Field evaluation of commonly used synthetic insecticides against *Thrips tabaci* (Thysanoptera: Thripidae) on onion (*Allium cepa*) in the Central Rift Valley of Ethiopia

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Abstract

Thrips are responsible for high onion yield losses and mainly controlled with the use of insecticides. There is a demand for new products against thrips due to failure of commonly used insecticides. Thus, commonly used insecticides are periodically evaluated to avoid total failure of thrips management on onion. The efficacy of nine insecticides from classes of pyrethroids, organophosphates, spinosyns, neonicotinoid and botanical were evaluated against thrips on onion using a randomized complete block design in four replications in two seasons in 2015 and 2016. The lowest thrips infestations were observed in plots treated with spinosad, spinetoram, and imidacloprid, which resulted in high marketable yield of onion both in cool and hot dry seasons. Alpha-cypermethrin, diazinon, neem and λ-cyhalothrin insecticides poorly performed on treated plots in both seasons with low marketable yields. Performance of dimethoate and profenofos was intermediate with the intermediate yield gain over the check. Rotational application of the most effective insecticide classes of neonicotinoid and spinosyns with less effective insecticide classes of pyrethroids and organophosphates need to be practiced to safeguard their long-term efficacies and utility to thrips management. Future researches directed to the management strategy of this pest should focus on insecticide resistance management and other effective IPM options wherever the pest problem prevails.

Keywords: Onion thrips, resistance, pyrethroids, organophosphates, neonicotinoids, spinosyns.

Introduction

Onion (*Allium cepa* L.) is the most widely grown vegetable crop by small and large scale producers in Ethiopia, especially in the Central Rift Valley. It ranks first among vegetables (Tebkew & Getachew 2015). The area under onion is increasing from time to time, because it is highly profitable, easily propagated with seed, and the increase in small-scale irrigation areas (FAO 2010). However, productivity is affected by several biotic and abiotic factors. Onion thrips, *Thrips tabaci* Lindeman is a key insect pest in most onion production regions of Ethiopia (Tebkew & Getachew 2015). In addition to *T. tabaci,* western flower thrips *Frankliniella occidentalis* Pergande has become equally important in many

Central Rift Valley areas of Ethiopia (Personal observation). According to Diaz-Montano *et al.* (2011), onion thrips is a global pest of onion, and it is a principal vector of Iris yellow spot virus (IYSV) that can cause 100% crop losses. This pest is responsible for bulb yield loss of 23 to 85% in Ethiopia in different seasons (Yeshitla 2015).

Management of thrips is a major concern to the production and profitability of onion (Nault *et al.* 2013). Management methods include cultural, host plant resistance, biological and chemical protection. However, use of chemical insecticides remains the major management strategy for thrips in commercial onion production in several countries, including Ethiopia (Gill *et al.* 2015). Experiences in the Central Rift Valley of Ethiopia show that vegetable growers heavily rely on the use of old and broad-spectrum synthetic insecticides (Gashawbeza 2011). Moreover, rate and frequency of applications are not as per the recommendations (Belay *et al.* 2017). Extensive and frequent use of broad-spectrum chemical insecticides in agriculture often leads to the development of genetically resistant pest populations or strains that are no longer affected by or do not become sensitive to some commonly used synthetic pesticides (Gameel 2004). In addition, the indiscriminate use of insecticides without taking into consideration the efficacies of insecticides is economically wasteful, and also destroys beneficial natural enemies that serve as biocontrol agents (Bommarco *et al.* 2011).

Several synthetic insecticides have been tested against onion thrips management in Ethiopia (Ibrahim *et al.*, 2015; Tadele *et al.* 2013; Tadele & Mulugeta 2014), but most of them are pyrethroids and organophosphates. However, there are also other groups of insecticides in use elsewhere and also available on the local markets that are relatively new chemistry with little effect on non-target organisms, including natural enemies, and also have minimal adverse effects on human health. In addition, most of the registered insecticides available on the local markets are old and broad-spectrum. Consequently, onion growers widely use these broad-spectrum insecticides and apply indiscriminately. Therefore, periodic screening of the insecticides in use is required to find which ones are still effective and also provide information for insecticide resistance development management due to thrips on onion. Hence, this research was designed to evaluate the efficacies of different insecticides for the management of onion thrips and increase in onion bulb yield.

Materials and Methods

Descriptions of the study area

The study was conducted at Melkassa Agricultural Research Center (MARC). The Center is located at 8°24' N, 30°21'E, with elevation of 1550 meters above sea level and characterized by low and erratic rainfall with an average of 771 mm rainfall per year, over 80% of which falls between April and October, with the peak in July and August. The soils are mainly sandy with pH of 6.9-7.9 and mean temperature of 21 °C (Lemma & Shimeles 2003).

Treatments and Experimental Designs

The performance of different insecticides against onion thrips was evaluated for two seasons in 2015 and 2016. The first experiment was conducted between October 2015 and January 2016 (cool dry) and the second between March 2016 and June 2016 (hot dry) under irrigation at Melkassa Agricultural Research Center. Nine insecticides and untreated check were considered for the study. The test insecticides included one botanical formulation (neem-oil-based botanical insecticide), two natural products of spinosyns (spinetoram, spinosad), one neonicotinoid (imidacloprid), two synthetic pyrethroids (λ-cyhalothrin, alpha-cypermethrin), and three organophosphates (diazinon, dimethoate, profenofos) (Table 1). The tested insecticides have been registered for onion thrips management in Ethiopia (MoANR 2018) and are widely used by vegetable growers in the Central Rift Valley (CRV). The treatments were arranged in a randomized complete block design (RCBD) with four replications. The plot size was 3 m by 3 m with five double rows and each row with 30 plants making a total of 300 plants in a plot. Spacing between water furrows, plant rows and plants were 40, 20 and 10 cm, respectively. Spacing between plots and blocks were 1.5 m each. Seedlings of the onion variety "Bombay Red" was raised in nursery bed and transplanted at 2-3 leaf stage. The experimental field was irrigated twice per week for the first three weeks after transplanting and weekly afterwards. The field was fertilized with di-ammonium phosphate (DAP) and urea at the rate of 200 and 150 kg ha^{-1}, respectively. DAP was applied during transplanting and urea was applied in two splits; the first half during transplanting and the remaining half 30 days after. Other recommended agronomic practices were carried out as required. Application of insecticides was started when thrips population reached 5-10 thrips per plant (Tsedeke 1983) and applied weekly for seven weeks at a rate recommended by manufacturers using a manual operated knapsack sprayer of 15 liters capacity.

Data collection

Starting from 15 days after transplanting (i.e. when thrips population reached 5-10 thrips per plant), the insecticides were applied at seven-day interval and the post spray data were taken on the same date prior to each insecticide application. Thrips population was counted on five randomly tagged plants from the central rows of each plot by visually examining the entire plant parts. At maturity, onion bulbs were harvested from the middle three double rows in each plot and then sorted out into marketable and unmarketable bulbs. Healthy bulbs weighing between 20 and 160 g were considered as marketable, while undersized, oversized, diseased, decayed and physiologically disordered bulbs were considered as unmarketable (Lemma & Shimeles 2003)

Data analyses

Thrips population and yield data were analyzed using the general linear model (GLM) of statistical analysis using SAS version 9.0 (SAS 2003) at 5% level of significance. Significant treatment means ($p<0.05$) were separated using Student-Newman-Keuls (SNK) test. Corrected efficacies were calculated using Abbott's formula (Abbott 1925):

$$\text{Corrected \%} = \left(1 - \frac{\text{n in T after treatment}}{\text{n in Co after treatement}}\right)*100$$

Where: n= insect population, T= treated, Co= control

Table 1. List of insecticides tested and their application rate against thrips on onion at Melkassa Ethiopia, 2015/16.

Trade Name	Common Name	Class	Rate (ml/ha)
Diazinon 60% EC	diazinon	Organophosphate	1500 ml
Agro-thoate 40% EC	dimethoate	Organophosphate	1000 ml
Con-fidence 350 SC	imidacloprid	Neonicotinoid	400 ml
Karate 5% EC	λ-cyhalothrin	Pyrethoid	300 ml
Fastac 10% EC	alpha-cypermethrin	Pyrethroid	300ml
Girgit-plus 72% EC	profenofos	Organophosphate	600 ml
Nimbicidine	Azadirachtin	Botanical	3000 ml
Radiant 120 SC	Spinetoram	Spinosyn	130 ml
Tracer 480 SC	spinosad	Spinosyn	200 ml

Results

Thrips population

Applications of spinetoram, spinosad and imidacloprid resulted in significantly lower number of thrips; 9.55, 11.30 and 17.72 thrips/plant, respectively, than the rest of the treatments during the cool dry season (Table 2). The number of thrips was significantly higher in plots treated with diazinon, neem, alpha-cypermethrin and λ-cyhalothrin insecticides: 76, 73.5, 69.2 and 65.6 thrips/plant, respectively, than the rest of the treatments except the untreated check (Tables 2). Performance of dimethoate and profenofos was intermediate between the best performing treatments (spinetoram, spinosad and imidacloprid) and the rest of the treatments. Similar trends were observed in the performance of the insecticides in the hot dry planting season of 2016 (Table 3)

Table 2. Mean number (±SE) of thrips/plant on onion treated with different insecticides in cool dry season, Melkassa, 2015/16.

Insecticides	Sampling dates							Season mean	% Efficacy (%)
	16-Nov	23-Nov	30-Nov	7-Dec	14-Dec	21-Dec	28-Dec		
diazinon	21.9±4.01a	13.1±2.46c	42.6±5.36bc	110.9±8.43a	99.4±5.36ab	123.9±8.28a	120.6±7.90ab	76.1±2.40ab	2.27
dimethoate	20.9±2.46a	11.6±1.91c	13.4±2.59e	50.8±4.11cd	43.1±2.07d	41.7±5.17cd	39.0±3.96cd	31.5±2.59c	59.52
imidacloprid	11.2±1.17bc	7.9±1.83c	15.4±2.26e	25.2±3.01e	19.0±1.32e	24.3±2.93de	21.2±3.06de	17.7±1.17d	77.23
alpha-cypermethrin	18.9±1.72ab	50.4±4.88a	48.2±6.11b	83.4±1.56b	96.6±4.78b	94.9±2.75b	92.2±2.84b	69.2±1.29ab	11.08
profenofos	7.2±1.74c	7.6±1.20c	19.7±3.27de	43.2±7.03cd	69.3±5.34c	52.9±5.88c	49.6±5.62c	35.6±1.91c	54.24
λ-cyhalothrin	12.9±2.85abc	25.2±3.49b	30.8±2.73cd	75.3±3.16b	93.0±6.22b	112.3±9.75ab	109.9±9.54ab	65.6±3.06b	15.68
neem	21.8±3.82a	29.7±4.56b	45.5±3.21bc	82.3±5.44b	106.4±6.78ab	115.9±8.64ab	113.0±8.62ab	73.5±1.45ab	5.56
spinetoram	10.7±2.07bc	3.4±0.92c	7.3±1.59e	11.7±2.04f	6.8±1.57e	17.5±6.25de	9.7±2.66de	9.6±1.94d	87.73
spinosad	11.2±1.7bc	2.1±0.2c	6.5±1.6e	31.3±3.7de	14.3±2.99e	8.4±1.5de	5.5±1.45e	11.3±1.32d	85.48
Control	16.8±2.7ab	23.7±2.6b	62.0±7.7a	72.4±5.4b	114.6±5.8a	132.3±10.9a	123.0±10.5a	77.8±4.9a	
SE±	1.69	4.72	6.16	9.85	13.2	15.10	15.37	8.96	
CV (%)	28.4	29.9	29.5	15.5	15.3	18.5	18.36	10.57	

Means followed by the same letter(s) in a column are not significantly different at 5% SNK. SE= Standard error, CV= Coefficient of Variability.

Table 3. Mean number of thrips/plant on onion treated with different insecticides in the hot dry season, Melkassa, 2016.

Insecticides	Sampling dates							Season Mean	Efficacy (%)
	11-Apr	18-Apr	25-Apr	2-May	9-May	16-May	23-May		
diazinon	21.5±1.81a	32.7±3.02ab	43.4±7.95b	76.1±6.76b	147.2±12.41a	121.1±8.93b	74.4±2.73b	73.8±1.40bc	16.64
dimethoate	16.3±2.75ab	30.2±4.48ab	39.9±5.32b	69.7±9.55b	111.3±14.02ab	92.4±7.30bc	39.8±6.32cd	57.0±2.64d	35.56
imidacloprid	10.5±0.80b	26.1±4.58ab	6.5±0.93c	14.9±3.89c	9.7±2.07d	30.9±10.01d	8.6±0.51e	15.3±1.41f	82.72
alpha-cypermethrin	10.4±2.16b	25.9±5.23ab	52.2±1.69ab	114.2±6.05a	122.2±11.89ab	176.2±16.02a	95.5±0.88b	85.2±3.20ab	3.7
profenofos	11.2±2.38b	28.7±3.58ab	11.1±2.58c	62.8±7.21b	54.0±3.67c	77.9±9.73c	42.1±10.73cd	41.1±1.68e	53.55
λ-cyhalothrin	15.7±1.48ab	27.0±4.34ab	36.1±2.32b	78.1±10.95b	98.6±13.61b	119.0±11.74b	123.0±12.96a	71.1±6.16c	19.69
neem	15.7±2.05ab	40.8±3.74a	39.1±5.72b	133.1±15.32a	121.1±8.48ab	187.2±9.90a	47.9±3.55c	83.5±5.03ab	5.58
spinetoram	8.2±0.69b	15.9±2.10b	7.9±1.00c	17.2±4.29c	21.2±4.85d	15.9±5.33d	6.5±1.62e	13.3±1.26f	85.02
spinosad	8.0±1.6.b	17.7±5.33b	19.3±2.35c	37.1±7.17c	7.9±1.34d	25.7±6.42d	16.5±4.78de	18.9±2.19f	78.68
Control	13.2±4.50b	27.4±5.60ab	60.1±8.33a	118.3±9.15a	140.1±10.92a	168.5±11.74a	91.9±18.39b	88.5±4.04a	
SE±	1.34	2.22	6.04	13.03	17.34	20.21	12.66	9.59	
CV (%)	28.4	29.6	27.6	21.3	22.9	18.7	29.3	12.1	

Means followed by the same letter(s) in a column are not significantly different at 5% SNK. SE= Standard error, CV= Coefficient of Variability.

Onion bulb yield

Marketable yield varied significantly between treatments in both seasons (Table 4). Higher marketable yields were obtained from plots treated with spinosad (28.88 t ha^{-1}) and spinetoram (27.77 t ha^{-1}) than the rest of the treatments. Marketable onion bulb yields were low for λ-cyhalothrin (15.18 t ha^{-1}), diazinon (18.05 t ha^{-1}), and neem (19.35 t ha^{-1}) treated plots in the cool dry season (Table 4). A similar trend was observed in marketable yield in the hot dry season. The onion total bulb yield was negatively associated with thrips number in cool dry (R^2=0.785; p = 0.0012) and hot dry (R^2=0.90; p = 0.0001) seasons (Figures. 1, 2).

Yield increase over control

The highest mean marketable bulb yield increase was recorded from spinosad (8.87 t ha^{-1}) and spinetoram (8.38 t ha^{-1}) treated plots, which accounted for 46.86 and 44.26% increase over the check, respectively. Subsequent high bulb yield increases were obtained from imidacloprid, profenofos and dimethoate with 7.66, 4.31 and 3.33 t ha^{-1} bulb yield with 40.46, 22.76 and 17.59% increase over check, respectively. The yield increase obtained by spraying the pyrethroids alpha-cypermethrin was low (1.2%). On the other hand, onion yield from the plots treated with λ-cyhalothrin and diazinon were lower than the untreated check and resulted in negative gain.

Table 4. Marketable bulb yield of onion treated with different insecticides against thrips in cool and hot dry seasons, Ethiopia, 2015/16.

Insecticides	Marketable yield (tons/ha) and percent of yield gain over control				
	Cool dry	Hot dry	Mean	Increment of yield over control (t/ha)	% yield gain over control
	Marketable	Marketable	Marketable		
diazinon	18.1±1.12bc	18.8±0.92c	18.4±0.75d	-0.51	-2.69
dimethoate	23.3±2.90ab	21.2±1.42c	22.3±1.76bc	3.33	17.59
imidacloprid	23.5±1.84ab	29.67±2.55a	26.6±1.51a	7.66	40.46
alpha-cypermethrin	20.5±0.76bc	17.9±0.48c	19.2±0.55bcd	0.23	1.21
profenofos	24.3±1.48ab	22.2±1.38bc	23.2±0.66b	4.31	22.76
λ-cyhalothrin	15.2±1.10c	17.8±0.50c	16.5±0.67d	-2.45	-12.94
neem	19.4±1.10bc	19.3±1.48c	19.3±0.78bcd	0.37	1.95
spinetoram	27.8±2.59a	26.9±1.38ab	27.3±1.27a	8.38	44.26
spinosad	28.9±2.49a	26.7±1.55ab	27.8±1.98a	8.87	46.86
Control	19.7±0.66bc	18.1±1.27c	18.9±0.69bcd	-	-
CV (%)	13.9	13.34	14.59		
SE±	0.76	0.78	0.73		

Means followed by the same letter(s) in a column are not significantly different at 5% SNK. SE= Standard error, CV= Coefficient of Variability.

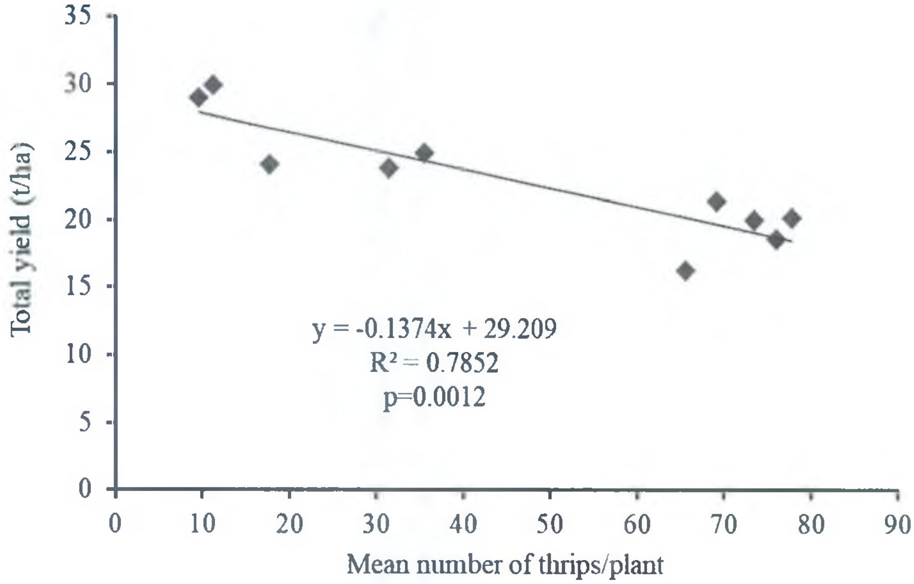

Figure 1. Relationship between mean number of thrips and total onion bulb yield (t ha^{-1}) in cool dry season, 2015/16

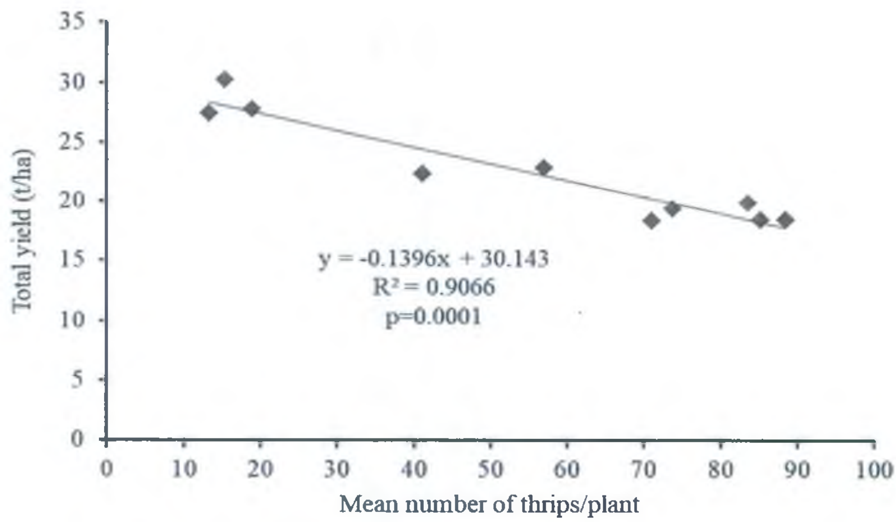

Figure 2. Relationship between mean number of thrips and total onion bulb yield (t ha^{-1}) in hot dry season, 2016

Discussion

Among the insecticides tested, spinosad and spinetoram effectively suppressed onion thrips as compared to other insecticides. These insecticides are recently registered in Ethiopia. The newer spinosyns derived products, specifically the spinosad (Tracer) and spinetoram (Radiant) showed great promise for *T. tabaci* management in onions with low lethal dose values in the USA (Greenberg *et al.* 2012). Spinosad and spinetoram are new selective insecticides belonging to novel classes of chemistry that have shown excellent management of *T. tabaci* infestations (Diaz-Montano *et al.* 2011). In addition, spinosad, a natural reduced-risk insecticide derived from an actinomycete bacterium, is compatible with natural enemies and currently provides the most effective chemical management of western flower thrips (Mouden *et al.* 2017). Spinosyns, the active ingredient of spinetoram and spinosad, act as nicotinic acetylcholine receptor (nAChR) allosteric modulators (IRAC 2018). Furthermore, these products have translaminar and/or systemic activity so that they are able to penetrate into areas of the plant where thrips are located (Reitz 2014). Spinosyns act on insects which come in contact with treated leaf surface or ingest the treated tissue (Siebert *et al.*, 2016). Insecticides with systemic mode of action have high efficacy against sucking insect pests (Ahmed *et al.* 2014). Therefore, the result of our insecticide performance evaluation against onion thrips agrees with the result of the abovementioned scientists. But, most of the vegetable growers in the CRV largely rely on less expensive and older insecticides (Belay *et al.* 2017), which are readily available and supplied by many dealers (Gashawbeza 2011).

The insecticides λ-cyhalothrin, alpha-cypermethrin, neem and diazinon failed to suppress thrips on onion in this study. Earlier report by Banchiamlak *et al.* (2012) showed that λ-cyhalothrin, diazinon, profenofos and spinosad were effective against thrips on onion in the Rift Valley of Ethiopia. Pyrethroids, carbamates, and organophosphates groups of insecticides have been used to manage insect pests on vegetable crops for many years in Ethiopia (Yalemtsehay & Agonafir 2002) and are still widely used. These insecticides are applied indiscriminately in high frequencies and doses (Belay *et al.* 2017; Tebkew & Getachew 2015). It is a common practice to spray mixes of insecticides at times when sole insecticide applications become less effective. Failure in the efficacy of insecticides to subdue onion thrips could be due to the development of resistance to insecticides. Several studies have indicated that *T. tabaci* has developed resistance to commonly used insecticides. Nault and Shelton (2010) and Shelton *et al.* (2003, 2006) documented resistance in thrips populations to the pyrethroid (λ-cyhalothrin), organophosphates and carbamates in many New York onion fields. Broughton & Herron (2009) also reported that resistance to insecticides by western flower thrips is common.

The present study showed that the yield reduction due to onion thrips infestation was very high and protection with the most effective insecticides, like spinosad, spinetoram and imidacloprid, increased bulb yield of onion. Several researchers have reported high yields when onion is protected from thrips with best performing insecticides. Basil and geranium protected from thrips with acephate and fipronil gave high yield (Moorthy *et al.* 2013). Khaliq & Tahir (2015) also reported higher yields of onion from plots treated with insecticides as well as botanicals than untreated checks. In the current study, lower marketable bulb yields were obtained from plots treated with diazinon, λ-cyhalothrin, alpha-cypermethrin and botanical formulation (neem) insecticides. On the contrary, Ibrahim *et al.* (2015) reported significantly higher onion yield from λ-cyhalothrin (23.3%) sprayed plots than the check plots in Tigray, Ethiopia. Anomalies in the performance of insecticides could be explained by the variation on the level of resistance by different populations of the thrips found in different parts of the country.

Conclusion and Recommendations

Onion thrips have become a serious problem, especially in the Central Rift Valley of Ethiopia, and the continuous use of insecticides might have resulted in resistant populations to commonly used insecticides. The insecticides spinosad, spinetoram and imidacloprid reduced number of thrips and increased onion bulb yield. On the other hand, λ-cyhalothrin, alpha-cypermethrin, diazinon and neem were less effective than the other insecticides tested. Variations in the performance of insecticides in the field could be due to some factors, such as the chemistry of the insecticide, higher populations of thrips, inappropriate application of timing, rate and coverage. Therefore, studies are needed to detect and monitor the development of thrips resistance to commonly used insecticides. Onion growers in the CRV should be advised to rotate the old class insecticides with the new classes during a season to delay development of resistance and prolong the service life of these insecticides.

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