 mL/qt) or

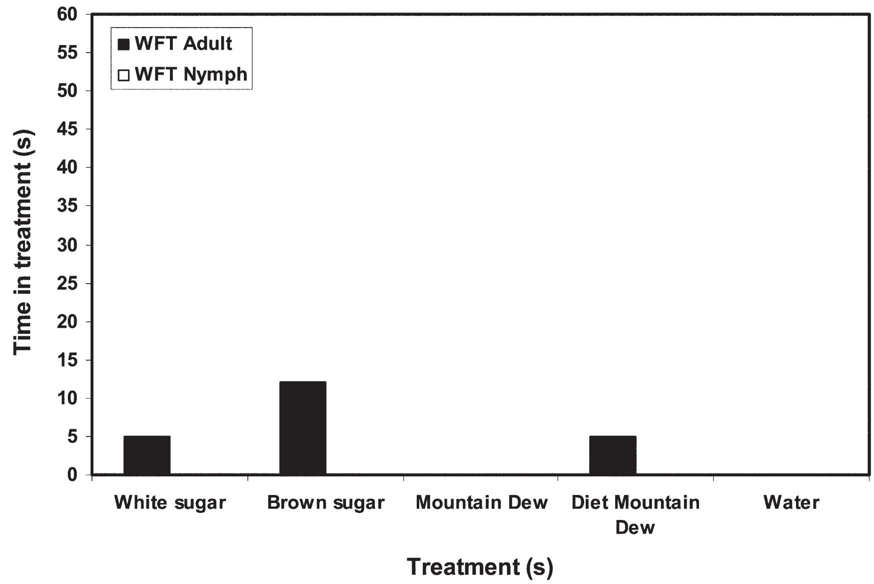

Fig. 3. Time spent (out of 300 s total) by western flower thrips (WFT) adult (black bars) and nymph (white bars) in each of the treatments (at the initial rates) associated with the multiple-choice bioassays. Rates used were Mountain Dew (PepsiCo, Deep Gap, NC) at 0.18 mL/100 mL (0.2304 fl oz/gal), Diet Mountain Dew at 0.18 mL/100 mL, white sugar at 0.12 g/100 mL (0.1602 oz/gal), and brown sugar at 0.12 g/100 mL.

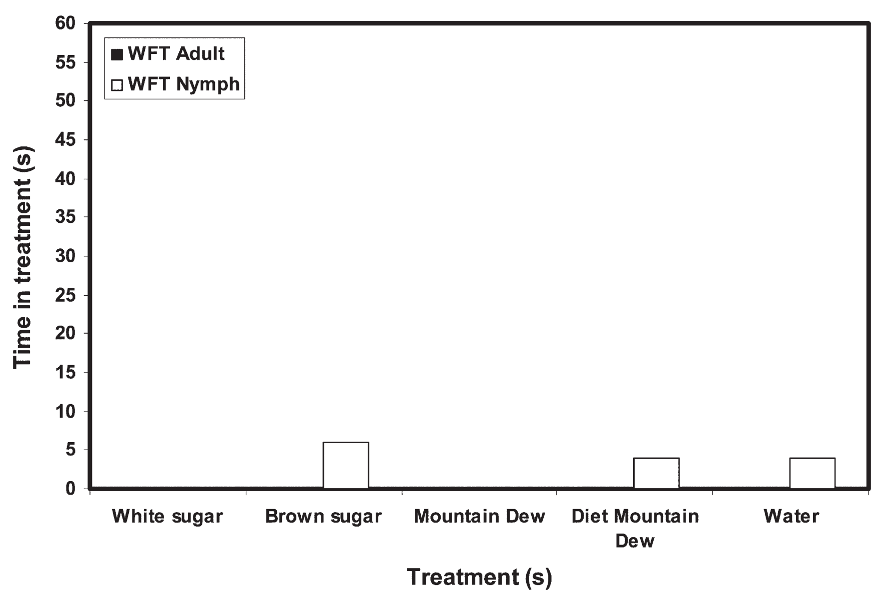

Fig. 4. Time spent (out of 300 s total) by western flower thrips (WFT) adult (black bars) and nymph (white bars) in each of the treatments (at the high rates) associated with the multiple-choice bioassays. Rates used were Mountain Dew (PepsiCo, Deep Gap, NC) at 0.36 mL/100 mL (0.4608 fl oz/gal), Diet Mountain Dew at 0.36 mL/100 mL, white sugar at 0.24 g/100 mL (0.3204 oz/gal), and brown sugar at 0.24 g/100 mL.

brown sugar (0.56 or 1.1 g/qt) as none of the other sugar-based compounds evaluated in Expt. 1 resulted in any mortality of western flower thrips. The treatments and rates used in the experiments are presented in Table 2.

Seven days after application of the treatments, flowers were harvested, placed into plastic petri dishes (14-cm diameter) with lids, and then macerated under laboratory conditions. The numbers of live, dead, and total number of western flower thrips adults were counted. Percent mortality values for each treatment was calculated by dividing the number of dead western flower thrips by the total number recovered per flower (i.e., replicate). Percent mortality values were then normalized by arcsine square-root transformation and subject to a one-way analysis of variance (ANOVA) with treatment as the main effect (SAS version 9.1; SAS Institute, Cary, NC). Significant treatment means were separated using a Fisher's protected least significant difference (LSD) test at $P \leq 0.05$. All data presented are nontransformed.

Results and discussion

Laboratory experiments. Western flower thrips adults and nymphs were not attracted to any of the sugar-based compound treatments regardless of rate (initial and high) based on the negligible (if any) amount of time spent (<60 s out of 300 s total) in any of the treatments (Figs. 1–4). These results were similar to the assays in which the insecticides were mixed with the sugar-based compounds as western flower thrips spent ≤29 s across all the experiments out of 300 s total (Table 3). This is the reason why statistics were not conducted on the data.

Greenhouse experiments. There was no significant difference ($F = 1.00$; df = 8, 44; $P = 0.4529$) among the treatments in Expt. 1 as none of the sugar-based compounds provided any mortality of western flower thrips. In Expt. 2, although there was a significant difference ($F = 1019.97$; df = 9, 49; $P \leq 0.0001$) among the treatments, the addition of Mountain Dew at the rate of 26.8 mL/100 mL failed to enhance the efficacy of any of the treatments against western flower thrips (Fig. 5).

Table 3. Time in treatment spent by western flower thrips nymphs and adults associated with the initial rate (IR) [Mountain Dew (PepsiCo, Deep Gap, NC) at 0.18 mL/100 mL (0.2304 fl oz/gal), Diet Mountain Dew at 0.18 mL/100 mL, white sugar at 0.12 g/100 mL (0.1602 oz/gal), and brown sugar at 0.12 g/100 mL] and high rate (HR) [Mountain Dew at 0.36 mL/100 mL (0.4608 fl oz/gal), Diet Mountain Dew at 0.36 mL/100 mL, white sugar at 0.24 g/100 mL (0.3204 oz/gal), and brown sugar at 0.24 g/100 mL] of the sugar-based compounds, and the three insecticides [tau-fluvalinate at 8.0 fl oz/100 gal (0.625 mL·L^{-1}), pyridalyl at 8.0 oz /100 gal (0.599 g·L^{-1}), and spinosad at 6.0 fl oz /100 gal (0.468 mL·L^{-1})]. There were 10 replications per treatment for each insecticide and western flower thrips life stage.

	Tau-fluvalinate				Pyridalyl				Spinosad			
	Nymphs		Adults		Nymphs		Adults		Nymphs		Adults	
Treatment	IR	HR	IR	HR	IR	HR	IR	HR	IR	HR	IR	HR
Mountain Dew	0.4	0.0	0.0	1.6	0.2	0.0	10.8	0.0	7.8	0.0	0.0	0.4
Diet Mountain Dew	0.4	0.5	0.0	11.8	0.0	0.0	0.0	0.0	3.5	0.5	0.0	0.8
White sugar	0.0	0.3	0.0	0.0	1.8	0.0	6.9	0.0	0.0	2.7	0.0	5.6
Brown sugar	0.0	0.0	0.3	4.7	0.0	0.4	29.0	0.4	0.0	0.0	3.3	14.4
Water control	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0

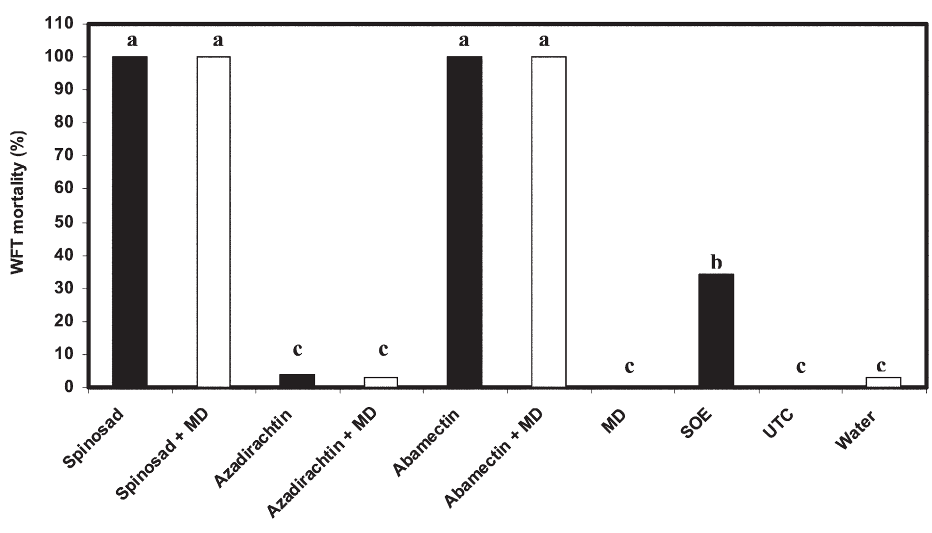

Fig. 5. Percent mortality of western flower thrips (WFT) for all treatments 7 d after application with five replications per treatment; MD = Mountain Dew (PepsiCo, Deep Gap, NC), UTC = untreated control, Water = water control. Insecticides used were spinosad, azadirachtin, abamectin, and sucrose octanoate ester (SOE). Rates used are listed in Table 1. Bars with common letters are not significantly different from each other ($P \geq 0.05$) based on Fisher's protected least significant difference mean separation test.

However, it was difficult to assess if mixing Mountain Dew had any real effect since the spinosad and abamectin individual treatments provided nearly 100% mortality of the western flower thrips. The addition of Mountain Dew did not enhance the efficacy of azadirachtin as percent mortality was <10% for both treatments (Fig. 5). The sucrose octanoate ester (SucraShield™) treatment provided <40% mortality of western flower thrips.

Treatment was significant for Expt. 3 (F = 24.27; df = 9, 49; $P \leq 0.0001$) and Expt. 4 (F = 43.6; df = 9, 49; $P \leq 0.0001$); however, the addition of the initial and high rate of either Mountain Dew or brown sugar did not enhance western flower thrips mortality for any of the insecticide treatments (Table 4).

This study is the first to quantitatively demonstrate that western flower thrips adults and nymphs are not attracted to sugar-based compounds because of the lack of retention time in any of the treatments and treatment combinations in the laboratory experiment, and based on greenhouse experiments; there was no significant increase in efficacy or enhancement associated with western flower thrips mortality when the insecticides evaluated were mixed with either the initial or high rate of Mountain Dew or brown sugar.

Western flower thrips prefer to feed on pollen, which is essential for larval growth, sexual maturation, and egg-laying (Andrewartha and Kilpatrick, 1951; Bournier et al., 1979; Murai and Ishii, 1982). In addition, protein nitrogen is the primary food source required by insects (McNeill and Southwood, 1978) and results in a general increase in the rate of survival, growth, and reproduction (Strong et al., 1984). Although the form and availability of nitrogen may affect insects, total nitrogen is a viable indicator of the nutritional value of plants (Kirk, 1997a,b). A sugar may not provide any essential nutrients (proteins) required for development and reproduction (Kirk, 1995). For example, the oviposition rate of the banded greenhouse thrips (*Hercinothrips femoralis*) adult females declined from one egg per 12 h to zero over a 2- to 3-d period after feeding on a sucrose solution (Laughlin, 1971).

The insecticides used in the study were selected because they are all labeled for control of western flower thrips, vary in their efficacy against western flower thrips, and are in different chemical classes with distinct modes of action (Abalis et al., 1986; Salgado, 1997, 1998; Verkerk and Wright, 1993; Ware and Whitacre, 2004; Yu, 2008). In addition, these insecticides are widely used by greenhouse producers against western flower thrips (R.A. Cloyd, unpublished data). Although pyrethroid insecticides such as tau-fluvalinate may have repellent properties (Hall, 1979; Hull and Starner, 1983; Thompson and Wilkins, 2003), this did not appear to be a factor in our study as, in general, there was no difference in the time spent (retention time) among the insecticide and sugar-based compound treatments (Table 3).

The sucrose octanoate esters (SucraShield™) treatment was included in Expt. 2 because it is a sugar-based compound that is registered for thrips. The a.i. is an extract from the leaf hairs of wild tobacco (*Nicotiana gossei*) plants (Neal et al., 1994). In previous studies, we have found minimal efficacy against both the nymph and adult life stages of western flower thrips (Cloyd, 2009; R.A. Cloyd, unpublished data). In Expt. 2 of the current study, the product provided <40% mortality of western flower thrips (Fig. 5).

Alternative products containing attractants/stimulants or alarm pheromones are commercially available against mite pests such as the twospotted spider mite (*Tetranychus urticae*). For example, the product Stirrup M® (Troy Biosciences, Phoenix, AZ) contains the alarm pheromone farnesol, which is suppose to increase mite activity and thus enhance exposure to miticide applications in addition to reducing mite feeding (Regev and Cone, 1975). In addition, there is a product called Konsume® (Troy Biosciences) that may act as a feeding stimulant thus increasing exposure to spray residues. This is a similar concept to the mixing of sugar-based compounds with insecticides

Table 4. Percent western flower thrips (WFT) mortality associated with each individual insecticide treatment (tau-fluvalinate, pyridalyl, and spinosad) and in combination with both the high rate (HR) and initial rate (IR) of Mountain Dew (PepsiCo, Deep Gap, NC) [0.36 mL/100 mL (0.4608 fl oz/gal) and 0.18 mL/100 gal (0.2304 fl oz/gal)] for Expt. 3 and brown sugar [0.24 g/100 mL (0.3204 oz/gal) and 0.12 g/100 mL (0.1602 oz/gal)] for Expt. 4.

Expt. 3

Treatment	Rate (per quart)[z]	WFT mortality [mean ± se (%)]
Tau-fluvalinate	0.51 mL	4 ± 2c[y]
Pyridalyl	0.56 g	62 ± 13b
Spinosad	0.44 mL	98 ± 10a
Tau-fluvalinate + Mountain Dew (HR)	0.51 mL + 3.4 mL	1 ± 1c
Pyridalyl + Mountain Dew (HR)	0.56 g + 3.4 mL	63 ± 13b
Spinosad + Mountain Dew (HR)	0.44 mL + 3.4 mL	100 ± 0a
Tau-fluvalinate + Mountain Dew (IR)	0.51 mL + 1.7 mL	13 ± 5c
Pyridalyl + Mountain Dew (IR)	0.56 mL + 1.7 mL	66 ± 11b
Spinosad + Mountain Dew (IR)	0.44 mL + 1.7 mL	93 ± 4a
Untreated control	—	0 ± 0c

Expt. 4

Treatment	Rate (per quart)[z]	WFT mortality [mean ± SE (%)]
Tau-fluvalinate	0.51 mL	6 ± 2de[y]
Pyridalyl	0.56 g	48 ± 16b
Spinosad	0.44 mL	100 ± 0a
Tau-fluvalinate + brown sugar (HR)	0.51 mL + 1.1 g	7 ± 3de
Pyridalyl + brown sugar (HR)	0.56 g + 1.1 g	53 ± 9bc
Spinosad + brown sugar (HR)	0.44 mL + 0.56 g	100 ± 0a
Tau-fluvalinate + brown sugar (IR)	0.51 mL + 0.56 g	5 ± 1de
Pyridalyl + brown sugar (IR)	0.56 g + 0.56 g	30 ± 6cd
Spinosad + brown sugar (IR)	0.44 mL + 0.56 g	95 ± 3a
Untreated control	—	0 ± 0e

[z]1 mL/qt = 0.1353 fl oz/gal = 1.0567 $mL \cdot L^{-1}$, 1 g/qt = 0.1411 oz/gal = 1.0567 $g \cdot L^{-1}$.

[y]Means followed by a common letter are not significantly different from each other ($P \leq 0.05$) based on Fisher's protected least significant difference (LSD) mean separation test.

to suppress western flower thrips populations.

In conclusion, this study has demonstrated that western flower thrips adults and nymphs are not attracted to sugar-based compounds and as such there is no benefit of adding these types of materials into spray solutions designated for control of western flower thrips. Therefore, when using insecticides to deal with western flower thrips, greenhouse producers need to obtain thorough coverage of all plant parts, apply insecticides frequently enough, and rotate insecticides with different modes of action to avoid populations developing resistance (Heugens et al., 1989; Jensen, 2000; Lewis, 1997; Loughner et al., 2005; Seaton et al., 1997; Zhao et al., 1995).

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