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Comparative efficacy and economic efficiency of different insecticides against cotton thrips (*Thrips tabaci* L.) (Thysanoptera: Thripidae) on cotton in the Middle Awash, Ethiopia

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Thrips, *Thrips tabaci (*Thysanoptera: Thripidae) on the cotton plant is an extremely invasive and destructive pest that reduces yield. Field studies were conducted at Werer Agricultural Research Center, Middle Awash, Afar, Ethiopia, for two consecutive years (2017 and 2018) to determine the effectiveness of different synthetic chemical insecticides for the control of cotton thrips (*T. tabaci*) on the Deltapine-90 cotton variety. A total of eleven treatments with untreated control were laid out in a Randomized Complete Block Design (RCBD) replicated thrice per treatment. The field was sprayed two times with an economic threshold level attained in two weeks intervals after the first round of data. Thrips population count data on thrips populations were collected before and after three, five, seven and ten days of insecticide application. The yield and yield component, and economic returns data were also collected. The percent efficacy was calculated using a modified Abbott's formula. The efficacy of the insecticide Rectro 20% Sc, Imidacloprid 20% SC, Closer 240% SC and Dimethoate 40% EC resulted in fewer numbers of thrips and higher yields than Diazinon 60% EC, Chlorpyrifos 48% EC, Chloropyrafose 36 SC, Deltamethrin 06% and Curadore 45%. The economic analysis of the insecticides chemical showed good cost-benefit for Rectro 20% SC (2.55), Closer 240% SC (1.93) and Dimethoate 40% EC (1.49) with good advantage. Additionally, the protection of cotton thrips using the insecticide chemicals namely Imdacloropride 20% SC, Rectro 20% Sc and Curador 45% EC would return 1.33, 1.24 and 1.24 birr return. The result confirmed that the application of more effective insecticides when the thrips population was high resulted in better control and higher economic returns. Therefore, the use of sequential applications in the insecticides, Closer 240% SC, Dimethoate 40% EC, Rectro 20%SC and Imidacloprid is recommended to manage the cotton thrips in the middle awash areas of Ethiopia.

Key words: Insect pest, resistance, management, insecticides, sequential, economic returns.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an annual fiber crop that is grown commercially in over 80 countries worldwide, particularly in the tropics (Lundbaek, 2002). It is one of the globally vital natural fibers in volume and value traded

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in human civilization (Smith and Cothren, 1999; Basra et al., 2002). Cotton is used to manufacture textile and garment, edible oil, soap, and livestock feeds; it also provides income for hundreds of millions of people (EIAR, 2017; Jjumba et al., 2016, Alemu et al., 2021; Brandenburg et al., 2022). In Ethiopia, cotton is mainly grown in many areas including the Awash Valley, Arbaminch-Sile, Abaya, Woito, and Omorate and North Bale; in the South; Gambella in the West Beles in the North; and Metema and Humera in the North-West (ICAC, 2014; EIAR, 2017; Keneni et al, 2021; Taye et al., 2019).

The country has a good potential in cotton yield from areas varying in altitude from sea level to about 1000 m.a.s.l. (EIAR, 2012, Abebe et al., 2021). Both abiotic and biotic stresses affect cotton production. Major abiotic stresses affecting cotton production include drought, salinity and heat stress; while biotic stresses include insect pests, diseases and weeds (Maiti et al., 2020). Cotton is considered as a museum of insect pests due to the diverse insect herbivore species feeding on it. A total of 70 species of insect and mite pests are known to attack cotton in Ethiopia (Ermias et al., 2009; Bayeh and Meisso, 2013). Insect pest infestation causes substantial losses in cotton production which could reach up to 70% in the absence of pest control measures (Rehman et al., 2016).

Sap feeders have been reported to cause a loss in yield to the extent of 8.45 q/ha in hirsutum cotton (Radhika et al., 2006). A complex of thrips species may infest the seedling stage cotton. These species include tobacco thrips, *Frankliniella fusca* (Hinds), flower thrips, *Frankliniella tritici* (Fitch), onion thrips, *Thrips tabaci* (Lindeman), western flower thrips, *Frankliniella occidentalis* (Pergande), and soybean thrips, *Neohydatothrips variabilis* (Beach) (Stewart et al., 2013). The onion thrips and western flower thrips are more invasive and damaging than tobacco thrips throughout the world (Faircloth et al., 2001; Greenberg et al., 2009; Stuart et al., 2011; Gao et al., 2012).

The two more invasive species are also present in cotton in Ethiopia. When the species co-occur, one species tends to eventually predominate over the other. Both *T. tabaci* and *F. occidentalis* were mostly collected from weeds flowering in spring and summer when these plants were most abundant (Silva et al., 2018). The seasonal composition of thrips populations on cotton changed from predominately *T. tabaci* on seedling cotton to *F. schultzei* and *F. occidentalis* on mature flowering cotton later in the season (Silva et al., 2018). High *T. tabaci* abundance on early-season cotton was attributed to the abundance of *T. tabaci* on the surrounding weed species. In contrast, the abundance of *F. occidentalis* and *F. schultzei* on cotton was not connected to their abundances (Silva et al., 2018).

Thrips are found on the underside of the leaves damaging them by piercing the epidermis of the tissues and sucking the sap oozing out of wounds (Sanjta and Chauhan, 2015). As a result, leaves become slivery due to the formation of white patches or streaks which finally cause scarring and distortion of leaves (Patel and Patel, 2014). The detection and estimation of damage caused by cotton thrips can be done using hyperspectral radiometry (Ranjitha et al., 2014). These insects have piercing-sucking and rasping mouthparts and feed on almost all portions of the cotton plant and stage, with the most significant injury occurring on seedlings at plant emergence to five true leaves (Terefe and Shonga, 2006; Cook et al., 2011; Reay-Jones et al., 2017). Excessive feeding injury can produce severely stunted plants, often resulting in loss of yield or at least a delay in crop maturity.

Preventive control tactics are commonly recommended to manage early-season infestations of thrips in cotton (Lopez et al., 2008; Toews et al., 2010). The most commonly applied insecticide classes in Ethiopia include Carbamate, organophosphate, organochlorine and pyrethroid, which are often applied repeatedly and indiscriminately in the Central Rift Valley of Ethiopia (Belay et al., 2017). However, the efficacy of these insecticides used on thrips has not been assessed in cotton-producing areas of Ethiopia. Even though, most of the insecticides used were registered in onion and cotton, their comparative efficacy decreases or increases with the plant canopy nature and degree of pesticide exposure in the production. This lack of information is the cause of concern which needs to be addressed to provide accurate information to cotton producers. Hence, this research was designed to evaluate the efficacy and efficiency of the different insecticides used in the management of cotton thrips in middle Awash, Ethiopia.

MATERIALS

The experiment was conducted at Werer Agricultural Research Center (WARC) in irrigated cotton production period in the main seasons for two consecutive years (2017-2018). The cotton variety Deltapine 90 was used. The efficacies of 10 different insecticides were compared with the controls for the experiment (Table 1).

METHODS

The eleven treatments (including one untreated check) were laid out in a Randomized Complete Block Design (RCBD) with three replications per treatment. Each total plot size had a plot size (6.3 m * 5 m) of 31.5 m^2. The distance between the row to row and plant to plant was 90cm and 20 cm, respectively. Agronomic practices such as thinning and weeding were done manually as recommended.

Thrips pest assessment random sampling was done on 10 plants in each plot, and 5 leaves were checked for thrips pest; the number of nymphs and adults were counted on weekly basis.

Spraying frequency of the insecticides in the field

For foliar treatment, the insecticides were diluted with water (200

Table 1. Description of treatments used in the experiment.

Common name	Trade name	Rate/ha
Control	Water only	
Ethiozinon	Diazinon 60% EC	2 lt
Dursban	Chloropyrafose 48 EC	2 lt
Chlorfenapyr	Tutan 36 SC	225 m
Deltamethrin	Deltahock 0.6% ULV	2.5 lt
Ethiothoate	Dimethoate 40% EC	2 lt
Lufernuron+Profenofos	Curador 55 EC	650 ml
Imidaclorpride+lambdacyhalothrin	Rectro 25 SC	1 lt
Acetamiprid	Pritact 10% EC	2 lt
Imidaclorpride	Confidor SL 200	400 ml
Sulfoxaflor	Closer 240 SC	150ml

EC = Emulisifiable concentrate, SC = Soluble concentrate, ULV = Ultra Low Volume, IGR = Insect growth regulators.
Source: Authors

l/Ha). Each was sprayed using a knapsack sprayer with one nozzle. Each year, the treatments were applied two times after reaching economic threshold level of 5 thrips per plant during the growth period at two weeks intervals in the field starting 60 days and 105 days after planting in 2017 and 2018, respectively. Late application of the spray in 2018 was due to late ETHL as a result of high rainfall.

Data collected

Data were collected on pre and post-spray insect count, and cotton plant population stand was counted. The number of opened and unopened bolls per plant as well as plant height measurements was taken from randomly selected plant. 10 plants were tagged from each of the treatment plots. The 65% boll opening of the experimental material of the variety DP-90 was known, so we took that time and recorded if there was a difference between treatments. The height of ten randomly selected plants from the central five rows at maturity time (one or two days before first peaking) was measured in cm from each plot using wooden ruler from the ground level to the tip of the plants and was averaged.

For the assessment of the numbers of thrips, a random sampling was done on 10 plants in each plot, and 5 leaves were checked. The number of nymphs and adult thrips was counted on a weekly basis. The pre-assessment of thrips was done weekly starting from seedling to maturity of the cotton plants. The post spray assessment of the number of thrips was conducted on the $3^{rd,}$ $5^{th,}$ $7^{th,}$ and 10^{th} days after insecticide application. Cotton seed weight was measured by weighing the total harvested cotton in each plot and then converted to quintals per hectare.

Economic analysis (cost-benefit ratio)

The relative economic returns of the treatments were calculated by subtracting the cost of insecticides and their application cost from the gross return. The price of cotton was estimated based on the farm gate price in Ethiopia 21 Birr^{-1}kg in 2017. The application cost in the first experiment was estimated at ETB^{-1} ha 100 birrs for the two-round 200 ETB. In the second season, the price of cotton was estimated based on the farm gate price in Ethiopia as 23 Birr^{-1} kg in 2018 and the insecticide application cost in the first round was estimated at ETB per ha 100 birrs for the two-round 200 ETB. The prices of sulfoxaflor, deltamethrin, ethiopyrifos, ethiothoate, chlorfenapyr, lufenuron + profenofos, Ethiozinon, Imidaclorpride, Imidaclorpride + lambda-cyhalothrin, and Acetamiprid per liter were ETB 3400, 800, 480, 600, 3000,1000, 700, 1400, 1000 and 800, respectively. During the study period the exchange rate of the ETB to US dollar was 45 ETB=1$. The partial budget analysis was used for comparing the impact of a technological change on-farm costs and returns.

Partial Marginal Benefit = $(TB_1 - TB_0) / (Q_1 - Q_0)$

When TB_0 = Initial total benefit at quantity Q_0, TB_1 = Final total benefit at quantity Q_1, Q_0 = Initial quantity and Q_1 = Final quantity.

Benefit-Cost Ratio = ∑ *Present Value of Future* **Benefits** / ∑ *Present Value of Future* **Costs**.

Data analysis

Thrips mortality analysis

The mean number of insects per plant for the overall effect of sprays was determined for each treatment. Percent mortality for the cotton thrips as well as the population was calculated using Abbott's formula for corrected mortality (Abbott, 1925):

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

Where n in T = population in the treated plot after treatment; n in Co = population in control after treatment. The data collected including the efficacy derived pre and post spray mealybug count data were subjected to efficacy calculation using the formula of Fleming and Retnakaran (1985). Then ANOVA analysis was done using R software. The mean data least significant difference (LSD at 5%) level was used for treatment mean comparison.

RESULTS

First year (2017)

The result showed that the thrips population decreased significantly after the application of insecticides (DF= 10,

Table 2. Mean values of pre and post spray thrips population and its efficacy at 1st round spray application, in 2017.

Treatment	Pre	3 DAS (efficacy)	5 DAS (efficacy)	7 DAS (efficacy)	10 DAS (efficacy)	MPSC (efficacy)
1.	8.93	14.0^{a}(0.0)^{d}	15.13^{a}(0.0)^{c}	16.4^{a}(0.0)^{e}	14.33^{a}(0.0)	14.97^{a}(0.0)^{b}
2.	6.27	2.53^{c}(73.9)^{ab}	1.93^{b}(78.8)^{a}	3.3^{b}(72.5)^{bcd}	3.73^{b}(23.0)	2.87^{b}(69.8)^{a}
3	5.93	1.93^{c}(78.1)^{a}	3.13^{b}(69.55)^{ab}	3.7^{b}(67.9)^{d}	3.73^{b}(22.5)	3.12^{b}(67.60)^{a}
4.	8.53	3.27^{bc}(73.53)^{ab}	3.07^{b}(75.57)^{ab}	3.7^{b}(73.3)^{bcd}	3.33^{b}(24.6)	3.33^{b}(69.74)^{a}
5.	7.40	3.73^{bc}(68.06)^{ab}	2.27^{b}(81.13)^{a}	4.1^{ab}(68.3)^{cd}	3.80^{b}(38.4)	3.47^{b}(69.97)^{a}
6.	6.07	5.07^{bc}(48.01)^{bc}	3.40^{b}(64.43)^{ab}	1.6^{ab}(84.6)^{ab}	2.27^{b}(66.1)	3.09^{b}(69.32)^{a}
7.	6.73	6.68^{bc}(39.01)^{c}	2.47^{b}(76.67)^{ab}	2.93^{b}(75.7)^{abcd}	3.93^{b}(28.4)	4.00^{b}(63.29)^{a}
8.	7.60	3.27^{bc}(71.3)^{ab}	1.80^{b}(80.9)^{a}	2.27^{b}(80.7)^{abc}	3.73^{b}(14.6)	2.77^{b}(71.09)^{a}
9.	6.33	5.00^{bc}(52.1)^{ac}	2.40^{b}(73.94)^{ab}	1.5^{b}(86.7)^{a}	4.07^{b}(50.0)	3.24^{b}(69.22)^{a}
10.	7.67	7.67^{b}(47.9)^{bc}	5.87^{b}(57.95)^{b}	2.5^{b}(79.8)^{abcd}	4.20^{b}(71.1)	5.07^{b}(64.61)^{a}
11.	8.53	2.67^{c}(77.4)^{a}	2.73^{b}(80.21)^{a}	2.7^{b}(78.4)^{abcd}	2.73^{b}(36.9)	2.72^{b}(75.5)^{a}
Mean	7.27	5.07(57.2)	4.02(67.2)	4.1(69.8)	4.5(34.1)	4.42(62.74)
LSD	3.19	4.98(26.9)	4.59(19.3)	3.03(12.8)	5.9(78.9)	3.70(16.06)
CV	25.7	25.7^(27.6)	28.45^(16.8)	15.56^(10.8)	35.8^(135)	49.20(15.03)

Means followed by the same letter(s) within a column are not significantly different from each other at a 5% level of significance. DAS= Days after spray. MPSC= mean of post spray count. Values in parentheses were percent efficacy. The data's were square root transformed.
Source: 2017 field experiment results in Werer

20; F= 1.0^{ns}, 4.19**, 6.12***, 16.56***, 2.71* and 8.05***; P>0.01) at pre, three, five, seven, ten days post spray count, respectively. The efficacy result showed that the population decreased significantly (DF= 10, 20; F= 6.61***, 12.89***, 30.36***, 0.64^{ns,} and 14.95*** at, three, five, seven, ten days post spray efficacy, respectively (Table 2). All the insecticides were found to reduce the thrips up to ten days after application; however, treatment Closer 240% SC, Dimethoate 40% EC, Rectro 20%SC and Imidacloprid were most effective in reducing the number of thrips (Table 2). The number of thrips was lower at the early growth stage and during the boll formation stage and the population increased in the cool dry period of September and October. During the rainy hot periods, this trend was not observed as the populations were generally variable with the amount of rainfall. Among the insecticides applied in 2017 treatment Closer 240% SC, Dimethoate 40% EC, Rectro 20% SC and Confidor SL 200 resulted in fewer thrips population numbers per plant (Tables 2 and 3). The numbers of thrips were significantly higher on the untreated checks (Tables 2 and 3). Sulfoxaflor reduced thrips by 60 to 70% compared to the reduction caused by spinetoram.

The results revealed that the thrips population decreased significantly after the application of insecticides (DF= 10, 20; F= 3.33*, 5.70***, 21.58***, 13.43***, 7.48***, and 43.4***; P>0.01) at pre, three, five, seven, ten days post spray count, respectively. The efficacy result showed that all the treatments decreased the thrips population significantly (DF= 10, 20; F= 1.15^{ns}, 6.56***, 2.36*, 1.04^{ns,} and 3.41**) at three, five, seven, ten days post spray efficacy, respectively. All the insecticides reduced thrips population up to ten days after application. However, Treatment 5 Deltahock 0.6% ULV, Dimethoate 40% EC, Confidor SL 200 and Closer 240 SC are effective in reducing thrips with good efficacy at the mean of post spray count application (Table 3).

Second year (2018) population density of cotton thrips

The result showed that the thrips population decreased significantly after the application of insecticides (DF= 10, 20; F= 0.70^{ns}, 20.02***, 16.45***, 16.57***, 13.55*** and 37.26***; P>0.01) at pre, three, five, seven, ten days post spray count, respectively. The efficacy result showed that the population decreased significantly (DF= 10, 20; F= 19.23***, 24.36***, 11.08***, 11.28***, and 31.86***) at three, five, seven, ten days post spray efficacy, respectively (Table 4). All the insecticides reduced the thrips up to ten days after application; however ttreatments Tutan 36 SC, Curador 55 EC, Confidor SL 200, Closer 240 SC and Pritact 10% EC were effective in reducing thrips population (Table 4). Some level of resistance or reduction in efficacy on the 10th day was still observed with the chemical Confidor SL 200; Closer 240 SC and Dimithoate40% EC were better in reducing the thrips population as shown in Table 4.

The result also shows that the cotton thrips chemical management shows great efficacy even in field condition at three to ten days interval. Even though there is no significant difference at ten-day, the insecticides Closer 240 SC(86.7%), Pritact 10% EC (85.6%), Dimethoate 40% EC(85%) and Confidor SL 200 (83.4%), insecticides have good efficacy (Table 4 and 5).

The result showed that the thrips population decreased significantly after the application of insecticides (DF= 10,

Table 3. Mean values of pre and post spray thrips population and its efficacy at 2nd round spray application, Werer, in 2017 production year.

Treatment	Pre	3 DAS (efficacy)	5 DAS (efficacy)	7 DAS (efficacy)	10 DAS (efficacy)	MPSC (efficacy)
1	14.13^{a}	16.13^{a}(0.0)	17.47^{a}(0.0)^{e}	17.8^{a}(0.0)^{b}	16.53^{a}(0.0)	16.98(0.0)^{b}
2	6.73^{c}	6.33^{b}(14.7)	4.53^{b}(45.57)^{cd}	4.00^{b}(53.61)^{a}	5.73^{bc}(29.24)	5.15(35.02)^{a}
3	8.67^{bc}	5.53^{b}(40.61)	4.40^{b}(56.9)^{abcd}	6.07^{b}(45.12)^{a}	7.66^{b}(21.91)	5.92(42.45)^{a}
4	8.80^{bc}	5.47^{b}(39.65)	3.27^{b}(69.41)^{ab}	6.00^{b}(40.47)^{a}	4.00^{bc}(47.91)	4.68(50.83)^{a}
5	10.80^{ab}	5.40^{b}(55.96)	5.13^{b}(60.93)^{abcd}	7.00^{b}(46.11)^{a}	6.47^{bc}(43.49)	6.00(52.51)^{a}
6	8.60^{bc}	5.87^{b}(39.65)	3.47^{b}(67.82)^{abcd}	5.57^{b}(47.72)^{a}	4.73^{bc}(52.60)	4.91(52.78)^{a}
7	8.47^{bc}	2.93^{b}(69.16)	5.33^{b}(46.96)^{bcd}	6.80^{b}(33.71)^{a}	7.20^{bc}(23.68)	5.57(43.27)^{a}
8	8.50^{bc}	3.93^{b}(58.02)	3.13^{b}(68.72)^{abc}	5.07^{b}(47.67)^{a}	6.33^{bc}(31.17)	4.62(52.51)^{a}
9	7.40^{c}	4.87^{b}(37.87)	4.93^{b}(45.3)^{d}	6.10^{b}(34.22)^{a}	6.46^{bc}(25.29)	5.57(36.66)^{a}
10	11.53^{ab}	5.27^{b}(57.53)	4.73^{b}(59.98)^{abcd}	6.20^{b}(55.23)^{a}	6.13^{bc}(50.25)	5.58(55.94)^{a}
11	9.0^{bc}	4.20^{b}(58.16)	3.20^{b}(70.49)^{a}	4.53^{b}(62.80)^{a}	6.80^{bc}(34.44)	4.68(57.02)^{a}
Mean	9.33	5.99(42.92)	5.42(53.83)	6.83(42.42)	7.09(32.73)	6.33(43.57)
LSD	3.37	4.32(56.65)	2.59(23.38)	3.02(31.69)	3.56(44.8)	14.81(26.03)
CV	21.19	42.4(77.5)	28.07(25.50)	25.94(43.85)	29.5(80.4)	1.60(35.1)

Means followed by the same letter(s) within a column are not significantly different from each other at a 5% level of significance. DAS= Days after spray. MPSC= Mean of post spray count. Values in parentheses were Percent efficacy. The data was square root transformed.
Source: 2017 field experiment results in Werer

Table 4. Mean values of pre and post spray thrips population and its efficacy at 1st round spray application, Werer, in 2018 production year.

Treatment	Pre	3 DAS (efficacy)	5 DAS (efficacy)	7 DAS (efficacy)	10 DAS (efficacy)	MPSC (efficacy)
1	8.73^{a}	12.2^{aa} (0.0)^{b}	13.73^{aa}(0.0)^{c}	13.73^{aa}(0.0)^{e}	11.80^{a}(0.0)^{c}	12.86^{a}(0.0)^{c}
2	8.27^{a}	1.0^{cc} (89.4)^{a}	2.87^{bc}(74.1)^{b}	3.80^{bc}(64.2)^{bcd}	1.33^{d}(85.8)^{a}	2.25^{bc}(77.8)^{a}
3	9.07^{a}	1.80^{bc} (84.0)^{a}	3.73^{bb}(76.6)^{b}	4.60^{bc}(62.3)^{cd}	1.60^{d}(85.9)^{a}	2.9b^{c}(76.8)^{ab}
4	9.93^{a}	2.93^{bc} (78.9)^{a}	2.57^{bc}(83.8)^{ab}	2.53^{cde}(83.4)^{abc}	1.47^{d}(88.8)^{a}	2.37^{bc}(83.7)^{ab}
5	8.73^{a}	2.07^{bc} (82.5)^{a}	2.53^{bc}(81.8)^{ab}	5.53^{b}(56.6)^{d}	1.40^{d}(86.7)^{a}	2.88^{bc}(76.6)^{ab}
6	10.07^{a}	1.73^{bc} (86.7)^{a}	2.63^{bc}(81.4)^{ab}	1.20^{e}(91.7)^{a}	8.87^{b}(27.2) ^{c}	3.61^{b}(73.0)^{b}
7	10.40^{a}	2.73^{bc} (82.0)^{a}	0.93^{cc}(94.2)^{a}	2.27^{cde}(86.1)^{ab}	1.60^{d}(88.9)^{a}	1.88^{c}(87.9)^{a}
8	9.20^{a}	2.73^{bc} (74.2)^{a}	2.53^{bc}(77.9)^{b}	3.60^{bcde}(70.9)^{abc}	1.33^{d}(86.7)^{a}	2.55^{bc}(77.3)^{ab}
9	8.73^{a}	2.67^{bc} (75.8)^{a}	2.33^{bc}(84.7)^{ab}	1.60^{de}(87.1)^{a}	1.67^{d}(84.7)^{ab}	2.07^{c}(83.3)^{ab}
10	8.67^{a}	1.40^{bc} (88.6)^{a}	1.93^{bc}(86.2)^{ab}	2.66^{cde}(81.0)^{abc}	4.73^{c}(58.7)^{b}	2.68^{bc}(79.1)^{ab}
11	10.27^{a}	3.40^{bb} (76.5)^{a}	2.47^{bc}(84.9)^{ab}	3.33^{bcde}(79.9)^{abc}	2.07^{cd}(86.3)^{a}	2.81^{bc}(81.9)^{ab}
Mean	9.28^{ns}	3.15 (74.4)	3.48(75.1)	4.08(69.4)	3.44(70.9)	3.54(72.5)
LSD	2.64	0.66^ (16.96)	0.84^15.2)	0.76^(22.7)	0.63^(26.5)	1.5(12.8)
CV	16.73	23.81 (13.4)	29.02(11.9)	23.95(19.3)	22.30(22)	25(10.3)

Means followed by the same letter(s) within a column are not significantly different from each other at a 5% level of significance. DAS= Days after spray. MPSC= Mean of post spray count. Values in parentheses were Percent efficacy. The data was square root transformed.
Source: 2018 field experiment results in Werer

20; F= 1.99^{ns}, 12.26***, 81.62***, 74.72***, 66.44*** and 101.80*; P>0.01) at pre, three, five, seven, ten days post spray count, respectively (Table 5). The efficacy results showed that the population decreased significantly (DF= 10, 20; F= 2.92*, 30.08***, 24.27***, 15.54***, and 30.08***) at three, five, seven, ten days post spray efficacy, respectively. All the insecticides reduced the thrips population up to ten days after application. However, treatment Dimethoate 40% EC, Curador 55 EC, Confidor SL 200 and Closer 240 SC were most effective in reducing thrips population (Table 5).

Effect of insecticides on yield and yield components of cotton in 2017 and 2018

The results showed that the yield and boll number parameters significantly increased after the application of insecticides (DF= 10, 20; F= PHT (0.70 ^{ns}, 1.44 ^{ns}), stand count at emergency (1.03^{ns}, 1.04^{ns}) and at harvest (1.45^{ns}, 1.07^{ns}), boll number (0.94^{ns}, 1.04^{ns}), yield (0.85, 12.06^{ns}) P>0.01) during 2017 and 2018, respectively (Table 6). The yield and yield components of cotton was affected with the insect population and application of

Table 5. Mean values of pre and post spray thrips population and its efficacy at 2nd round spray application, Werer, in 2018 production year.

Treatment	Pre	3 DAS (efficacy)	5 DAS (efficacy)	7 DAS (efficacy)	10 DAS (efficacy)	MPSC (efficacy)
1	14.67^{a}	16.6^{a} (0.0)^{b}	18.4^{a}(0.0)^{b}	17.9^{a}(0.0)^{d}	17.23^{a}(0.0)^{b}	17.5^{a}(0.0)^{b}
2	8.80^{b}	2.4^{b} (71.4)^{a}	1.2^{b}(83.9)^{a}	1.0^{bcd}(87.2)^{abc}	2.47^{b}(69.23)^{b}	1.77^{b}(78.2)^{a}
3	7.67^{b}	3.2^{b} (59.8)^{a}	1.3^{b}(83.9)^{a}	0.47^{bcd}(94.6)^{abc}	1.87^{bc}(80.63)^{ab}	1.72^{b}(80.2)^{a}
4	7.87^{b}	3.2^{b} (61.97)^{a}	1.3^{b}(87.8)^{a}	1.87^{bc}(79.6)^{c}	1.13^{bc}(87.5)^{ab}	1.88^{b}(79.4)^{a}
5	10.73^{ab}	4.3^{b} (64.6^{a}	0.66^{b}(95.7)^{a}	2.0^{b}(84.4)^{abc}	1.46^{bc}(88.5)^{ab}	2.12^{b}(83.5)^{a}
6	7.73^{b}	2.87^{b} (64.9)^{a}	0.66^{b}(94.5)^{a}	0.40^{bcd}(94.8)^{abc}	1.20^{bc}(85.0)^{ab}	1.28^{b}(85.0)^{a}
7	7.93^{b}	2.13^{b} (76.5)^{a}	0.93^{b}(90.8)^{a}	1.0^{bcd}(89.6)^{abc}	1.26^{bc}(84.8)^{ab}	1.33^{b}(85.7)^{a}
8	8.20^{b}	2.73^{bc} (60.61)^{a}	0.66^{b}(93.1)^{a}	2.13^{b}(81.1)^{bc}	0.40^{cc}(96.5)^{a}	1.73^{b}(82.9)^{a}
9	6.86^{b}	4.4^{b} (48.4)^{a}	0.93^{b}(90.8)^{a}	0.20^{cd}(97.9)^{ab}	0.60^{cc}(92.9)^{a}	1.53^{b}(83.4)^{a}
10	8.46^{b}	3.13^{b} (67.17)^{a}	1.27^{b}(91.8)^{a}	0.07^{d}(99.2)^{a}	1.33^{bc}(87.42)^{ab}	1.45^{b}(86.7)^{a}
11	10.73^{ab}	3.93^{b} (65.40)^{a}	1.13^{b}(91.3)^{a}	0.20^{cd}(98.1)^{a}	1.13^{bc}(87.7)^{ab}	1.60^{b}(85.6)^{a}
Mean	9.06*	4.53 (58,24)	2.59(82.14)	2.48(82.4)	2.74(78.2)	3.08(75.5)
LSD	4.4	0.94^ (35.5)	1.7(14.8)	1.8(16.9)	1.75(15)	1.40(13.6)
CV	28.4	28.1 (35.8)	38.8(10.6)	41.9(12.03)	37.6(20.1)	26.7(10.5)

Means followed by the same letter(s) within a column are not significantly different from each other at a 5% level of significance. DAS= Days after spray. MPSC= Mean of post spray count. Values in parentheses were percent efficacy. The data was square root transformed
Source: 2017 field experiment results in Werer

Table 6. Mean values for yield and yield components of cotton at Werer, during the 2017 and 2018 cropping seasons.

Treatment	2017			2018			Combined		
	PHT	BN	Y(q/ha)	PHT	BN	Y(q/ha)	PHT	BN	Y(q/ha)
1	63.0	17.13^{ab}	22.9^{b}	68.5^{b}	21.07^{a}	29.49^{c}	65.73^{b}	21.10	26.20^{c}
2	62.8	15.3^{b}	31.7^{ab}	68.0^{b}	18.07^{ab}	35.87^{abc}	65.40 ^{b}	18.60	33.78^{abc}
3	64.2	16.6^{ab}	31.6^{ab}	74.5^{ab}	22.60^{a}	34.37^{abc}	69.33 ^{ab}	21.60	32.98^{abc}
4	65.3	17.4^{ab}	31.3^{ab}	77.13^{ab}	20.67^{ab}	36.8^{abc}	71.20 ^{ab}	21.03	34.06^{ab}
5	67.6	17.5^{ab}	37.1^{a}	91.7^{a}	19.93^{ab}	40.03^{ab}	79.67^{a}	20.73	38.57^{a}
6	61.1	16.9^{ab}	29.7^{ab}	86.3^{ab}	22.73^{a}	40.87^{ab}	73.70^{ab}	21.80	35.32^{ab}
7	70.7	16.73^{ab}	28.9^{ab}	81.4^{ab}	22.40^{a}	42.37^{a}	76.07^{ab}	21.57	35.61^{ab}
8	66.8	17.13^{ab}	30.7^{ab}	74.0^{ab}	19.40^{ab}	35.27^{abc}	70.40^{ab}	20.43	32.98 ^{abc}
9	71.1	17.7^{a}	26.3^{ab}	70.8^{ab}	15.53^{b}	29.85^{c}	70.97^{ab}	18.60	28.17^{bc}
10	69.3	17.7^{a}	29.0^{ab}	84.3^{ab}	21.27^{ab}	32.3^{bc}	76.80^{ab}	21.47	30.65^{bc}
11	62.9	18.3^{a}	32.1^{ab}	79.5^{ab}	18.07^{ab}	34.67^{abc}	71.20^{ab}	20.17	33.39^{abc}
Mean	65.9	17.12	30.2	77.8	20.18	35.6	71.86	20.65	32.88
LSD	12.2	2.37	11.2	18.8	6.48	8.98	13.28*	3.62^{ns}	7.58*
CV	10.8^{ns}	8.14*	26.2	14.2	18.85	14.8	10.85	10.28	13.54

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance. PHT = Plant height; BN = Boll number; Y (q/ha) = yield (quntal $^{-1}$ hactare)
Source: 2017 and 2018 field experiment results in Werer

insecticdes. The agronomic parameter did not affect the plant height and boll number of the cotton; however, it affected the yield of cotton greatly. The treatments showed asignificant differences (Table 6).

Thrips population effect on cotton yield and yield component in 2017

In the first year, the thrips population was observed increasing from time to time possibly due to the re-infestations from neighboring onion fields. Over the crop growth period in the first year, the thrips population in the control plots, where only water was sprayed during each spraying time (37, 51, 67, and 86 days after planting), was relatively higher than the rest of the treatments.

The yield and yield component result of each insecticide or the sum gain of a product for a farmer can be approved with their cost benefit ratio. The yield and yield components of cotton affected the insect population

Table 7. Cost benefits analysis of different management against onion thrips on cotton, Werer.

Treatment		Gross returns (ETB/ha)	Cost Ha^{-1}	Net monetary return (ETB)	Marginal Benefit	Cost-benefit ratio
1	Control	57648.1^{c}	0^{k}	57648.15^{C}	0.0^{bc}	0.0^{c}
2	Diznone 60% EC	74311.1^{abc}	3000^{b}	71511.11^{abc}	2336.7^{abc}	0.78^{abc}
3	Dursban 48% EC	72559.3^{abc}	2120^{e}	70639.26^{abc}	-835.4^{c}	-0.4^{c}
4	Chlorfenapyr	74922.2^{ab}	1550^{g}	73572.22^{abc}	1923.7^{abc}	1.24^{abc}
5	Deltameterin 06% EC	84863.0^{a}	4200^{a}	80862.96^{a}	1824.4^{abc}	0.43^{bc}
6	Dimithioate 40% EC	77692.6^{ab}	2600^{d}	75292.59^{abc}	3884.6^{ab}	1.49^{abc}
7	Curador 45% EC	78344.4^{ab}	1500^{h}	77044.44^{a}	1854.2^{abc}	1.24^{abc}
8	Rectro 25 SC	72559.3^{abc}	1700^{f}	71059.26^{abc}	4328.2^{a}	2.55^{a}
9	Confidor SL 200	61966.7^{bc}	3400^{b}	58766.67^{bc}	1713.9^{abc}	0.5^{bc}
10	Closer 240 SC	67425.9^{bc}	1320^{i}	66305.93^{abc}	1749.3^{abc}	1.33^{abc}
11	Pritacet 10% EC	73455.6^{abc}	1220^{j}	72435.56^{abc}	2355.8^{abc}	1.93^{ab}
	Mean	72340.7	2055.5	70467.1	1921.4	1.009
	LSD	16686.97	190	16686.97		
	CV	13.5	5.45	13.90369		

Means followed by the same letter (s) within a column are not significantly different from each other at 5% level of significance. In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Student Newmans Keul's (SNK) test. L = λ-cyhalothrin, I = Imidacloprid, P = Profenofos, S=Spinetoram, Ha = hectare, Kg = kilogram.
Source: 2017 and 2018 field experiment results in Werer

and the application of insecticdes. The agronomic parameter did not affect the plant height and boll number of the cotton; however, it affected the yield of cotton greatly and the treatments showed asignificant differences (Table 7).

DISCUSSION

Ten (10) insecticides products were assessed for the control of thrips during flowering and boll setting periods, when they reached ETHL. The products, Imdaclorופride 20 % SC, Rectro 20% SC, and Curador 45% EC had 1.33, 1.24, and 1.24 birr return economic advantage through their good efficacy. The result confirmed the application of more effective insecticides when the thrips population was high resulting in better control and higher economic returns. Therefore, the sequential applications of insecticides Closer 240 % SC, Dimethoate 40% EC, Rectro 20%SC, and Imidacloprid were recommended to manage the cotton thrips in the middle awash areas of Ethiopia. Treated plots had the lowest thrips population across all assessment dates (Figure 1). On the third spraying time (67 and 110 days after transplanting), Closer 240 % SC, Dimethoate 40% EC, Rectro 20%SC, and Imidacloprid had a significantly lower populations. In line with our findings, preliminary data from Queensland indicated that there are very few effective insecticides that will control thrips. Repeat applications will undoubtedly increase any residue levels within the crops and increase resistance on the thrips such as *F. occidentalis*. Marquini et al. (2002) found that imidacloprid sprays to the foliage gave up to 8 days control of T. tabaci. The literature has shown various thrips species to be susceptible to a wide range of insecticides (Marquini et al., 2002; Thoeming et al., 2006; Mo 2007; Nderitu et al., 2007); it is just a matter of getting the chemicals to where the thrips are hiding.

This is clearly a waste of time and money. Jianhua (2004) showed that Dimethoate was effective for adult thrips management. Thoeming et al. (2006) also investigated the systemic effects of neem against western flower thrips larvae on primary bean leaves and observed maximum corrected mortality of 50.6%. Pesticides neonicotinoid (Imidacloprid) interfere with nicotine acetylcholine receptors in the nervous system of insects (Yamamoto, 1996). The results agreed with Aslam et al. (2004), who discovered Confidor profoundly compelling against thrips. Further, the management of *T. tabaci* was also evaluated through agronomic practices in onion field by Khaliq et al. (2016), and Faircloth et al. (2002) also reported that cotton seedlings were more susceptible to thrips attack and observed the effect of insecticide treatment and environmental factors on thrips population, plant growth and yield of cotton. Besides, the eco-friendly management practices were necessary to keep pest population below economic damages by assuring safe mode to beneficial reported by (Khaliq et al., 2014).

The efficacy of the insecticide chemicals listed above and below resulted in good cost-benefit ratio for Cotton thrips management. Rectro20% SC (2.55), Closer240 % SC (1.93), Dimithioate40% EC (1.49) showed the insecticides have good comparative advantage. Still,

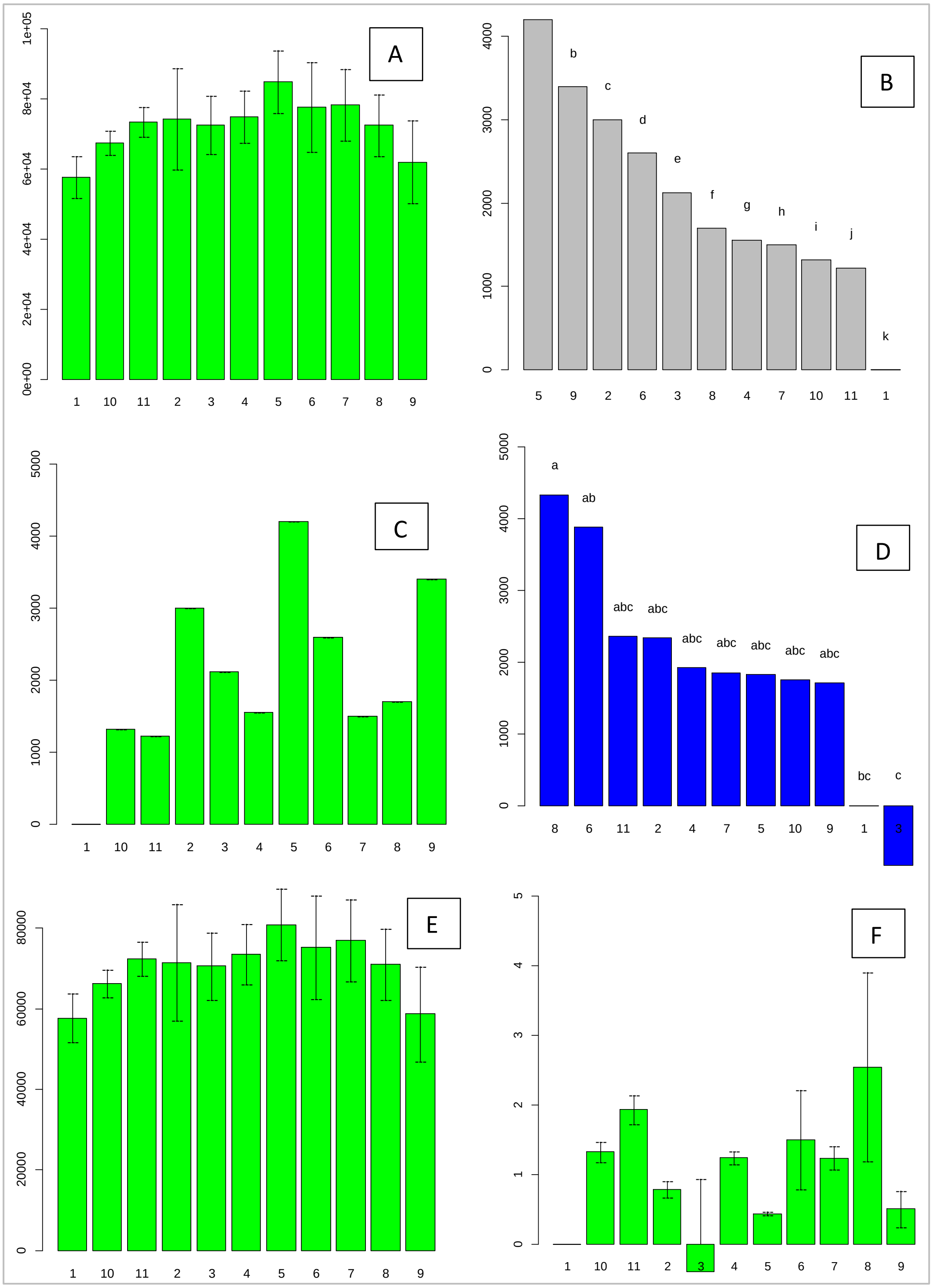

Figure 1. The economics of comparative return of insecticides Gross returns (ETB/ha) (A), Cost per ha (B), Net cost per ha(C), marginal benefit (D), net monetary return ETB (E), Cost-Benefit Ratio (F).
Source 2017 and 2018 field experiment results in Werer.

each birr investment to the protection of Cotton thrips using the insecticide Imdaclorópride twntysc, Chlorfenapyr, and Curador 45% EC would return 1.33, 1.24, and 1.24 birr. The management of T. tabaci was also evaluated through agronomic practices in onion field by Khaliq et al. (2016). Faircloth et al. (2002) also stated that cotton seedlings were more susceptible to thrips attack and observed the effect of insecticide treatment and environmental factors on thrips population, plant growth and yield of cotton. Besides, the eco-friendly management practices were necessary to keep pest population below economic damages by assuring safe mode that is beneficial (Khaliq et al., 2014). Sahito et al. (2017) observed the same kind of the research studied on comparative efficacy of novel pesticides against sucking complex as jassid on cotton crop under field conditions and found significant results ($p<0.05$). More work needs to be undertaken to look at what damage if any the different species of thrips do to bean pods. Growers are known to spray their crops when they find thrips in the flowers and if they know that *F. occidentalis* is one of these thrips then there is a clear need to apply a suitable insecticide, which is generally a spinosad spray.

CONCLUSIONS AND RECOMMENDATION

The results of the study on field efficacy showed that Rectro20% sc (2.55), Closer 240% SC (1.93), Dimithioate40% EC (1.49) showed good partial economic return advantage against Cotton thrips management. Closer 240 SC at 0.36 g a.i.L^{-1} was highly effective in controlling thrips in pomegranate, did not show any phytotoxic effects, relatively safer to natural enemies and realizing higher yield. Hence, it may be recommended for the management of thrips in pomegranate. This saves the farmer's yield and its value appreciably. The combined two years' data showed a significant yield increase in treatments, insecticides and botanicals, particularly the tree tobacco. Thus, it provides better and wide control options, locally available, ecologically sound and cost-effective solutions. The present study confirmed that the application of Imdaclorpride, 20%SC, Dimethoate 40% EC, Closer 240% EC and Rectro 20% EC resulted in good yield and economic returns with the lowest population density of thrips populations. Therefore, to alleviate the loss of yield due to thrips population these insecticides are recommended to farmers for the management of this pest in middle Awash. Future studies are needed to monitor the level of insecticide resistance and test botanical pesticides that are ecologically sound and cost-effective solutions.

The two years of research result indicates positive findings which reflect significant differences between the parameters that are of interest to the producers. The population dynamics of the pest in the controlled plots and overall pest population for first and second spray mean was higher. Thrips are consistent and predictable insect pests of seedling cotton with the dry spiel in the Awash valley during June and sometimes in September. Although a complex of species infests seedling cotton in the region, onion thrips are the predominant species requiring management in the crop. Control strategies rely heavily on chemical control used at planting. Cultural control strategies, such as the use of cover crops, reduced tillage operations, delayed planting date, targeted irrigation, and starter fertilizer, can complement chemical control likely help slow the population of thrips development. Producers and managers of cotton in Awash Valley should consider using a multi-tactic approach that uses several best management practices in an overall IPM approach for managing thrips. But insecticide management issues with insecticide resistance will still emerge, so it is better to consider candidates of insecticides that reduce resistance.

CONFLICT OF INTERESTS

The author does not have any conflict of interests.

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