Research Article

Testing the Contact and Residual Toxicity of Selected Low-Risk Pesticides to *Tetranychus Urticae* Koch and its Predators

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Abstract | Occasionally *Tetranychus urticae*, two-spotted spider mite (TSSM), become a major problem in crops. TSSM is mainly controlled with synthetic acaricides. Some low-risk pesticide options are available and included in IPM. In this study, contact and residual toxicity of selected low-risk pesticides were tested against TSSM adult females and three commonly available predators (*Phytoseiulus persimilis* Athias-Henriot, *Neoseiulus fallacis* McGregor and *Stethorus punctillum* Weise). TSSM adult females and adults of TSSM predators were released on the leaf discs either before spray (contact bioassay) or after the spray (residual bioassay). In contact bioassay, all of the tested pesticides killed more than 95% of the TSSM after 72 hours except diatomaceous earth (DE). Diatomaceous earth killed only 24.6±3.2% TSSM that was significantly lower than all the other pesticides used. When mites were released onto treated leaf discs (spray residues), only garlic/chilli extract gave relatively acceptable levels of mortality 72.0±5.8% while bifenazate caused 95.2±3.7% mortality. TSSM females laid significantly more eggs on the garlic/chilli treated leaf discs in both contact and residual bioassays. When sprayed directly (contact bioassay), all of tested low-risk pesticides mortality of 85.2-100% to *P. persimilis* except DE. All of tested low-risk pesticides were moderately harmful to *N. fallacis* and *S. punctillum* causing 30.5-83.6% and 34.6-78.6% mortality, respectively. All of the tested low-risk pesticides were harmless to slightly harmful in the residual toxicity bioassay causing 6.8% - 39.4% mortality in all predators tested. In conclusion, predators could possibly be released 2-3 days after application of any of the tested low-risk pesticide.

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Introduction

The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae), is an economically important pest of agricultural and ornamental plants worldwide (Walter and Proctor, 1999, Vergel et al., 2011). This mite species has become a major problem due to the large-scale use of chemical insecticides. One explanation for this increase in population is that widespread usage of broad spectrum insecticides has almost eliminated many of the mites' natural enemies, resulting in a reduction in predation pressure on the mites (Prischmann et al., 2005). Consequently, using biological control agents, e.g. predatory mites, has become an increasingly popular option in suppressing spider mite populations because their use is considered more environmentally friendly and are commonly being used in organic production (Zhang, 2003).

Two predatory mite species, *Phytoseiulus persimilis* Athias-Henriot and *Neoseiulus* (=*Amblyseius*)

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californicus McGregor, have effectively controlled TSSM in strawberries in Florida (Liburd et al., 2003; Rhodes and Liburd, 2006; Rhodes et al., 2006). *Phytoseiulus persimilis* is a specialist predator that feeds exclusively on tetranychid mites (Schausberger and Croft, 1999). *Neoseiulus (=Amblyseius) fallacis* prefer to feed on pest mites and can move within and between plants searching for them (Kain and Nyrop, 1995). *Stethorus spp.* (Coleoptera: Coccinellidae) feeds exclusively on tetranychid mites (Felland and Hull, 1996). *Stethorus punctillum* has been recorded in fruit orchards as predator of spider mite (Ivancich, 1974). All of these biological control agents are commercially available.

Effective control of TSSM may not be possible using a single control tactic (Kim and Seo, 2001; Rhodes and Liburd, 2006). Combining tactics involving reduced-risk pesticides and selective well-timed releases of predatory mites (maintaining predatory mite populations in the field) may yield more acceptable control of TSSM (Hoy and Cave, 1985; Hoy and Ouyang, 1986; Rhodes et al., 2006). Moreover, the ccommonly used conventional pesticides for TSSM control are not allowed in organic production and are banned for cosmetic use on indoor and outdoor plants and urban agriculture in several countries, for example Canada (Health Canada, 2013). Low-risk pesticides are also called minimum risk pesticides because of very low or no risk to human health, these include soaps, plant extracts, mineral oils, etc. Under the minimum risk exemption regulations, these low-risk pesticides are excluded from FIFRA (Federal Insecticide, Fungicide, and Rodenticide Act) (EPA, 2015).

Different pesticides were compared for compatibility with the TSSM predators to improve existing integrated pest management programs of spider mites for organic production and urban agriculture. This research will quantify toxicity of several low-risk pesticides to *T. urticae*, *P. persimilis*, *N. fallacis* and *S. punctillum*.

Materials and Methods

Test individuals and chemicals

A laboratory culture of *T. urticae* (TSSM) was initiated from mites collected from roses from Durham College greenhouse at the Whitby campus. Uninfested kidney bean plants were provided as food to the TSSM colony. The TSSM culture was maintained inside an insect rearing cage at 27±2^{0}C, 65% RH and 16:8h photoperiod. Adult females (3-4 days old) for bioassays were collected from the TSSM culture when required. Spider mites predators (*P. persimilis, N. fallacis* and *S. punctillum*) were purchased from a commercial supplier (Natural Insect Control, Ontario, Canada).

Safer's brand End All 3 in1 (potassium salts of fatty acids 12.38% and sulfur 3.31%), and Safer's insecticidal soap Concentrate (50.5%) were bought from Home depot, Canada, Agri-Mek 1.9EC (abamectin 19g L^{-1}) was supplied by Syngenta Crop Protection Canada, Inc., Opal (potassium salts of fatty acids 47%) by Omex Agriculture Inc. Canada, DE_cide (diatomaceous earth as silicon dioxide 67%) by Absorbent Products Ltd. Canada and Bifenazate (Floramite SC) by Arysta Life Science Canada. Abamectin is a commercial product for spider mite control and was used as positive control. DE_cide is fine powder and the supplier recommended aqueous solution was used. The homemade garlic/chilli extract was prepared using recipe by Laura (2012). Briefly, 10g (2-3 garlic cloves), 5g (12 small hot chili peppers), 15ml vegetable oil, 15ml natural liquid soap and 500ml water were blended and strained through a cloth. The extract was used undiluted. The label application rates of pesticides were freshly prepared for application as in Table 1.

Bioassay

A 3cm diameter bean leaf disc (abaxial side up) placed on wet cotton was sprayed with two mL of pesticide solutions with a Potter spray tower at 70 Kilopascal. In separate experiments, TSSM and the three predators were placed on the leaf discs either before or after the spray. Placement of arthropods before spray simulated applying pesticides directly when mites are present in the field or when predators are released in the field prior to pesticide application. Release of TSSM/predators after spray (on leaf discs) was called release on spray residues. Spray residues were air dried for 4-6h and 24, 48 and 72 hours aged residues were used in bioassays. Spray residues simulated TSSM not present at the time of spray and later came in contact with the residues, and predators were released 1, 2 and 3 days after spraying a field with the low-risk pesticides. The Petri dishes after treatment were placed in an incubator at 27±1^{0}C, 65±5% RH and 16:8h photoperiod. All of the 8 treatments were replicated 4 times seperately for

Table 1: *Some low-risk pesticides used in contact and residual bioassays of T. urticae by Potter tower.*

	Treatments	Active ingredient	Label application rate	ai-g/Label rate
1	Safer's insecticidal soap 50.5% concentrate	Potassium salts of fatty acids 50.5%	10 mL per 500 mL water	5.05
2	Safer's End All 3in1	Potassium salts of fatty acids 12.38% and Sulfur 6.48%),		12.38 + 6.48
3	DE_cide	Silicon dioxide 67% (Diatomaceous earth)	90 gm per liter water	60.3
4	Homemade garlic/chilli extract	Garlic Chilli	10g garlic + 5g chilli/ 100ml water	
5	Floramite SC	Bifenazate 22.6%	125ml per 400L water	28.3
6	Opal (Commercial insecticidal soap)	Potassium salts of fatty acids 47%	1L per 1000L water	470
7	Agri-Mek 1.9 EC (Positive control)	Abamectin 19g L^{-1}	20mL per 100L water	0.38
8	Absolute control			DI water

contact and residual bioassays. Except the predatory beetles, 20 test individuals were used per replication. A total of 640 spider mites, *P. persimilis* and *N. fallacis* and only 320 *S. punctillum* (10 per replication; because of availability) were used in each type of bioassay. Predators were supplied with TSSM nymphs and adult females during the bioassays. The number of dead and alive test individuals was recorded after 24h, 48h and 72h. The eggs laid by the surviving females were also counted after 24h, 48h and 72h in both contact and residual bioassays. Replicates with more than 20% control mortality were discorded and Abbott's formula (Abbott, 1925) was used to calculate corrected percent mortality. Some TSSM and predatory mites were found dead away from the treated leaf discs in the moist cotton in all treatments except in the garlic+chilli extract residues treatment where they were alive. In all cases TSSM away from the discs were recorded as dead. ANOVA (analysis of variance) was calculated using SPSS V19.0 and means are separated by $LSD_{0.05}$. The criterion for assessing toxicity of pesticides to predators was adopted from the IOBC (International Organization of Biological Control) (Boller et al., 2006). According to the IOBC criterion, a pesticide is considered harmless to slightly harmful, moderately harmful or harmful to a predator if it causes $\leq$ 30%, 31-79% or $\geq$ 80% mortality, respectively.

Results and Discussion

When applied directly (contact bioassay), all of the tested pesticides killed 93.4-100%, 93.4-100% and 95.6-100% of the TSSM 24h, 48h and 72h after exposure except diatomaceous earth. Percent mortality in TSSM was not different among the three observation intervals therefore only 72h data is presented in Figure 1. The insecticidal soap + sulfur and insecticidal soap concentrate killed 96.8% and 95.6% TSSM respectively, in contact bioassay, which was similar to the commercial soap formulation. Garlic+chilli extract also killed 95.0% TSSM. However, diatomaceous earth killed significantly ($p>0.023$) lower TSSM (24.6%) compared to all the other pesticides used. Therefore, when directly sprayed on TSSM insecticidal soap and garlic+chilli extract gave comparable results to commercially available insecticidal soap (Opal®). All of the tested low-risk pesticides had no residual activity. When TSSM were released onto treated leaf discs (spray residues) only garlic+chilli extract gave relatively acceptable level of mortality (72.0%). Bifenazate gave 95.2% mortality. Some TSSM and predatory mites were found alive away from the treated leaf discs in the moist cotton in the garlic+chilli extract residues treatment indicating this extract might have worked as repellant.

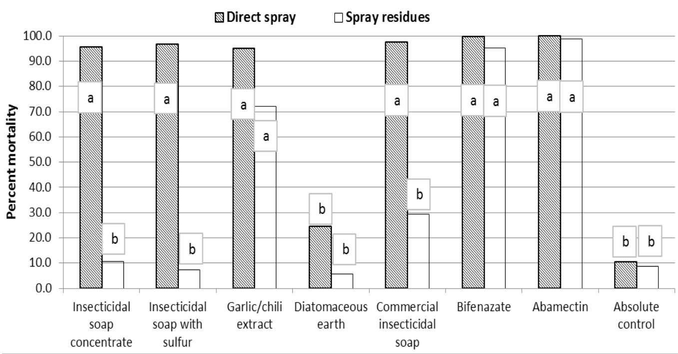

Figure 1: *Percent mortality caused by several pesticides to adult female Tetranychus urticae 72 hours after treatment by Potter tower (Direct spray F=79.6, df=7, p<0.001; Spray residues F=19.7, df=7, p<0.001). Means followed by the same letter between same bar type are not statistically different, LSD (p<0.05).*

Table 2: *Percent corrected mortality (mean±se) recorded in contact and residual bioassays in P. persimilis at 24, 48 and 72 hours after treatment with low-risk pesticides using Potter tower.*

Insecticides	Contact bioassay 24 Hrs	48 Hrs	72 Hrs	Residual bioassay 24 Hrs	48 Hrs	72 Hrs
Insecticidal soap concentrate	90.3±3.26a	94.1±5.56a	96.7±4.32a	7.3±1.24c	5.5±2.32c	4.6±1.12c
Insecticidal soap with sulfur	82.5±4.78a	85.5±2.88a	88.9±4.08a	8.3±2.68c	7.6±3.12c	3.1±1.13c
Garlic/chili extract	93.4±6.45a	94.0±8.90a	95.1±6.25a	32.7±3.92b	25.2±2.34b	21.6±2.64b
Diatomaceous earth	39.4±4.79b	45.2±5.09b	46.4±4.83b	6.8±2.31c	7.0±3.31c	3.2±2.14c
Commercial insecticidal soap	84.0±6.43a	84.0±6.43a	84.0±6.43a	9.8±2.14c	8.1±2.14c	6.1±2.33c
Bifenazate	98.3±4.68a	99.2±4.35a	100.0a	39.4±3.35b	28.3±1.39b	24.7±3.47b
Abamectin	100.0a	100.0a	100.0a	96.5±5.69a	94.4±3.34a	87.6±5.34a
Absolute control	18.8±1.9c	18.8±1.9c	18.8±1.9c	5.9±1.8c	6.3±1.1c	7.2±1.4c
	F (6,21)=3.13, *p<0.05*	F (6,21)=2.07, *p<0.05*	F (6,21)=2.56, *p<0.05*	F (6,21)=19.54, *p<0.001*	F (6,21)=28.79, *p<0.001*	F (6,21)=22.67, *p<0.001*

Means followed by the same letter within each column are not statistically different, LSD (p<0.05).

There was an increase in the total number of eggs laid by an individual surviving female from 24 h to 72 h in all treatments. Females laid significantly (*p=0.006*) more eggs on the discs treated with garlic/chilli extract, both on spray residues and direct spray, compared to all other treatments including positive control (Figure 2). Bifenazate and Abamectin treated discs had the lowest number of eggs per alive female.

Mortality caused by different pesticides was assessed after the test individuals were either sprayed directly or released on spray deposits. According to IOBC criteria used for assessing toxicity of pesticides to predators, a pesticide killing less than 30% test individuals are considered as harmless to slightly harmful while those killing more than 80% test individuals are considered as harmful. The harmfulness of the tested pesticides was species dependent. In contact bioassays, all of tested low-risk pesticides were harmful to one predatory mite species, *P. persimilis*, causing 82.5±4.78 to 96.7±4.32% mortality except DE (Table 2). When *P. persimilis* was released onto the 72 hours residues, all of tested low-risk pesticides including bifenazate were harmless and caused only 3.2±2.14 to 28.3±1.39% mortality.

All of tested low-risk pesticides were moderately harmful causing 32.4±3.9 to 78.6±6.85% mortality in the other species of predatory mite *N. fallacis* (Table 3). When *N. fallacis* was released onto the 72 hours residues, all of tested low-risk pesticides including Bifenazate were harmless and caused only 8.9±3.874 to 18.6±4.42% mortality. The low risk pesticides were also moderately toxic to the predatory beetle (*S. punctillum*) and caused 38.0-72.3% mortality (Table 4). All of tested low-risk pesticides including Bifenazate were harmless to *S. punctillum* When released onto the 72 hours residues causing only 5.2±2.1 to 19.7±3.47% mortality.

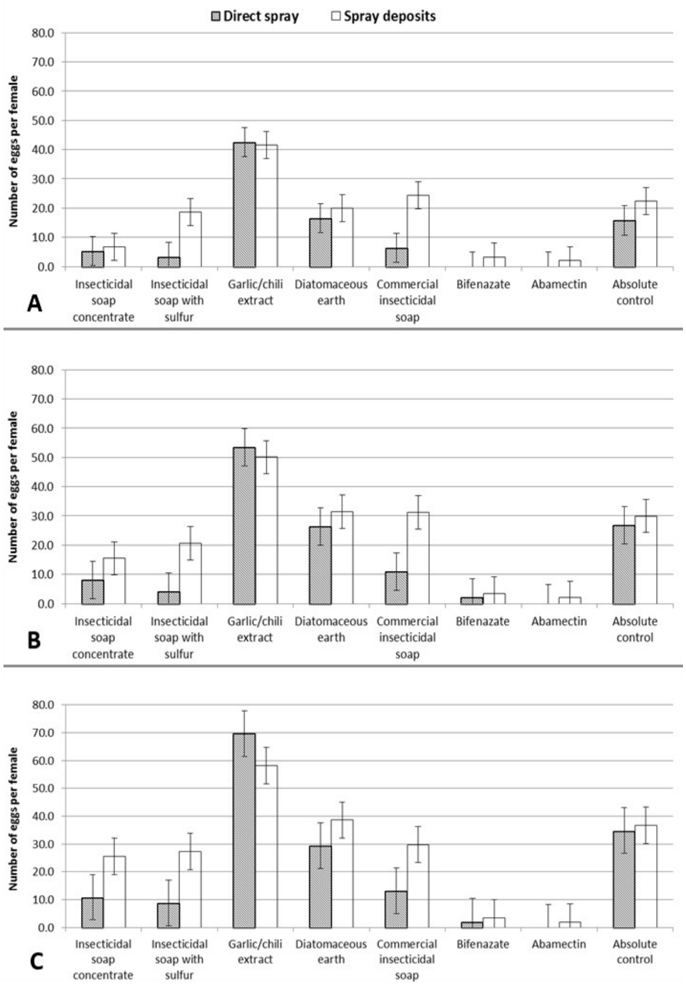

Figure 2: *Number of eggs (±se) laid by a single Tetranychus urticae female in 24 (A), 48 (B) and 72 (C) hours after treatment with several pesticides (Direct spray F=4.36, df=7, p=0.006; Spray residues F=5.24, df=7, p=0.006). Means followed by overlapping standard error between same bar type are not statistically different.*

Table 3: *Percent corrected mortality (mean±se) recorded in contact and residual bioassays in N. fallacis at 24, 48 and 72 hours after treatment with low-risk pesticides using Potter tower.*

Insecticides	**Contact bioassay 24 Hrs**	**48 Hrs**	**72 Hrs**	**Residual bioassay 24 Hrs**	**48 Hrs**	**72 Hrs**
Insecticidal soap concentrate	75.3±7.52a	76.0±8.96a	78.6±6.85a	9.6±3.5b	8.4±4.32b	6.3±3.52b
Insecticidal soap with sulfur	70.3±6.54a	74.3±8.99a	73.6±6.35a	7.5±3.25b	8.5±3.65b	5.6±2.63b
Garlic/chili extract	65.2±5.15a	67.4±3.55a	75.2±3.82a	24.5±4.31b	22.6±7.62b	18.6±4.42b
Diatomaceous earth	32.4±3.9b	34.2±4.26b	34.3±4.26b	8.9±3.25b	8.5±4.03b	6.4±4.32b
Commercial insecticidal soap	70.7±5.63a	70.1±4.52a	71.5±5.33a	15.4±3.72b	12.7±3.42b	9.7±4.12b
Bifenazate	82.7±4.36a	83.6±3.29a	91.7±5.87a	18.9±3.14b	16.3±3.96b	8.9±3.87b
Abamectin	85.7±4.21a	88.1±4.29a	93.4±3.98a	87.4±4.45a	84.4±3.25a	81.6±3.43a
Absolute control	12.7±1.7c	16.7±1.5c	17.9±1.3c	8.5±1.7b	9.5±1.3b	7.8±1.9b
	$F (6,21)=11.70$, $p<0.001$	$F (6,21) =8.40$, $p<0.001$	$F (6,21) =6.54$, $p<0.001$	$F (6,21) =6.54$, $p<0.05$	$F (6,21) =8.82$, $p<0.05$	$F (6,21) =2.85$, $p<0.05$

Means followed by the same letter within each column are not statistically different, LSD ($p<0.05$).

Table 4: *Percent corrected mortality (mean±se) recorded in contact and residual bioassays in S. punctillum at 24, 48 and 72 hours after treatment with low-risk pesticides using Potter tower.*

Insecticides	**Contact bioassay 24 Hrs**	**48 Hrs**	**72 Hrs**	**Residual bioassay 24 Hrs**	**48 Hrs**	**72 Hrs**
Insecticidal soap concentrate	62.8±6.69ab	67.4±7.68ab	68.3±6.87ab	7.8±2.51b	6.5±2.58b	5.5±2.35b
Insecticidal soap with sulfur	33.7±6.221bc	37.7±6.01bc	38.0±5.41bc	7.0±2.14b	7.0±2.14b	5.2±2.18b
Garlic/chili extract	63.2±3.34ab	67.4±3.96ab	71.5±3.56ab	24.2±3.25b	22.9±4.35b	19.7±3.47b
Diatomaceous earth	34.6±4.27bc	37.7±5.21bc	41.3±5.11bc	18.9±4.06b	16.7±3.24b	12.9±3.56b
Commercial insecticidal soap	65.7±6.58ab	70.4±7.08ab	72.3±6.47ab	28.8±4.02b	25.9±4.32b	16.7±4.85b
Bifenazate	78.6±5.34a	82.8±4.96a	85.9±5.24a	21.9±3.16b	18.6±2.86b	17.0±2.16b
Abamectin	86.7±5.14a	88.1±5.98a	93.7±5.16a	88.6±4.19a	88.1±3.35a	83.5±3.16a
Absolute control	10.8±1.4d	11.1±1.8d	13.4±2.2d	10.3±1.5b	7.3±1.6b	8.3±1.8b
	$F (6,21) =10.68$, $p<0.05$	$F (6,21) =13.83$, $p<0.05$	$F (6,21) =12.35$, $p<0.05$	$F (6,21) =7.84$, $p<0.001$	$F (6,21) =7.84$, $p<0.001$	$F (6,21) =7.84$, $p<0.001$

Means followed by the same letter within each column are not statistically different, LSD ($p<0.05$).

In direct contact bioassay, Bifenazate caused 100, 91.7 and 85.9% mortality after 72 hours in *P. persimilis, N. fallacis* and *S. punctillum*, respectively. Abamectin caused 93.4-100% mortality in direct contact bioassay and 81.6-87.6% mortality in residual bioassay in all three predators. There was a non-significant difference among the three observation dates in all the treatments in the direct contact and the residual bioassays. However, there was an increase in mortality from 24 to 72 hours in the direct contact bioassay while a decrease in mortality was observed in the residual bioassay in all the tested low-risk pesticides.

Neoseiulus fallacis, *P. persimilis* and *S. punctillum* are predators regularly used in greenhouses to manage various arthropod pests (Bostanian and Akalach, 2006). *Phytoseiulus persimilis* plays an important role in the biological control of tetranychid mites. However, pesticides often affect these predatory mites and information about the side-effects of these products against these beneficial arthropods is essential to guarantee their efficacy. The side effects of some pesticides remain unknown and the primary aim of this study was to fill this gap. We have further used this information and that collected from other sources to compare the response of these three-mite species to pesticides.

Osborne and Petitt (1985) used Safer's insecticidal soap against *Tetranychus urticae* adults and found that the lowest effective rate was 12.5 ml/liter but it also killed 100% of *P. persimilis* in standard slide-dip tests. The standard slide-dip test compares to the contact bioassay in this study. They found no effects on the eggs of *P. persimilis* though and recommended releasing *P. persimilis* 3 days before spraying with soap. Soaps also caused 84.0-96.7% mortality in *P. persimilis* in our studies.

Oetting and Latimer (1995) recorded contact and residual toxicity of insecticidal soap by using a 1.5-cm disc from a chrysanthemum leaf dipped in the test solution for 5 seconds and placing *N. cucumeris* adults immediately on the discs (direct effect) or after being air dried (residual effect). They found that *N. cucumeris* adults had only 25% mortality when released on residues compared to direct application (90% mortality) of insecticidal soap. These results are comparable to ours. They concluded that release of *N. cucumeris* after insecticidal soap application was compatible for thrips management on ornamentals.

Bostanian and Akalach (2006) found insecticidal soap very toxic to both *N. fallacis* and *P. persimilis* in a contact bioassay. Insecticidal soaps caused 74-94% mortality to these predatory mites in our contact bioassays (direct application). *Phytoseiulus persimilis* was found to be relatively more susceptible species compared to *N. fallacis* and *N. californicus* to the commonly used pesticides (Argolo et al., 2013).

Cobanoglu and Alzoubi (2013) applied different dosages of soft soap to bean plants under laboratory conditions to find their residual effects on *P. persimilis* that would be released for the control of the TSSM. They found that according to IOBC standards soft soap, in contact toxicity testing, was moderately toxic @ 5-7 ml/L to *P. persimilis* adults and caused 42.3-50.0 % mortality.

Soaps can be used to manage arthropod pests including spider mites. Insecticidal soaps work by disrupting the cuticle layer by removing the protective waxes that cover the insect, causing death through dehydration. Soaps act strictly as contact insecticides, with no residual effect (Caldwell et al., 2013). Lawson and Weires (1991) found that soaps have little efficacy against mite eggs. In order to be effective, soap solution must be applied directly to and thoroughly covering the target organism. Individuals walking on dried soap residues will not be affected. The result is a minimal impact on surviving individuals and individuals not exposed to the direct spray. Our results on the residual toxicity of soaps suggested low mortality of 5.5-9.8% mortality in *P. persimilis* adults which suggest release of this predatory mite 2-3 days after the soap application is safe.

Plant extracts are also formulated as acaricides. Garlic extract also exert an effect on spider mites (University of California IPM) because of Sulphur-containing amino acids and their derivatives that are found in *Allium spp.* and are toxic to mites (Hincapié et al., 2008). Other studies have demonstrated that extracts containing these compounds have repellent effects against *TSSM* (Boyd and Alverson, 2000; Chiasson et al., 2004). Stoleru and Sellitto (2016) used undiluted wild garlic (*Allium sativum*) infusion for control of mites and suggested repeatedly treating the plants every 3 days. Antonious et al. (2007) used crude extracts from fruits of *Capsicum* spp. and found it repellent to the spider mite. Our observations also showed the repellant effects of the garlic/chili extract. Although the direct toxicity bioassay showed acceptable results for controlling the TSSM adults, this extract also showed mortality of 63.2-95.1% of the predators. The 24h aged residues had significantly lower toxicity to the predators.

In the garlic/chilli treatment, significantly higher number of eggs laid was recorded in both the contact and residual bioassays. Liburd et al. (2007) recorded higher number of eggs by TSSM in activated garlic extract treatment while Mamduh et al. (2017) in a study found that garlic extract, increased the rate of fecundity of predatory bug *Podisus maculiventris* and its gross reproductive rate (offspring/individual) also increased. In both studies, there was no significant difference in fecundity compare to absolute control but in our study the increase in fecundity was significant. Increase in fecundity of TSSM after garlic/chilli extract increases the possibility of higher population after several generations. The fact that garlic extract might have stimulated TSSM reproduction is very important factor and needs to be further investigated.

Diatomaceous earth products are considered eco-friendly and are registered for use against several arthropod pests (National Pesticide Information Center, NPIC) including spider mites (Absorbent Products Ltd. Canada). Hill (1986) mentioned that DE is non-selective and kill beneficial insects. In our experiment, DE did not give any satisfactory control of TSSM.

Bifenazate appeared to be toxic to TSSM when applied directly. Liburd et al. (2007) in a greenhouse experiment recorded 87% mortality in TSSM and found no eggs on the treated strawberry plants. Bifenazate was also found less toxic to either *P. persimilis* or *N. californicus* (Ahn et al., 2004). The 72h aged residues caused only 8.9-24.7% mortality in all the three predators. Liburd et al. (2007) recommended it to be included in a TSSM IPM program.

Conclusions and Recommendations

Biological control agents are being used in suppressing TSSM populations. The low-risk pesticides that are also called minimum risk pesticides are considered harmless to human health. They also have no or little toxicity to the bio-control agents and should be selected for management of TSSM. It is recommended to thoroughly spray the plants aiming directly at spider mites with any of the tested pesticide except diatomaceous earth. In the presence of *P. persimilis*, *N. fallacis* or *S. punctillum* whether naturally present or released, the tested pesticides should not be applied. All of the predators can be released 2-3 days after spraying any of the tested low-risk pesticides.

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Novelty Statement

Low-risk insecticides, when applied directly, are also toxic to the predators used for the control of spider mites. The tested insecticides are not toxic if predators are released 2-3 days after application.

Authors' Contributions

RS carried out all the bioassays, analysis of data, and wrote the manuscript. RS also read and approved the final manuscript for publication. MA helped in experiments.

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