CONTROL OF WESTERN FLOWER THRIPS, *FRANKLINIELLA OCCIDENTALIS* (PERGANDE) (THYSANOPTERA: THRIPIDAE), BY PLANT EXTRACTS ON STRAWBERRY IN GREENHOUSE CONDITIONS

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ABSTRACT: The western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), is a most important pest of vegetable, fruit and ornamental crops around the world. The presence of this pest in strawberry fields has been associated with undesirable bronzing of the fruit. Experiments were conducted to assess the efficiency of four plant extract for control *F. occidentalis* on the strawberry in greenhouse conditions. Taguchi's design of experiments method has been used for to plan a minimum number of experiments and optimization to control of *F. occidentalis*. Four factors, which influence the control thrips, were chosen. These factors are type of pesticide (neem extract, coconut soap, tobacco extract and garlic-onion-pepper extract), dosage (recommended and twice dose), droplet size (250 µm and 1000 µm) and application value of pesticide (60 cc and 90 cc per vase). Orthogonal array L_8 was used with three replicates. In order to determine the optimum levels of the control factors precisely, analysis of variance was performed. After optimization, the results showed that application value was the most effective factor. The optimum condition for control of *F. occidentalis* was found to be garlic-onion-pepper extract in twice of recommended dosage (Grind 20 g of garlic, 30 g of onions and 7 g pepper) with droplet size 1000 µm, and 90 cc of pesticide per vase for application value. This study is warranted to determine suitability of garlic-onion-pepper extract, as botanical insecticide, for inclusion in *F. occidentalis* integrated pest management programs.

KEY WORDS: *Frankliniella occidentalis*, Strawberry, Plant extracts, Taguchi method, Greenhouse, Garlic-onion-pepper extract, Organic pesticides.

The western Flower Thrips (WFT), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), is a most important pest of vegetable, fruit and ornamental crops around the world (Thoeming et al., 2003; Broughton et al., 2009; Funderburk, 2009; Reitz, 2009).On strawberry fruit, WFT feeding on seeds after the buds open (Anonymous, 2010; Obryki, 2004). Adults and nymphs of Western flower thrips with rasping-sucking mouthparts pierce skin cells of strawberry flowers and fruits to obtain sap (Anonymous, 2010; Reitz, 2009; McCamant, 2007). *F. occidentalis* feeding during bloom and fruit set causes the dead of individual cells, creating a bronzed semblance on the strawberry petals, sepals and fruits. The skin cannot correctly expand as fruit ripens, and the seeds stick out of the skin, which led to small and seedy fruits (Anonymous, 2010; Steiner, 2009; McCamant, 2007; Obryki, 2004). However, the inconsiderate use of insecticide, have led to the development of resistance in populations of *F. occidentalis* to major insecticide groups: organochlorines, organophosphates, carbamates, pyrethroids and spinosyns in many parts of the world (Parrella &

Murphy, 1996; Herron & James, 2005; Bielza et al., 2008; Broughton & Herron, 2009).

Recently, concerns have been raised over the impacts of the agricultural pesticides on human health and the environment (Moser et al., 2008). Pollution of the environment by synthetic pesticides has been increasing due to their use to manage various pests (Senthil Nathan et al., 2007). Before finding of synthetic pesticides plant or plant-based products were the only pest-managing agents accessible to farmers around the world (Georges et al., 2008). The use of natural pesticides with selectivity effects has increased in recent years, particularly in agricultural systems that rely on natural enemies as a main component of integrated pest management (Weathersbee & Tang, 2002).

As a sample, the oil from seeds of neem tree, *Azadirachta indica* A. Juss. (Sapindales: Meliaceae), is marketed as popular pesticide of integrated pest management (IPM) programs at around the world (Li et al., 2003). It's generally considered less baneful to the environment and relatively safe for mammals and beneficial insects because of more effective as oral toxins than as contact poisons, and confined permanency in the environment (Li et al., 2003; Tran & Perry 2003). Active compounds in neem have numerous effects on insects; they are a strong antifeedent, repellent, antiovipositional and growth-regulating compound for many pest insects (Senthil Nathan et al., 2007 & 2005; Kumar & Poehling, 2007; Huang, 2007; Athanassiou, 2005; Tran & Perry, 2003; Rong et al., 2000) and reduce fecundity in some female insect pest populations (Ghazawi et al., 2007; Mitchell et al., 2004; Tran & Perry 2003). The biopesticide NeemAzal-T/S (Trifolio GmbH, Lahnau, Germany) has been registered in Germany since October 1998 for the control of various biting and sucking insects in different horticultural crops (Thoeming et al., 2003).

Tobacco, *Nicotiana tobaccum* L. is belongs to the large family Solanaceae. It has immense insecticide properties and farmers use for killing of insect pests since time immemorial. Pure nicotine is a tobacco extract highly toxic to warm-blooded animals. The insecticide usually is marketed as a 40% liquid concentrate of nicotine sulfate, which is diluted in water and applied as a spray. Nicotine is recorded for use on a wide range of crops. It degrades rapidly, so can be used on many food plants nearing harvest (English, 2005). In a similar manner, Garlic, *Allium sativum* L., is a native of temperate western Asia and is other example of plant-based pesticidesis. The experimental use of garlic as a pesticide was inspired by the public household use of garlic as an insect repellent for protecting food grains (Huang et al., 2000). Gardeners have been using soap to control insects since the early 1800s. During the first half of the 19th century, whale oil soap and, more customarily, fish oil soaps were an important item of insect control. The most effective soaps have carbon chains of C-12 or C-18. Laurate (C-12) is the main component of most dishwashing liquids and various other products in common use. The richest natural source of this is coconut oil (English, 2005). The objective of this study was to determine the effective organic pesticide of four plant extract for control *F. occidentalis* on strawberry. The used organic pesticides were: NeemAzal-T/S, coconut soap, tobacco and garlic-onion-pepper extracts.

MATERIAL AND METHODS

Western Flower Thrips and Arena Experiments. *F. occidentalis* populations were reared on strawberries (*Fragaria* × *ananasa* Duch. Cultivar, Selva) in experimental greenhouse. Plants were grown under temperature of 26±2

°C with 60±10% RH, and a photoperiod of 14:10 h L:D, which was suitable for the plants to flower and for populations of western flower thrips to be established. Experiments were conducted in an experimental greenhouse of the Iranian Research Organization for Science and Technology (IROST) in Tehran, Iran.

Botanical insecticides Source and Preparation of the extracts. NeemAzal-T/S 1% azadirachtin (containing 10 g azadirachtin per liter as active ingredient) was obtained from Bayer Company and Palizin (coconut soap 65%±5, water soluble concentration, SC) from Kimia Sabzavar Co. Extracts used were Tobacco extract was prepared according to a modified method of Murali (2010) and Fusire (2008) (soak of 250 g dried leaves and stalks of tobacco for 24 hours with 4 liters of water and strain the solution and add 30-g soap and mix well) and also garlic-onion-pepper extract (Grind separately 10 g of garlic, 15 g of onions and 3.5 g pepper and dissolve in 1 liter of water for 24 hours and filter through muslin cloth and also add 7 g soap). These organic pesticides were prepared at different concentrations.

Experimental Design. Essentially, traditional experimental design procedures are very complicated and not easy to use. A huge number of experimental works have to be performed when the number of process parameters increase. To find a solution for this problem, the Taguchi method uses a particular design of orthogonal arrays to study the whole parameter space with only a small number of experiments (Bagci & Ozcelik, 2005). In this research, the Taguchi design of experiments (Taguchi's DOE) method has been used to plan a minimum number of experiments and optimization of control procedure.

Four factors, which influence for control *F. occidentalis*, were chosen. These factors were type of pesticide (A) in four levels (neem extract, coconut soap, tobacco extract and garlic-onion-pepper extract), dosage (B) in two levels (recommended and twice dose which are shown in Table 2), droplet size (C) in two levels (250 μm and 1000 μm) and application value of pesticide (D) in two levels (60 cc and 90 cc per vase). Factors with their levels are shown in Table 1.

Commonly, on the base of the full factorial design, which represents the traditional or classical approach, considers all possible combinations of input factors and for the given situation would require 32 (4^1*2^3) experiments should be performed. Applying a specific orthogonal array only a small set from all the possible experiment is chosen. In accordance with the Taguchi's DOE method, the standard orthogonal array L_8 (4^1*2^3) (L and the subscript 8 represent the Latin square and the number of experimental runs, respectively), with one factor in four levels and three factors in two levels, was used with three replicates. The experimental settings are shown in Table 3.

Greenhouse Trials. Before experiments began, thirty strawberry plants were randomly selected and the number of all stages of *F. occidentalis* on flowers was counted (Tap flowers onto a white plate according to the method used by McCamant (2007)), and the mean number was calculated. Then 24 vases of strawberry were chosen (eight experiments in three replications) for experiments and three vases for the untreated control. Each three plant for a treatment was placed into cages, which were constructed of nylon fabric. Cages were used to keep western flower thrips from dispersing between plants. Applications of pesticides were via a small (500 ml capacity) hand-held sprayer per plant. After 24 hours of treatment, five open flowers per plant were randomly selected from strawberry plants (three plants per treatment), and the numbers of *F. occidentalis* were counted. Furthermore, for performance evaluation of optimum condition was performed this experimental condition and compared with untreated control in three replications.

Data Analyses and Statistics. In Taguchi's method the relative magnitude of the impact of different factors can be achieved by decomposition of variance, ANOVA (analysis of variance). Analyzing data calculate by MINITAB (release 14) software. Significant differences between optimum condition and untreated control were determined by t-test. Differences among means were considered significant at a probability level of five percent ($P \leq 0.05$).

RESULTS

The results (average of western flower thrips number for each treatment) of Taguchi design of experiment are shown in Table 4. The initial (before experiments began) average of western flower thrips was 5.6 per flowers.

Analysis of variance (ANOVA). ANOVA was first developed by Ronald A. Fisher in the 1920s to determine the effect of multiple factors on agricultural experiments (Sukthomya & Tannock, 2005). ANOVA is particularly beneficial in analyzing data from the statistically designed experiments and can disintegrate variations for any type of data and helps in rapidly calculating the magnitude of influence of the cause being considered (Khosla et al., 2006). ANOVA results of the mean for responses are illustrated in Tables 5.

From table 5, it can be observed that the application value of pesticide per vase factor (62.747%) was most significant factor for control *F. occidentalis* on the strawberry in greenhouse conditions. The droplet size (14.951%), dosage (12.187%) and type of pesticide (10.111%) were lower effect than application value for control, consecutively.

A radar plot showing the significance of each factor to the four characteristics (the closer to the centre, the more significant that factor) is plotted in Figure 1.

The main effects (average effects of factors) for each signal factor are tabulated in table 6. Plots displaying the mean effects of process factors at their different levels, on the mean are shown in Fig. 2, to illustrate how this graphing technique can help in selecting optimum level settings. Based on the Table 6, Fig.2 and the principle of "smaller is better" range analysis are indicated the best levels for each single factors and shows which factor is the most important in the control process. Hence, the lowest level of each factor in the main effects was employed as the optimum levels of this factor. The results are concluded in Table 7.

Performance evaluation of control by using optimal processing parameters. After the prediction, to evaluate the control of *F. occidentalis* on the strawberry, an experiment in three replications was trained by using these optimum conditions, as a confirmation run. Mean number of western flower thrips were 0.867 and 6.067 per flower at optimum condition and control, respectively (Fig. 3). There was significance difference between optimum conditions and untreated control in mean of western flower thrips number ($p=0.0174$, $t=3.91$), at a probability level of five percent ($P \leq 0.05$). Therefore, predicted optimum conditions confirmed by results of this experiment.

DISCUSSION

Botanical pesticides proffer desirable alternatives to using synthetic chemicals and can reduce environmental pollution, preservation of non-target organisms, and avert insecticide-induced pest resurgence (Tang et al., 2002; Weathersbee & McKenzie, 2005). Also botanical insecticides are more efficacious, safe, ecologically acceptable and nature friendly (Georges et al., 2008; Senthil Nathan et al., 2007).

The results in this study indicated that garlic-onion-pepper extract had significant effect on the control of western flower thrips in the strawberry greenhouse. The optimum conditions for control of *F. occidentalis* was found to be garlic-onion-pepper extract in twice of recommended dosage (Grind 20 g of garlic, 30 g of onions and 7 g pepper) with droplet size 1000 µm, and 90 cc of pesticide per vase for application value. This study is warranted to determine suitability of plant extract, as organic pesticides, for inclusion in *F. occidentalis* integrated pest management programs.

Mohapatra et al. (2009) showed that major insect pests of the vegetable can be controlled by *Calotropis* leaf extract+ garlic+ onion+ chili powder. This extract exhibited as the best antifeedant for vegetable pest. Also, their study indicated that *Calotropis* leaf extract+ garlic+ onion+ chili powder caused highest mortality of the brinjal fruit and shoot borer, pumpkin caterpillar and tapioca withefly tested. Kalu et al. (2010) studied the larvicidal activities of the ethanol extract of *Allium sativum* (garlic bulb) against larvae of *Culex quinquefasciatus* and observed larval mortality after 24 hours treatment. Sirvastava et al. (2001) reported the significant antifeedant activity from sesamin, a major lignan of *Piper mullesua*, against *Spilarctia obliqua* and more than 70% feeding-deterrence was observed at 80 µg sesamin/g diet and above. Lim & Mainlali (2009) found that chrysanthemum flower model trap can be used in strawberry greenhouses to reduce two flower thrips *Frankliniella intonsa* Trybom and *F. occidentalis* on strawberry flowers. One of the most important issues associated with plant-derived essential oil products is their incompatibility in controlling insect pests. For instance, it is possible that one extracts to be toxic to one pest; however, it to be ineffective in controlling other pest (Cloyd et al., 2009). Geographic origin of the plant used in the manufacturing process, environmental conditions (e.g., temperature, light intensity and quality, and relative humidity, exposure to stress factors and water availability), seasonal variations, age of plant and time of harvest, and extraction process, could affect the efficacy of plant-derived essential oils (Cloyd et al., 2009). Scott et al. (2004) demonstrated that *Piper nigrum* extracts were found to provide excellent knockdown of the lepidopteran species and European pine sawfly tested.

Organic farming has experienced substantial development in recent years. Advocates of organic farming emphasize on the environmental and nutritional advantages of organic systems. Regularly, Organic farming is promoted based upon the numerous benefits it is argued to provide, healthier food, an improved farmed environment. It is the environmental effects of organic farming which have gotten largest research attention and, while some still contest the environmental profits of organic farming there is a raising general agreement that it does actually offer particular environmental benefits over and above those of conventional agriculture (Lobley et al., 2009).

This article has described the application of Taguchi's DOE to the selection of the best control conditions of western flower thrips by botanical pesticide, illustrated by a case study using real commercial greenhouse data. Significant factors and their optimum settings were identified. In summary, garlic-onion-pepper extract can be control *F. occidentalis* on strawberry. Therefore, this extract, as botanical pesticide, could become an important and promising tool in integrated pest management program of westeren flower thrips.

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Table 1. Factors and their levels employed in the Taguchi's experimental design.

Factors	Levels			
	1	2	3	4
A. Type of pesticide	Neem extract	Coconut soap	Tobacco extract	Garlic-onion-pepper extract
B. Dosage	Recommended dose	Twice dose	-	-
C. Droplet size	250 µm	1000 µm	-	-
D. Application value per vase	60 cc	90 cc	-	-

Table 2. Levels of dosage factor.

Pesticide	Recommended dose	Twice dose
Neem extract	3 $ml.L^{-1}$	6 $ml.L^{-1}$
Coconut soap	1.5 $ml.L^{-1}$	3 $ml.L^{-1}$
Tobacco extract	62.5 g dried tobacco leaves in 1 L water	125 g dried tobacco leaves in 1 L water
Garlic- onion-pepper extract	Grind 10 g of garlic, 15 g of onions and 3.5 g pepper	Grind 20 g of garlic, 30 g of onions and 7 g pepper

Table 3. L_8 (4^1*2^3) orthogonal array of Taguchi experimental design (Trail conditions).

Experiment no.	A	B	C	D
1	Neem extract	Recommended dose	250 µm	60 cc
2	Neem extract	Twice dose	1000 µm	90 cc
3	Coconut soap	Recommended dose	250 µm	90 cc
4	Coconut soap	Twice dose	1000 µm	60 cc
5	Tobacco extract	Recommended dose	1000 µm	60 cc
6	Tobacco extract	Twice dose	250 µm	90 cc
7	Garlic- onion-pepper extract	Recommended dose	1000 µm	90 cc
8	Garlic- onion-pepper extract	Twice dose	250 µm	60 cc

Table 4. Design matrix and the experimental results (means of western flower thrips number for each treatment) for the L_8 orthogonal array experiment.

Experimental No.	Factors				Results (Average of thrips)
	A	B	C	D	
1	1	1	1	1	2.776
2	1	2	2	2	0.223
3	2	1	1	2	1.223
4	2	2	2	1	1.556
5	3	1	2	1	2.00
6	3	2	1	2	1.11
7	4	1	2	2	0.443
8	4	2	1	1	1.446

Table 5. ANOVA results of mean for control *Frankliniella occidentalis*.

Source of variation	Degree of freedom (DF)	Sum of squares	Variance	F ratio (F)	P value (P)	Contribution P (%)
Type of pesticide (A)	3	0.4603	0.1534	1.24	0.564	10.111
Dosage (B)	1	0.5548	0.5548	4.50	0.280	12.187
Droplet size (C)	1	0.6806	0.6808	5.52	0.254	14.951
Application value (D)	1	2.8561	2.8561	23.16	0.130	62.747
Residual Error	1	0.1233	0.1233	-	-	0.004
Total	7	4.6750	-	-	-	100.00

Table 6. Main effects (average effects of factors) factors for control *Francliniella occidentalis*.

Factors	Level 1	Level 2	Level 3	Level 4
Type of pesticide (A)	1.50	1.390	1.555	0.945
Dosage (B)	1.61	1.084	-	-
Droplet size (C)	1.639	1.055	-	-
Application value (D)	1.945	0.75	-	-

Table 7. Optimum levels and performance for each single factor in the L_8 orthogonal array experiment according to fig. 2 and table 6.

Factor	Level	Level description
Type of pesticide (A)	4	Garlic- onion-pepper extract
Dosage (B)	2	Twice dose (20 g of garlic, 30 g of onions and 7 g pepper)
Droplet size (C)	2	1000 µm
Application value (D)	2	90 cc

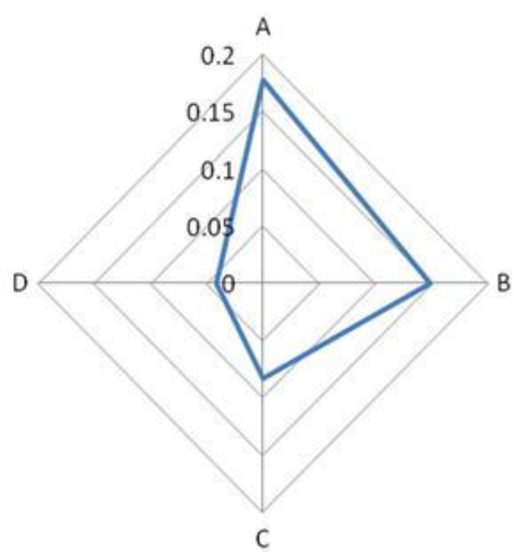

Figure 1. Radar plot of the rank of process factors.

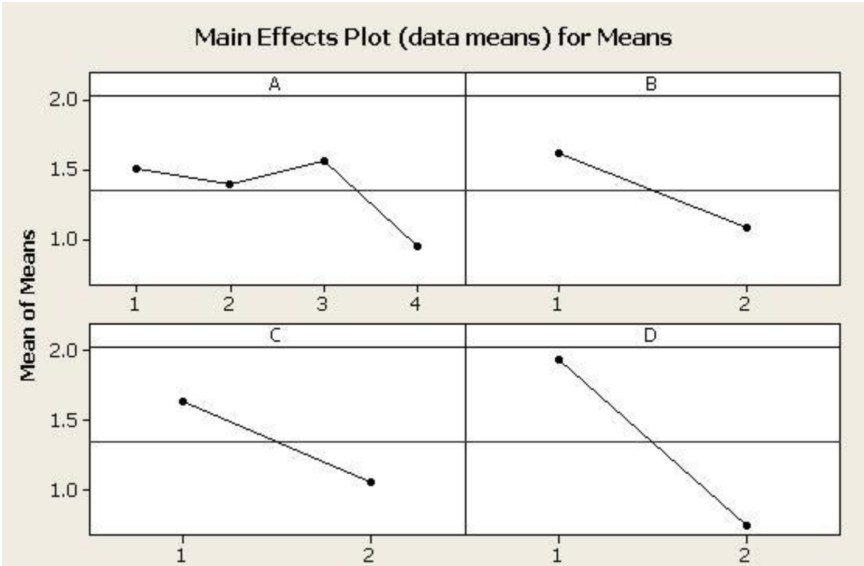

Figure 2. Main effect plot for means.

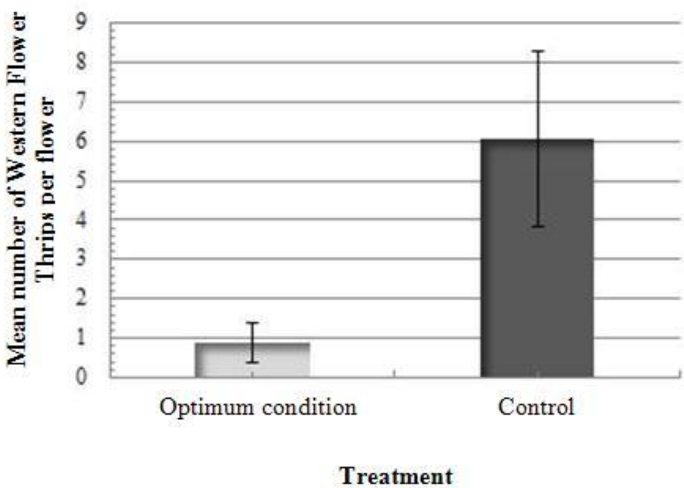

Figure 3. Mean number of western flower thrips per flower in optimum condition and control treatment.