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Full length research

Efficacy of Pesticides against Two-Spotted Spider mite (*Tetranychus urticae* Koch) (Acari: Tetranychidae) and Its Performance on Some Hosts in Greenhouse at Haramaya, Eastern Ethiopia

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Absract

The study was conducted in greenhouse (GH) of Haramaya University under 30±2 °C and 60±5% RH during 2016. The objectives were to evaluate the efficacy of some pesticides against T. urticae; and to evaluate the performance of the pest on six host plants. The efficacy of five pesticides, viz. Amitraz, Profenofos, Chlorantrniliprole +λ-cyhalothrin, and Profenofos"Q"720 g/l, @ manufacturers' rate and Paraffin oil @ 2.5%, were evaluated alone in addition to rotating Amitraz with the other four pesticides. All the experiments were arranged in completely randomized design and replicated four times. The pesticides were applied for straight three times at weekly interval. In the efficacy study, the results after third spray indicated a highly significant (p≤0.0001) difference between the treatments over the control. A week after third spray, all treatments provided 100% reduction of the mite. In the pest performance study, six plants were studied and replicated thrice. The mite counts were recorded until four weeks beginning two weeks after infestation. There were highly significant (p≤0.0001) differences in the mite population among the hosts. **Solanum incanum, Datura stramonium**, ***and*** **Solanum tuberosum** ***had not statistically different population size though the mite population on the hosts vary and were in order of performance. But these plants differed significantly from*** **Solanum lycopersicon**, **Capsicum spp.** ***and*** **Phaseolus vulgaris**. ***Therefore, the study showed that all the tested pesticides were effective to suppress T.urticae and gave opportunity to use them in rotation to slow or prevent pest resistance development. But, it needs careful research under farmers' field conditions. The study also revealed that*** **Capsicum spp.** ***was least preferred while*** **S.lycopersicon** ***and*** **P.vulgaris** ***were intermediate in status; however,*** **S. incanum, D.stramonium**, ***and*** **S.tuberosum** ***were the most preferred hosts. To this effect, host plants like*** **S.incanum** ***and*** **D.stramonium** ***should be removed from farm boundaries as these weeds are potential shelters of the pest. Further study is required on other host plants especially on weeds as documented materials are not available on Ethiopian conditions to manage the pest.***

Keywords: Efficacy, Host, Pesticides, Polyphagous, Preference, *Tetranychus urticae*

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Introduction

The two-spotted spider mite (TSSM), *Tetranychus urticae* Koch (Acari: Tetranychidae), is a highly polyphagous pest that feeds on more than 1,100 plant species, of which over 100 are important agricultural crops (Fellous *et al.,* 2014). *T. urticae* threatens greenhouse production and field, vine, and orchard crops worldwide, destroying economically important annual and perennial crops, such as tomatoes, peppers, cucumbers, strawberries, corn, apples, grapes, hops, almonds, peppermint, and citrus (Jeppson *et al.,* 1975).

Two-spotted spider mite belongs to an assemblage of web-spinning mites and the name 'spider' highlights their ability to produce silk-like webbing meant to establish a colonial micro-habitat, protect against abiotic agents, shelter from predators, communicate via pheromones and provide a vehicle for dispersion (Gerson, 1985). The TSSM larval and adult stages preferentially feed on the lower surface of the leaf (Jhonson and Lyon, 1991). The host plant can be affected in different ways, a decrease in photosynthesis and injection of phytotoxic substances when feeding (Jhonson and Lyon, 1991). Moreover, the accumulations of fecal matter, webbing, and/or defoliation also affect the plant's appearance as well as its commercial value (Jhonson and Lyon, 1991). The combination of these factors can decrease the economic interests of producers and consumers and leads to severe economic loss.

The two-spotted spider mite (*T. urticae*) is a serious pest of roses (Belder *et al.,* 2009) and tomato (Gashawbeza et al., 2009), and was earlier reported on pigeon pea in the Nazareth area of Ethiopia in 1986 (Tsedeke, 1987). In the 2014 main cropping season, however, two-spotted spider mite was observed as a serious field pest of potato in Haramaya district, East Hararghe Zone, causing significant yield loss in farmers' fields (Muluken *et al.,* 2016). A survey conducted in August 2015 revealed the geographic expansion of the pest to other areas of eastern Ethiopia, *viz.* Dire Dawa Administration, Kersa, Kombolcha and Fedis districts (Muluken *et al.,* 2016). Similarly, in the same season the pest invaded experimental plots and seed multiplication farms of Haramaya University. In addition to the main host potato, two-spotted spider mite infestations were observed on wild solanaceous plants, like *Datura stramonium* and *Solanum elaeagnifolium* and trees, like *Melia azadirach* and *Catha edulis* (Muluken *et al.,* 2016). The list of attacked plant species could be large as *T. urticae* is known for being polyphagous and feeds on over 1,100 different plant species belonging to more than 140 different plant families (Grbic *et al*., 2011). Two-spotted spider mite problem became serious in the 2015 'meher' season when there was El Niño induced shortage of rain, as many researchers believe that detrimental effects of spider mites in agriculture would increase with intensifying global warming (Migeon et al., 2009; Cranshaw and Sclar, 2014).

Pesticide use has become the first line of defense against insect and mite pests in different parts of Ethiopia. Yet vegetable growers in the Central Rift Valley of Ethiopia observed a decline in efficacy of pesticides used against two-spotted spider mite on tomato from time to time (Belete and Getahun, 2015). *Tetranychus urticae* is known for its ability to develop resistance to pesticides (Van Leeuwen *et al.,* 2010). Increased dose and frequency of pesticide application exercised by many farmers, including farmers of East Hararghe Zone, might lead to the development of resistance. Two-spotted spider mites have evolved resistance to more than 80 acaricides to date and resistance has been reported from more than 60 countries (Miresmailli, 2005). In Ethiopia, there are also suspicions of resistance in some areas (Mohammed *et al.,* 2004). Rapid evolution of pesticide resistance in TSSM is attributed to rapid development, high fecundity and haplodiploid sex determination (Grbic *et al.,* 2011). Since mites are different from insects; a separate group of pesticides known as miticides are required though certain insecticides might also have miticidal action. The miticides are not available in the local markets as their registration and supply was limited to flower farms. Therefore, proper selection and use of pesticides as part of broader integrated pest management scheme is very essential in avoiding the development of pesticide resistance by phytophagous mites.

There are a number of pesticides registered in Ethiopia for the management of mites mainly in flower, tomato, strawberry and cotton fields (Ministry of Agriculture [MOA], 2016). Paraffin and horticultural oils are also promising organic insecticides by suppressing mite populations within short period (Prasad *et al.,* 2008). However, the nationally registered miticides and mineral oils were not tested on potatoes as it was only recently that the two spotted spider mite was observed infesting potatoes.

Once identified, the pesticides can serve as a short-term solution and any organic insecticides identified in the long-term can be integrated with other management options. There is, therefore, a need to screen the available miticides, insecticides and organic pesticides against the devastating mite pest in an attempt to identify those with the highest efficacy and affordability and make the information available to farmers so that they use these products in the irrigation season.

The phytophagous two-spotted spider mite, *T. urticae*, has a broad host range and is a serious pest of several crops worldwide (Greco *et al.,* 1999). Although spider mites are highly polyphagous (Yano *et al.,* 1998), they are known to show preference to some plants compared to others having diverse host plant species. Some of the hosts reported are weeds that can be found on farm boundaries. However, despite the pest economic importance and worldwide distribution, the host preference and its relevance under the Ethiopian conditions are unknown. The mites' host preference in Ethiopia was not studied and there was a need to conduct such studies as it may serve in the development of management options against the pest in the future.

In the present study, therefore, experiments were carried out to provide data on some host plants and effective pesticides against TSSM for its management aimed at reducing damage by *Tetranychus urticae*. Hence, the objectives of the study were to evaluate the efficacy of selected pesticides against *T. urticae* on potted potato plants in the greenhouse; and to evaluate the performance of TSSM on some potted host plants under greenhouse conditions.

Materials and Methods

Description of the Study Area

The study was conducted in Greenhouse at Haramaya University during 2016. Haramaya is located at 42°3'E longitude and 9°26'N latitude and at an altitude of 2006 meters above sea level. The mean annual rainfall (RF) at the station is 780 mm and the mean annual temperature is 23.4°C. The average temperature and RH for GH was 30±2°C, 60±5%, respectively.

Species identification

The mite was identified, at the international center of insect physiology and ecology Biosystematics Unit, Nairobi, Kenya, as *Tetranychus urticae* Koch (Acari: Tetranychidae) (Muluken *et al.,* 2016). Population of *T. urticae* that was used in this study was obtained from wild solanaceous plants. The mite population was maintained on young potato plants (*Solanum tuberosum* L.) grown indoor by detaching and adding three spider mite infested wild solanaceous leaves onto rearing units. Fresh potato plants were supplemented at regular intervals to maintain the culture for experimentation.

Pesticides Used in the Experiment

Table 1. Application rates and type of pesticides evaluated for their efficacies against two-spotted spider mite, *Tetranychus urticae*, in the Greenhouse

Trade name	Common name	Rate/ha	Type of pesticide
Mitac 20 EC	amitraz	2.5 lt	Miticide
Ampligo150ZC	chlorantrniliprole+ λ-cyhalothrin	300 ml	Insecticide
Profit 72 EC	profenofos	1.0 lt	Insecticide
Selecron	Profenofos "Q" 720 g/l	1.0 lt	Insecticide
Paraffinic oil	paraffin	2.5%	Insecticide
Control	-	-	-

Table 2. Application rates evaluated for their efficacies against *Tetranychus urticae* in the greenhouse for three consecutive weeks

Pesticides	Rate/ha	Rate/plant	1st spray	2nd spray	3rd spray
Mitac 20 EC	2.5 lt	56.25 µl	Mitac	Mitac	Mitac
Ampligo 150 ZC	300 ml	6.75 µl	Ampligo	Ampligo	Ampligo
Profit 72 EC	1.0 lt	22.50 µl	Profit	Profit	Profit
Selecron	1.0 lt	22.50 µl	Selecron	Selecron	Selecron
Paraffin	2.5%	2.5%	Paraffin	Paraffin	Paraffin
Ampligo150 ZC and Mitac 20 EC	-	-	Ampligo	Mitac	Ampligo
Profit 72 EC and Mitac 20 EC	-	-	Profit	Mitac	Profit
Selecron and Mitac 20 EC	-	-	Selecron	Mitac	Selecron
Paraffin and Mitac 20 EC	-	-	Paraffin	Mitac	Paraffin
Control	-	-	untreated	Untreated	untreated

This experimental study included ten treatments that consisted of five pesticides (i.e., Amitraz, Chlorantraniliprole + λ - cyhalothrin, Profenofos, Profenofos "Q" 720 g/l, and Paraffinic oil) applied alone, plus Amitraz by rotating with the other four pesticides and untreated control. Manufacturers rate were employed for the common ready pesticides while 2.5% was applied for paraffin oil. In this experiment, treatments were arranged in a completely randomized design (CRD) with four replications.

Efficacy of Pesticides

Treatment Protocol

Pesticides were dissolved in water to prepare pesticide solutions on volume by volume (v/v) basis. Then, the aqueous solution was thoroughly mixed to ensure homogeneity. Briefly, sprouted potato tubers of the variety “Gudene” were planted in 4lt capacity pots filled with soil and kept weed free by hand weeding. Each plant was equally infested by adding about 100 mites. The mites were allowed to multiply on the potted potato plants for two weeks. Ten treatments, the untreated control inclusive, were applied **(**Table 2).

Three leaves (top, middle and bottom), were randomly detached from each plant two weeks after infestation. Then, the number of moving stages and eggs of TSSM were counted and the average populations that served as pre-spray count for the first treatment application were recorded. The first spray was applied to all experimental units and post-spray counts were made after a week, and this number served as pre-spray count for the second spray. Then the second and the third spray, and the post spray counts were made at seven days intervals. Actually, two consecutive counts were executed on a weekly base after the fourth count, but the results were not different from the fourth count and were not considered for analysis.

The visual scale of phytotoxicity proposed by Vieira *et a*l (2001) was used to rate the phytotoxic effects of pesticides, with 0: plants with normal leaves and no signs of burns; **1**: plants with slightly damaged leaves and/or with small burned areas; **2**: plants with medium damaged leaves, yellow with burnt edges and tips; **3**: plants with heavily damaged leaves, showing severe defoliation.

Performance of *Tetranychus urticae*

Treatment Protocol

This study included six host plants, namely tomato (*Solanum lycopersicon*), potato (*Solanum tuberosum* L.), haricot bean (*Phaseolus vulgaris* L.), datura weed (*Datura stramonium* L.), Sodom's apple (*Solanum incanum* L.) and hot pepper (*Capsicum* sp.). Single plants were maintained in each pot and infested equally by adding about 100 mites a month after planting. The treatments were arranged in CRD and replicated thrice. Paired-pots of infested and un-infested (untreated control) pots were maintained for each treatment for comparing the damage.

Data collected

For the pesticides efficacy study observations on the number of moving stages and eggs of TSSM on potato plant leaves were made a day before and a week after first, second and third sprays. Similarly, for the mite performance study the number of moving stages and eggs of the mite were registered by taking randomly three leaf (top, middle and bottom) samples using stereomicroscope starting two weeks after artificial infestation and continued until four weeks.

Data analysis

For the pesticides efficacy experiment, observations on the number of TSSM (movable stages and eggs) on potted potato plants were made a day before and a week after each spray. The efficacies of the tested pesticides, percent reductions due to pesticides, were calculated in the population of the mites over untreated control using Henderson and Tilton's equation (1955).

$$\text{Reduction (\%)} = \left(1 - \frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}}\right) \times 100$$

Where: n = number; Co = Control; T = Treatment

Percent of reduction were transformed using arcsine transformation to normalize the data before performing the analysis of variance (ANOVA). Likewise for the pest performance study the average number of moving stages and eggs were registered for four weeks at weekly interval. Then the data, for both experiments, were analyzed using General Linear Model (GLM) procedures of the analysis of variance (ANOVA) employing SAS version 9.1 packages (SAS Institute, 2004). Treatment means were compared by Tukey's HSD test (Snedecor and Cochran, 1980).

Results and Discussion

Efficacy of Pesticides against *Tetranuchus urticae*

The results of three consecutive sprays on a weekly basis resulted in a highly significant (p≤0.0001) difference among the treatments over the untreated control regarding reduction of eggs and movable stages of *T. urticae* (Tables 3, 4 and 5).

Efficacy against eggs and moving stages of Tetranychus urticae post-first spray

The highest and most effective ovicidal actions were obtained due to Chlorantrniliprole + λ-cyhalothrin + Amitraz (89.77%), Profenofos + Amitraz (84.31%), and Profenofos"Q" 720 g/l + Amitraz (81.18%), followed by Paraffin oil + Amitraz (79.68%), Profenofos"Q"720 g/l (79.07%), Profenofos (78.57%), Amitraz (78.26%), Paraffin oil (76.12%), and Chlorantrniliprole + λ-cyhalothrin (75.61%). On the other hand, the highest and most effective actions on movable stages of TSSM were obtained with Profenofos"Q"720 g/l (96.45%), Chlorantrniliprole + λ-cyhalothrin + Amitraz (96.17%), Profenofos (93.53%), and Profenofos + Amitraz (90.19%), followed by Amitraz (85.94%), Chlorantrniliprole + λ- cyhalothrn (85.21%) and Profenofos"Q"720 g/l + Amitraz (83.82%), while the lowest were obtained due to Paraffin oil (63.81%) and Paraffin oil + Amitraz (50.92%) (Table 3).

Table 3. Mean % efficacy of the pesticides against eggs and movable stages of Two-spotted spider mite in the greenhouse a week after first spray

Treatment	Mean Eggs N1	N2	%R	Mean Movable stages N1	N2	%R
Amitraz	657	185	78.26 a	169	17	85.94 ab
Chlorantrniliprole + λ- cyhalothrn	618	211	75.61 a	159	32	85.21 ab
Profenofos	597	146	78.57a	118	12	93.53 a
Profenofos"Q"720 g/l	977	201	79.07 a	307	15	96.45 a
Paraffin oil	723	250	76.12 a	199	103	63.81 ab
Chlorantrniliprole+λ-cyhalothrin+Amitraz	640	100	89.77 a	270	15	96.17 a
Profenofos+ Amitraz	509	110	84.31 a	90	14	90.19 ab
Profenofos"Q"720g/l +Amitraz	452	78	81.18 a	124	18	83.82 ab
Paraffinoil+ Amitraz	638	19	79.68 a	132	11	50.92 b
Control	827	1193	+44.26b	169	17	+104.65c
CV (%)		14.25			20.22	
CD (5%)		19.95			30.1	
SEM		4.13			6.24	

Means within columns followed by the same lower case letter did not differ significantly at α= 0.05. SEM is the standard error of the mean. CD is critical difference at the 5% level. CV (%) is the coefficient of variation of each treatment and experiment. N1=pre-treatment count; N2=post spray count; %R=Percent reduction.

Efficacy against eggs and moving stages of Tetranychus urticae post-second spray

Results showed highly significant (p≤0.0001) difference over untreated control on reduction percentages of the eggs of TSSM. The most effective pesticides were Chlorantrniliprole + λ-cyhalothrin and Profenofos which caused total mortality, followed by Profenofos"Q"720 g/l (99.95%), Amitraz (99.66%), Chlorantrniliprole + λ-cyhalothrin + Amitraz (99.65%), Profenofos"Q"

720 g/l + Amitraz (99.19%), Profenofos + Amitraz (98.31%), Paraffin oil + Amitraz (98.69%) and Paraffin oil (96.80%) though the percent mortality varied they were statistically at par with each other (Table 4).

The tested pesticides highly and significantly ($p \leq 0.0001$) reduced moving stages of *T. urticae*. All the treatments inflicted 100% reduction of moving stages of the mite population except Paraffin oil + Amitraz and Paraffin oil treatments (93.36%) and (92.01%), respectively (Table 4).

Table 4. Mean % efficacy of the pesticides against eggs and movable stages of Two-spotted spider mite in the greenhouse a week after second spray

Treatment	Mean Eggs			Mean Movable stages		
	N1	N2	% R	N1	N2	% R
Amitraz	185	1	99.66 a	17	0	100.00 a
Chlorantrniliprole + λ-cyhalothrn	211	0	100.00 a	32	0	100.00a
Profenofos	146	0	100.00 a	12	0	100.00a
Profenofos"Q"720g/l	201	1	99.95 a	15	0	100.00 a
Paraffin oil	250	9	96.80 b	103	11	92.01 a
Chlorantrniliprole+λ-cyhalothrin+Amitraz	100	1	99.65 a	15	0	100.00 a
Profenofos +Amitraz	110	2	98.31 ab	14	0	100.00 a
Profenofos"Q" 720g/l + Amitraz	78	1	99.19 a	18	0	100.00 a
Paraffin oil+Amitraz	199	3	98.69 ab	118	4	93.36 a
Control	1193	1590	+ 33.28 c	352	542	+ 53.98b
CV (%)			2.81		6.55	
CD (5%)			5.28		12.42	
SEM			1.09		2.57	

Means within columns followed by the same lower case letter did not differ significantly at α= 0.05. SEM is the standard error of the mean. CD is critical difference at the 5% level. CV (%) is the coefficient of variation of each treatment and experiment. N1=pre-treatment count; N2=post spray count; %R=Percent reduction.

Efficacy of pesticides against eggs and moving stages of Tetranychus urticae post-third spray

The tested pesticides highly and significantly ($p \leq 0.0001$) reduced eggs and the moving stages of TSSM. A week after third sprays all the treatments caused in 100% reduction of the moving stages and eggs of TSSM population. The results showed that all the tested pesticides were highly effective against the mite population; though reduction and the effect appeared after three consecutive applications at weekly intervals. The study showed that the tested pesticides were able to control all stages of the mite. However, pesticides application by rotation is preferred to the sole application as the former delays/prevents resistance development by the pest.

Table 5. Mean % efficacy of the pesticides against eggs and movable stages of Two-spotted spider mite in the greenhouse a week after third spray

Treatment	Mean Eggs			Mean Movable stages		
	N1	N2	% R	N1	N2	% R
Amitraz	1	0	100.00a	0	0	100.0 a
Chlorantrniliprole + λ-cyhalothrn	0	0	100.00a	0	0	100.0 a
Profenofos	0	0	100.00a	0	0	100.0 a
Profenofos"Q"7/l	1	0	100.00a	0	0	100.0 a
Paraffin oil	9	0	100.00a	11	0	100.0 a
Chlorantrniliproleλ-cyhalothrin +Amitraz	1	0	100.00a	0	0	100.0 a
Profenofos+Amitrz	2	0	100.00a	0	0	100.0 a
Profenofos"Q" 720g/lAmitraz	1	0	100.00a	0	0	100.0 a
Paraffinoil+Amitraz	3	0	100.00a	4	0	100.0 a
Control	1590	1920	+ 25.16b	542	632	+16.61b
CV (%)			0.00			0.00
CD (5%)			0.00			0.00
SEM			0.00			0.00

Means within columns followed by the same lower case letter did not differ significantly at α= 0.05. SEM is the standard error of the mean. CD is critical difference at the 5% level. CV (%) is the coefficient of variation of each treatment and experiment. N1=pre-treatment count; N2=post spray count; %R=Percent reduction.

In line with the present study, Labanowska and Tkaczuk (1991) conducted experiments with some new generation acaricides for the control of *T. urticae* on black currant and obtained excellent result with azocyclotin, fenbutatin oxide and bromopropylate. Similarly, Chahine *et al.,* (1992) compared the effectiveness of two acaricides on *T. urticae* infesting bean and reported that acaricides reduced the mite population effectively at the ninth day after application.

In the present investigation, mites increased in population density for about a month in untreated control pots. Afterward, the mites decreased gradually as the host plants died due to the massive attack by the pest. In pesticide sprayed pots, the mite population was curbed and reduced to nil. Thus, the use of the tested pesticides appears to be essential for better yield of treated crops.

Abraham (2002) evaluated seven acaricides for their efficacies against *T. urticae* on soybean; however, he did not mention Mitac 20 EC (Amitraz) as an effective acaricide in his finding, the observation of which is in disagreement with the current investigation; the reason could be the difference in the dosage applied at 2.5 L ha^{-1} in the present case and 1.5 L ha^{-1} in his trial. Pogoda and Pree (2000) examined two insecticides against psylla on pear, and they concluded that the Mitac (Amitraz) treated plots showed significantly fewer psylla nymphs than the pyramite-treated plots. Haitas *et al.,* (1997) reported that concentrations of 2% mineral oils significantly reduced both egg and mobile stages of *T. urticae*.

Among the tested pesticides against *T. urticae*, Amitraz (Recep *et al.,* 2005; MOA, 2016) was the only known miticide while the remaining pesticides Profenofos, Chlorantrniliprole+ λ-cyhalothrin, and Profenfos "Q" are insecticides (MOA, 2016). In Ethiopia however, Profenofos was registered for the control of pea aphids (*Acyrtosiphon pisum*) on field pea in Ethiopia (MOA, 2016). Paraffin oil, commonly used against soft scale insects (Muegge and Merchant, 2000), is also known for having miticidal effects (Prasad *et al*., 2008). The results obtained from the efficacy test indicated that besides the known miticide, Amitraz, insecticides like Profenofos, Chlorantrniliprole + λ-cyhalothrin and Profenofos "Q" gave an excellent control on all stages of the two-spotted spider mite. Chlorantrniliprole+ λ-cyhalothrin was registered in Ethiopia for the control of tomato leaf miner and fruit borer (*Tuta-absoluta*) while Profenfos "Q" was indexed by the Ministry of Agriculture for the control of maize stalk borer on maize (MOA, 2016).

Paraffin oil is one in the class of mineral oil often used for the control of insect and mite pests in other parts of the world. Mineral oils are preferred because there are no reported cases of resistance (Willett and Westigard, 1988) and that might be due to its modes of action (including hypoxia) or its relatively low selection pressure against pests (Fernandez *et al.,* 2005). Mineral oil is not, however, widely used in Ethiopia and the only exception is that there is a single white oil (medopaz) registered in Ethiopia for the control of red scale, orange scale, purple scale and black scale on citrus (MOA, 2016). Paraffin oil is available in pharmacies in Ethiopia and its use is currently limited to medical purposes. The excellent performance of the paraffin oil, local market availability, against *T. urticae* might indicate its potential use for integration with other methods in rotation with other pesticides. Two-spotted spider mites are known for developing resistance to pesticides (Van Leeuwen *et al.,* 2010). Rotation of pesticides during the year and/or year to year is often regarded as one strategy for the management of resistance in pests against pesticides (Mallet, 1989).). The identification of suitable miticide, insecticides and mineral oil by the current study would help to suppress mite population as alteration (use in rotational) or combination of the chemicals could delay development of resistance.

Visual symptoms of phytotoxicity were rated by two individuals in all the treatments of tested pesticides (i.e., Amitraz, Chlorantraniliprole + λ-cyhalothrin, Profenofos, Profenofos "Q" 720 g L^{-1}, Paraffinic oil, Amitraz + Chlorantraniliprole + λ-cyhalothrin, Amitraz + Profenofos, Amitraz + Profenofos "Q" 720 g L^{-1}, Amitraz + Paraffinic oil) in the greenhouse after three consecutive sprays at weekly interval. The study revealed that no phytotoxic symptoms were noticed on the sprayed potted potato plants during the investigation period.

Performance of *Tetranychus urticae* on some host plants in Greenhouse

The two-spotted spider mite performance on host plants was detected in association with six plants. The counts of moving stages and eggs of TSSM were recorded until four weeks beginning two weeks after infestation and the data were depicted (Tables 6 and 7). Analysis of variance (ANOVA) performed showed that there was a highly significant ($p \leq 0.0001$) difference in the number of the mite population, i.e. variation in performance of the mite among the host plants.

The count data recorded on movable stages and eggs of TSSM until four weeks beginning two weeks after infestation revealed that Sodom apple (*S. incanum*), Datura *(D. stramonium*), and Potato (*S. tuberosum*) had statistically non-significant population size difference though the population of mites on the crops varied and were in order of performance. But these plants significantly differ from tomato (*S. lycopersicon*), pepper (*Capsicum* spp.) and bean (*P. vulgaris*). Pepper was the least preferred while tomato and bean were intermediate in status; however, Sodom apple (*S. incanum*), Datura *(D. stramonium*), and Potato (*S. tuberosum*) were the most preferred hosts by the pest among the tested plants.

There is no a single method that can completely manage *T. urticae* all the time. The best way forward is to take preventive steps to reduce the likelihood of TSSM infestation and monitoring crops regularly. Therefore, this pest may be able to use the suitable hosts, especially *S. incanum* and *D. stramonium*, which are commonly found weeds in crop field boundaries and road sides, as shelter to quickly build up a large and damaging population when conditions are favorable and disseminate to crop fields. Thus, these host plants have to be cleaned from crop field boundaries and these features must be considered by growers to implement IPM programs. The results of this study provide a better understanding of the host range of the TSSM. Moreover, the study showed that the population density of *T. urticae* was dependent on host plants.

Razmjou *et al.* (2009) evaluated the population growth characteristics of *T. urticae* with common bean, cowpea, and soybean as host plants. They found that soybean as the most preferred host for TSSM, followed by cowpea and bean. The slowest population growth was observed on the common bean species, thus indicating the choice for host plant species as a major factor in affecting how fast spider mite populations reach damaging levels in a crop culture.

Table 6. Performance of *Tetranychus urticae* on some host plants in the greenhouse (Mean number of mites until four weeks)

Treatment	First count		second count		third count		fourth count	
	Moving stages	Eggs	Moving stages	Eggs	Moving stages	Eggs	Moving stages	Eggs
Solanum lycopersicon	87.00c	112.33c	104.0c	147.0b	127.67c	182.67b	138.33 c	249.33bc
Solanum tuberosum	144.67b	217.0b	182.67b	293.33a	220.67b	324.33a	233.33b	339.0ab
Capsicum spp.	3.0d	14d	11.67d	18.33b	16.0d	24.0c	20.0d	30.0d
P. vulgaris	71.67c	95.67c	103.67c	142.0b	121.67c	164.67b	134.67c	178.0dc
D.stramonium	162.67ab	242.67ab	218.67ab	299.33a	246.0ab	334.0a	267.67ab	383.0ab
S. incanum	202.67a	301.33a	254.0a	373.0a	275.67a	405.67a	291.33a	434.67a
CV (%)	13.1	15.45	9.72	22.17	9.67	21.17	9.80	21.69
CD	40.22	69.44	38.84	128.97	44.54	138.86	48.61	160.02
SEM	8.47	14.62	8.18	27.15	9.38	29.23	10.23	33.69

MS is Movable stages; Means within columns followed by the same lower case letter did not differ significantly at α= 0.05. SEM is the standard error of the mean. CD is critical difference at the 5% level. CV (%) is the coefficient of variation of each treatment.

Table 7. Performance of of *Tetranychus urticae*, four weeks count data, on six host plants in the greenhouse (average number of mites/week)

Host plants		Four weeks average count	
Scientific name	Common name	Eggs/week*	Moving stages/week*
Solanum lycopersicon	Tomato	172.83b	114.25b
Solanum tuberosum	Potato	293.25a	195.34a
Capsicum spp.	Pepper	21.58c	12.75c
Phaseolus vulgaris	Haricot bean	145.25b	108.09b
Datura stramonium	Datura	314.83a	223.92a
Solanum incanum	Sodom apple	378.67a	255.67a
CV (%)	22.25	21.69	
CD	110.52	73.91	
SEM	28.39	18.99	

*Means within columns followed by the same lower case letter did not differ significantly at α= 0.05. SEM is the standard error of the mean. CD is critical difference at the 5% level. CV (%) is the coefficient of variation of each treatment.

In the greenhouse trial the results of three consecutive sprays on a weekly basis indicated a highly significant ($p \leq 0.0001$) difference among the treatments over untreated control regarding reduction of movable stages and eggs of *T. urticae.* Mite number in the control pots increased gradually up to the 4th week then decreased and reduced to nil due to damage of host plants or shortage of food.

The present study revealed that all the tested pesticides, viz. Amitraz, Profenofos, Chlorantrniliprole + λ-cyhalothrin, Profenofos"Q" 720 g/l, at the recommended rates and Paraffin oil at 2.5% were effective for the management of two-spotted spider mites in greenhouse conditions. Moreover, these pesticides can be used alternatively alone and/or in rotation with Amitraz to suppress TSSM, but rotation is preferred to sole application as it delays or prevents resistance development by the pest. All of them are available in our country but on-farm verification of the pesticides together with farmers is required before large scale application.

Furthermore, the second study on performance of *T. urticae,* on six host plants the data recorded indicated that among the tested plants *Capsicum* sp. was the least preferred host, while *Solanum lycopersicon* and *Phaseolus vulgaris* had intermediate status. On the other hand, *S. incanum, Datura stramonium*, and *Solanum tuberosum* were the most preferred hosts by the pest.

Conclusions

Proper selection and use of pesticides as part of broader integrated pest management can serve as a short-term solution, and organic pesticides identified can be integrated with other options in the long-term. Although *Tetranychus urticae* are highly polyphagous they are known to show preference to some plants compared to others having diverse host plant species. However, despite the pest economic importance and worldwide distribution, the host preference and its relevance under the Ethiopian conditions are unknown. The study was conducted in greenhouse (GH) at Haramaya University under 30±2 ^{o}C and 60±5% RH during 2016. The objectives were to: 1) Evaluate the efficacy of some pesticides against *Tetranychus urticae*; and 2) Evaluate the performance of TSSM to six host plants. The efficacy of five pesticides, viz. Amitraz, Profenofos, Chlorantrniliprole + λ-cyhalothrin, and Profenofos"Q"720 g/l, @ manufacturers’ rates and Paraffin oil @ 2.5%, were evaluated alone and by rotating Amitraz with the other four pesticides. The treatments were applied for three consecutive weeks at weekly interval. A week after third spray, all the treatments provided 100% reduction of all stages of the mite. In the *T . urticae* performance study, the mite counts were recorded until four weeks beginning two weeks after infestation. *Solanum incanum*, *Datura stramonium*, and *Solanum tuberosum* had not statistically different population size though the mite population on the hosts vary and were in order of performance. But these plants differed significantly from *Solanum lycopersicon*, *Capsicum spp*. and *Phaseolus vulgaris*. The present study revealed that all the tested pesticides were effective for the management of two-spotted spider mites in greenhouse conditions. Moreover, these pesticides can be used alternatively alone and/or in rotation with Amitraz to suppress TSSM, but rotation is preferred to sole application as it delays or prevents resistance development by the pest. All of them are available in our country but on-farm verification of the pesticides together with farmers is required before large scale application. The study also revealed that Capsicum spp. was least preferred while *S. lycopersicon* and *P. vulgaris* were intermediate in status; however, *S. incanum*, *Datura stramonium*, and *S. tuberosum* were the most preferred hosts by the mite. To this effect, host plants like *S. incanum* and *D. stramonium* should be removed from farm boundaries as these weeds are potential shelters of the pest. Thus, further study is required on other host plants especially on weeds as documented materials are not available on Ethiopian conditions to manage the pest.

Conflict of Interests

The authors have not declared any conflict of interest.

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