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Management of Onion Thrips [*Thrips tabaci* Lind. (Thysanoptera: Thripidae)] on Onion Using Eco-Friendly Cultural Practices and Varieties of Onion in Central Zone of Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author GZ designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MW managed the analyses of the study. Author GA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Onion thrips, *Thrips tabaci* (Thysanoptera: Thripidae) is a major insect pest constraining onion production in the Central Zone of Tigray. Therefore, field experiment was conducted at Axum Agricultural Research from November 2015 to April 2016 to manage onion thrips using multiple techniques. The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement and replicated three times. Onion varieties Bombay Red and Nasik Red were used as main plot treatments and intercropping onion with one or two other vegetables including, cabbage, carrot and lettuce, as subplot treatments. Treating onion with the insecticide lambda-cyhalothrin (Karate) 5% EC and untreated sole onion were included as standard and control checks. Results showed that intercropping onion with cabbage, onion with cabbage + carrot and onion with cabbage + lettuce significantly reduced *T. tabaci* population by 58.47, 63.81 and

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50.51%, respectively at higher infestations. Similarly, intercropping onion with cabbage, onion with cabbage + carrot and onion with lettuce + carrot showed a better effect in reducing thrips damage severity by 23.37, 23.09 and 17.66%, respectively, at higher infestations. Predatory thrips were observed on onion intercrops except the Karate 5% EC treated check. The highest marketable onion yield (35.52 t/ha) was obtained from onion intercropped with carrot and lettuce, though not significantly different from the untreated check. The lowest (23.54 t/ha) was obtained from onion intercropped with cabbage + lettuce. However, onion intercropped with lettuce gave the highest gross income (307344 ETB/ha). The lowest gross income was recorded from the insecticide treated plot (194583 ETB/ha). The study clearly showed that intercropping onion with other vegetables reduced the number of onion thrips and their damage on onion in the central zone of Tigray and hence can form an integral component in the integrated management of thrips on onion.

Keywords: Carrot; lettuce; cabbage; intercropping; predatory thrips; lambda-cyhalothrin.

1. INTRODUCTION

Onion thrips (*Thrips tabaci)* is a phytophagous most invasive and vector insect pest of onion. It is considered to be the most economically important pest of onion worldwide [1]. If control measures are not practiced properly the pest may cause losses varying from 6 to 63% in weight depending up on genotype [2]. According to Tadele et al. [3] onion thrips is the most severe pests of onion and their allies that can totally destroy young plants.

In Ethiopia, it is an important insect pest that affect onion yield by direct feeding [4]. Onion fields can be destroyed by onion thrips, especially in dry seasons [5]. Tsedeke [4] and Bezawork [6] reported onion bulb yield losses of 33% and 26-57%, respectively due to onion thrips in Ethiopia. Similar studies at upper Awash Agro Industry Enterprises revealed yield losses of 10 to 85% due to onion thrips in Ethiopia [7]. In the study area even though the extent of damage on onion due to thrips has not been studied earlier, it is the most serious problem causing considerable yield losses. Onion producers expend additional costs for chemical purchasing even though, these chemicals were not effective against onion thrips.

Several non-chemical or cultural control methods of thrips were found effective in delaying or suppressing population of thrips on onion. Ibrahim et al. [8] and Diaz-Montano et al. [9] evaluated the effectiveness of botanical insecticides against onion thrips and obtained more than 60% suppression of onion thrips. Use of resistant cultivars such as onion cultivars with open growth nature, yellow-green, glossy to semi glossy leaf surfaces were less attractive to onion thrips [10]. Similarly, [11] and [12] reported that vegetable intercrops with onion were effective in onion thrips management with higher economic returns. The effects of these cultural methods of management were not evaluated in the study area and growers rely only on chemical insecticides for the management of thrips. Hence, the study was initiated to study the effect of intercropping onion with other vegetables on the management of onion thrips infesting onion.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

The experiment was conducted at Axum Agricultural Research Center (AxARC). The particular research site was Hatsebo which is 5 km east of Axum town. The study area is located at 14˚07'86.9"N latitude and 038˚46'08.3"E longitude with an altitude of 2101 m.a.s.l. It is located in northern part of the country in Central Zone of Tigray Region in the semiarid tropical belt of Ethiopia with "*weinadega*" agro climatic zone ("*weinadega*" means areas with medium altitude). This "*Weinadega*" is characterized by low and erratic rainfall with an average annual rainfall of 750 mm. The rainy season is mono-modal concentrated in one season from July to September. The long term mean maximum and minimum temperatures range from 24.4 (May) to 31.4˚C (June) and from 13.2 (July) to 8.7˚C (December), respectively. The soil type is classified as vertisol with a characteristic feature of clay soil type with P^H 7.5 to 8.3 [13].

2.2 Treatments and Experimental Design

The experiment was laid out in a randomized complete block design (RCBD) with split plot arrangement replicated three times. Two onion varieties Bombay Red and Nasik Red were used as main plot treatments. Intercropping onion with cabbage, carrot, lettuce and a combination of them (cabbage+carrot, cabbage + lettuce, carrot + lettuce) along with treating onion with the insecticide Lambda-cyhalothrin (Karate) 5% EC (at a rate of $1 Lha^{-1}$) and untreated control as checks were used as subplots. The plot size was 4.4 x 2 m, spacing between the main plots and the sub-plots were 2 and 1 m, respectively. Spacing between the furrow and ridges were 40 and 20 cm, respectively. The spacing between plants (intra-plant spacing) was 10, 40 and 20 cm for onion, cabbage and lettuce, respectively. A plot had 20 rows all planted with onion in the sole onion plots but only 10 alternative rows were planted with onion in the intercropped plots. Onion and the intercropped species were planted in the ridge in alternate rows each constituting ten rows. Carrot was sown directly by drilling on the corresponding rows in the experimental field.

2.3 Experimental Procedure and Field Management

Nursery Managements: Seeds of Bombay Red and Nasik Red were planted on November 01/2015 at a rate of 4.0 kg ha^{-1} with 95% germination [14] on 5x1 m well prepared seedbed for each of the variety. Onion varieties were sown spaced of 2 cm between seeds and 10 cm between rows. Cabbage and lettuce were seeded in a 5x1 m seed bed at the rate of $400gha^{-1}$ and 300 g ha^{-1}, respectively, on November 25/2015. Carrot was seeded on the main field at $5kgha^{-1}$ on the same date. Onion seedlings were managed in the nursery for 55 days, whereas cabbage and lettuce for 30 days only. All nursery management practices, such as mulching, watering, fertilizer application and weeding, were applied as per recommendation for raising vigorous and healthy seedling of each crop.

Transplanting: Seedlings were transplanted to the main experimental field when they attained 3-4 true leaves (on December 25/2015) by carefully uprooting them from nursery beds. One day before transplanting, the nursery beds were irrigated to ease uprooting of seedlings. During transplanting healthy, vigorous and uniform seedlings were transplanted and gap filling was made within a week after transplanting to maintain the desired plant population per plot. Carrot was directly sown on the rows allotted to it in the main field on November 25/2015. After germination thinning of crowded seedlings were done to maintain 5 cm spacing between plants.

Field Management: The field experiment was conducted at Axum Agricultural Research Center (AxARC) horticulture field. The field was ploughed using oxen and harrowed manually to bring the soil to fine tilth. Then the seedlings were transplanted to well prepared and irrigated experimental field. The field was furrow irrigated twice weekly in the first four weeks and weekly thereafter. Fertilizer Diammonium phosphate (DAP) was applied during transplanting at the rate of 100 kg ha^{-1} (18% N: 46% P_2O_5). But urea was applied at the rate of 100 kg ha^{-1} (46% N ha^{-1}) in split applications at transplanting and a month after transplanting [14]. Cultivation, weeding and all other agronomic practices, except chemical application, were performed as per the recommendation for onion production. Harvesting was done when plants attained physiological maturity. Lettuce was harvested starting 35 days earlier than onion but all plants were not picked at once. It was harvested continuously for three weeks. Cabbage was also harvested 15 days earlier than onion and carrot. Ten randomly tagged onion plants in each plot were used to measure number of thrips, incidence and severity of damage, number of predatory thrips and yield components of onion. All plants from each net plot area were harvested to record the marketable yield, total yield of onion and intercropped plants.

2.4 Data Collection

Data on number of thrips, infestation and damage severity were taken at 15 days intervals starting from a week after transplanting and continued until physiological maturity. Both nymphs and adults were counted by examination of the entire plant with the aid of 10x magnifying hand lens. Counting thrips was done during wind free time of the day normally, early in the morning and late afternoon.

The percent reduction of number of thrips/plant was calculated using the formula of Dutta et al.; [15]: percent thrips population reduction over untreated control =

$$\frac{(Mean\ of control - Mean\ of\ treatment)}{Mean\ of\ control} \text{x}100$$

Thrips infestation was calculated as a ratio of infested to total sampled plants (100 plants). Leaves of each randomly tagged standing plants were examined to assess severity on a scale of 1-5 based on (16) where 1 = no damage, 2 = up to 25%, 3 = 26-50%, 4 = 51-75% and 5 = >75% damage. Yield and yield component data were collected at physiological maturity, after harvesting and curing. Except the total yield, all data were taken from 10 randomly selected plants. Data on total yield and yield of intercrops were collected from the entire plot. Monetary return of each treatment was calculated based on the market price of the produce during harvest. The market price of onion, cabbage, lettuce and carrot in each treatment was converted into gross gain in ETB ha^{-1}. However, the additional cost of insecticide lambda-cyhalothrin and its application was subtracted from the gross return of onion in the treated standard check.

2.5 Data Analysis

Data were subjected to analysis of variance (ANOVA) using the PROC-GLM procedure of SAS version 9.1 (SAS Institute Inc., 2005) software. Differences among treatment means were separated using the Tukeys Studentized range test minimum significant difference (MSD) at 5% probability level.

3. RESULTS AND DISCUSSION

3.1 Effect of Intercropping on the Number of Onion Thrips on Onion

The number of *T. tabaci* per plant was low during the initial sampling periods, but progressively increased through time up to physiological maturity of onion. Thrips population was statistically similar in all treatments up to 15 days after transplanting (DAT). This might be the result of the stage of development of the premature intercropped species to render any notable effects on thrips population. However, from 30 DAT onwards, onion intercropped with vegetables had significantly ($P < 0.01$) lower thrips population than the plots treated with lambda-cyhalothrin and untreated onion sole crops (Table 1). Onion varieties had no significant difference ($P > 0.05$) on the number of onion thrips (Table 3).

Intercropping onion with cabbage, onion with cabbage + carrot, onion with carrot + lettuce, onion with cabbage + lettuce and onion with carrot highly significantly ($P < 0.01$) reduced the number of thrips per plant by 58.47, 63.81, 46.10, 50.51, and 28.16%, respectively at 60, 75 and 90 DAT (Table 2). The highest reduction of thrips population and damage (63.81%) was in onion intercropped with cabbage + carrot. The number of thrips was decreased in all treatments 115 DAT. This might be due to the full maturity of the crop and occurrence of unusual rainfall. Up to three Predatory thrips (*Aeolothrips Spp)* per plant was observed on onion intercropped plots and but were totally absent in the chemical treated plots because of the adverse differential effect of the insecticide on the natural enemies.

The intercropping treatments significantly reduced onion thrips per plant compared to chemical treated and untreated sole cropping. This could be due to plant volatile chemicals, the visual and physical interference by the mixed crop species. The companion plants act as physical barriers to the movement of the insect pest and provide food and shelter for predators. The chemical or visual communication between thrips and onion was also disrupted. The intercropped species acted as trap crops as cabbage collected up to 64 onion thrips per single leaf. The presence of multiple plants probably interfered with an insect's ability to detect host plant by physical masking of the host plant or by producing volatiles that confuse the insect.

In this study the highest number of *T. tabaci* per onion plant was recorded on insecticide treated (mean number of thrips per plant 205.83) compared to the untreated check and intercropped treatments. This could indicate the development of resistance to the insecticide lambda-cyhalothrin in pest thrips. However, due to the adverse effect of the insecticide on natural enemies there was no single predatory thrips recorded on onion sprayed with lambda-cyhalothrin. The onion monoculture year after year and repeated application of Lambda-cyhalothrin contributed to the failure of the insecticide to kill the pest. It is already established fact that use of persistent and broad spectrum pesticides kills differentially beneficial natural enemies. This caused pest resurgence, which was the rapid reappearance of a pest population in injurious numbers following pesticide application.

Various researchers reported the effects of intercropping on thrips population reduction. Hossain et al. [12] reported that intercropping onion with carrot and tomato significantly reduced thrips population by up to 52.42% and 48.84%, respectively. Intercropping of spider plant (*Chlorophytum comosum*) and carrot significantly ($P \leq 0.01$) reduced thrips population on three onion varieties (Bombay Red, Red Creole and Orient F1), with the spider plant resulting in the highest reduction up to 45.2% [11]. Intercropping reduced pests attack since the non host crop acted as physical barriers to the movement of insect pests [16]. Smith and Liburd [17] stated that when an herbivore encounters a plant it cannot feed on, it must expend additional time and energy searching for an acceptable plant. This reduces the time and energy of the insect that damage crop or deposit offspring and in some instances discourages and forces the insect to migrate from the area.

According to Baidoo et al. [18], the diagnostic dose bioassays showed that 15 of 16 field collected onion thrips populations were resistant to lambda-cyhalothrin, 8 of 16 were resistant to diazinon and all were resistant to deltamethrin. These results indicated that insecticide resistance is a wide spread problem in onion thrips. Similar to the current study, at Upper Awash and Ziway areas in Ethiopia, onion thrips had developed resistance to the insecticide Lambda-cyhalothrin and onion producers were forced to shift to other insecticides, such as selecron to manage onion thrips. Bezawork [6] reported that the performance of lambda-cyhalothrin was lower than selecron and botanical treatments in the experiment carried out at Shoarobit (Ethiopia) in 2003 and 2004.

In the current study, intercropping of onion with cabbage had a mutual effect on insect pest reduction. Very few numbers of cabbage aphids and diamondback moth were observed on cabbage compared to cabbage monocropping in the nearby farmer’s field. Similarly, Smith et al. [16] stated that significantly lower numbers of *Brevicoryne brassicae* on the intercropped plants was attributed to the confusing olfactory and visual cues offered by onion which reduced their ability to disperse. MacIntyre et al. [19] reported that intercropping cabbage with garlic and onion significantly reduced the populations of aphids on cabbage. The odor from onion is able to repel diamondback moth (*Plutella xylostella*) from settling on cabbage when onion was used as an intercrop. Garlic and onion produce a pungent alliaceous compound, allyl-epropyl-disulphide, which is responsible for its pest repellance attribute [20].

Table 1. Effect of intercropping on the number of *T. tabaci* (mean number of thrips per plant)

Intercropping onion with	(Days after transplanting)						
	15	30	45	60	75	90	115
Cabbage	11.62^{a}	11.1^{d}	29.45^{c}	60.02^{e}	60.93^{de}	68.73^{ef}	23^{d}
Carrot +lettuce	13.47^{a}	15.25^{cd}	31.27^{bc}	74.57^{d}	67.27^{de}	89.20^{d}	35.60^{c}
Untreated	15.63^{a}	23.18^{b}	46.20^{b}	92.60^{b}	127.73^{b}	165.50^{b}	51.97^{b}
Lettuce	15.07^{a}	17.08^{bcd}	39.48^{bc}	82.45^{c}	94.80^{c}	112.13^{c}	52.37^{b}
Lamdacyhalothrin	14.85^{a}	32.30^{a}	64.07^{a}	122.60^{a}	169.50^{a}	205.83^{a}	80.83^{a}
Cabbage +carrot	11.30^{a}	13.25^{dc}	29.75^{bc}	72.55^{d}	58.27^{e}	59.90^{f}	21.67^{d}
Cabbage +lettuce	12.27^{a}	18.38^{bc}	38.45^{bc}	73.02^{d}	92.43^{c}	81.90^{de}	35.50^{c}
Carrot	14.70^{a}	16.30^{bcd}	34.67^{bc}	77.47^{dc}	80.07^{dc}	118.9^{c}	26.87^{dc}
MSD($p \leq 0.05$)	5.52	7.16	16.71	7.34	21.53	4.34	9.98
CV (%)	19.92	19.14	20.95	4.4	11.26	6.21	11.95

MSD (5%) =Minimum significant difference at P ≤ 0.05, CV (%) = Coefficient of variation in percent. Means in columns with the same letter(s) are not significantly different at 5% level of significance using Tukeys Studentized range test

Table 2. Number of *T. tabaci* reduction (%) over control

Intercropping onion with	Days after transplanting						
	15	30	45	60	75	90	115
Cabbage	26.65	52.11	36.25	35.18	52.29	58.47	55.74
Carrot +lettuce	13.82	34.21	32.32	19.47	43.33	46.1	31.49
Untreated	-	-	-	-	-	-	-
Lettuce	3.58	26.32	14.54	10.96	25.78	32.25	-
Lamdacyhalothrin	-	-	-	-	-	-	-
Cabbage +carrot	27.7	42.84	35.61	21.65	54.38	63.81	58.3
Cabbage +lettuce	21.49	20.71	16.77	21.14	27.64	50.51	31.69
Carrot	5.95	29.68	24.96	16.33	37.3	28.16	48.29

Table 3. Effect of onion varieties on the number of *T. tabaci*

Varieties	Days after transplanting						
	15	30	45	60	75	90	115
Nasik Red	13.37[a]	17.95[a]	38.54[a]	81.87[a]	94.21[a]	113.28[a]	41.12[a]
Bombay Red	13.86[a]	18.76[a]	39.79[a]	81.94[a]	93.54[a]	112.25[a]	40.83[a]
MSD(P≤0.05)	1.68	2.17	5.08	2.23	6.54	4.34	3.03
Significance level	NS	NS	NS	NS	NS	NS	NS

MSD (5%) =Minimum significant difference at P ≤ 0.05, NS = No significant difference at P> 0.05

Table 4. Effect of intercropping onion with other vegetables on thrips damage severity scale 1-5

Intercropping onion with	Days after transplanting						
	15	30	45	60	75	90	115
Cabbage	1.10[c]	1.28[e]	1.52[d]	2.25[e]	2.68[d]	2.82[e]	2.8[e]
Carrot+lettuce	1.23[bc]	1.38[de]	1.52[d]	2.27[e]	2.88[cd]	3.03[de]	2.97[de]
Untreated	1.53[a]	1.87[ab]	2.38[a]	3.03[b]	3.35[b]	3.68[b]	3.58[b]
Lettuce	1.32[b]	1.82[bc]	2.08[b]	2.75[c]	3.28[b]	3.43[bc]	3.32[bc]
Lamda-cyhalothrin	1.58[a]	2.10[a]	2.65[a]	3.4[a]	4.03[a]	4.28[a]	4.15[a]
Cabbage+carrot	1.13[bc]	1.22[e]	1.62c[d]	2.38[e]	2.75[d]	2.83[e]	2.85[de]
Cabbage +lettuce	1.30[bc]	1.62[cd]	1.85[bc]	2.63[cd]	3.22[bc]	3.27[cd]	3.13[dc]
Carrot	1.23[bc]	1.53[d]	1.63[cd]	2.43[de]	3.05[bcd]	3.13[d]	3.02[de]
MSD(p<0.05)	0.2	0.25	0.29	0.23	0.37	0.29	0.29
CV%	7.66	7.62	7.52	4.28	5.76	4.31	4.53

MSD (5%) =Minimum significant difference at P ≤ 0.05, CV (%) = Coefficient of variation in percent. Means with the same letter(s) within a column are not significantly different at 5% level of significance using Tukeys Studentized Range Test

Table 5. Thrips damage severity reduction (%) over control

Intercropping onion with	Days after transplanting						
	15	30	45	60	75	90	115
Cabbage	28.1	31.55	36.13	25.74	20	23.37	21.79
Carrot+lettuce	19.61	26.2	36.13	25.08	14.03	17.66	17.04
Untreated	-	-	-	-	-	-	-
Lettuce	13.72	2.67	12.6	9.24	2.09	6.79	7.26
Lamda-cyhalothrin	-	-	-	-	-	-	-
Cabbage+carrot	26.14	34.76	31.93	21.45	17.91	23.09	20.39
Cabbage +lettuce	15.03	13.37	22.27	13.2	3.88	11.14	2.57
Carrot	19.61	18.18	31.51	19.8	8.95	14.94	15.64

3.2. Effect of Intercropping on Thrips Infestation and Damage Severity on Onion (%)

The analysis of variance showed that thrips damage severity was highly significant ($P < 0.01$). It was lower on onion intercropped with vegetables than both treated and untreated onion sole crops (Table 4). However, thrips incidence was not significantly affected by both varieties and intercropping (Table 6). Thrips damage severity was low during the first sampling (15 DAT) but increased gradually over time on the onion crop. However, thrips infestation was high from the first week of sampling and remained high until the physiological maturity. Intercropping onion with cabbage, onion with cabbage + carrot, onion with lettuce + carrot, and onion with carrot had highly significantly ($P < 0.01$) lower thrips damage severity than onion sole cropping. Intercropping onion with cabbage, onion with cabbage + carrot, onion with lettuce + carrot and onion with carrot showed a better effect in reducing thrips damage severity by 36.13, 31.93, 36.13 and 31.51% at 45 DAT and 23.37, 23.09, 17.66 and 14.94% at 90 DAT, respectively (Table 5).

Intercropping played an important role in reducing thrips damage severity by decreasing the number of onion thrips population. This was due to the physical, visual, and chemical interferences in addition to conserving more natural enemies. The highest thrips damage severity was recorded on onion treated with the insecticide lambda-cyhalothrin through time up to physiological maturity. 75% of the onion leaves were damaged on the insecticide treated plots ((mean scale = 4.28) (Table 4)). This could be due to the highest number of infestation (205.83 onion thrips) per plant (Table 1). Onion thrips feeding damage results in leaf tissue silvering and photosynthesis reduction, leading to bulb size reduction and yield loss.

The significant effect of intercropping on thrips damage severity reduction in the present study was in line with other findings. Hossain et al. [12] reported that intercropping onion with vegetables; carrot, tomato and french bean had significantly reduced thrips damage severity on onion. Similarly, [11] observed intercropping onion with carrot, french bean and spider plant that significantly reduced thrips damage severity on onion. Trdan et al. [21] studied intercropping against onion thrips and observed that the least damage was recorded on the onions intercropped with buckwheat (*Fagopyrum* spp) and *Lacy phacelia*.

3.3 Effect of Intercropping on Yield and Yield Components of Onion

The highest bulb diameters, 6.26 and 6.15 cm were recorded on onion intercropped with lettuce + carrot and carrot, respectively. Similarly, the highest bulb length (4.71 cm), bulb weight (116.49 g) and biomass weight (121.28 g) per plant were recorded on onion intercropped with carrot only. These parameters were also the highest on onion intercropped with carrot + cabbage but not significantly different (P > 0.05) from the untreated control. Onion intercropped with cabbage, onion with lettuce and onion with cabbage + lettuce gave the smallest bulb length, bulb diameter, bulb weight and biomass weight per plant compared to the untreated control (Table 7). This could be due to competition for nutrients, water and light. Similarly, the smallest measurements of bulb length, bulb diameter, bulb weight and biomass weight of 4.21 cm, 5.39 cm, 76.19 and 81.41 g, respectively were observed on insecticide treated onion sole cropping. This might be due to the highest thrips population that severely damaged the crop. Overall there was no significant difference (P > 0.5) in the yield and yield contributing characters of onion between Nasik Red and Bombay Red varieties. The two varieties have the same productivity potential (30 t/ha) by SAS [14].

Onion Intercropped with carrot+ lettuce and onion with carrot gave statistically similar marketable bulb yield of 35.52 and 31.87 t/ha, respectively compared with the untreated check (34.21 t/ha). The lower onion marketable yield, were recorded on intercropping onion with cabbage+ lettuce, onion with cabbage and onion with cabbage+ carrot with yields of 23.54, 24.53 and 26.77 t/ha, respectively, followed by the insecticide treated onion (27.76 t/ha) compared to the untreated check. The reduction in yield in the intercropping treatments could be due to competition for light, nutrient and water. There might be also a shading effect; the lowest bulb yield was recorded in onion intercropped with large canopy plants cabbage+ lettuce. The onion marketable yield reduction in the current study concurs with findings reported by other researchers. Hossain et al. [12] observed onion yield reduction in intercrops of onion with carrot, tomato and french bean compared to that of insecticide treated and untreated onion monocropping. Axum [11], working on onion intercropping with spider plant and carrot,

Table 6. Effect of intercropping onion with other vegetables on thrips infestation (%)

Intercropping onion with	Days after transplanting						
	15	**30**	**45**	**60**	**75**	**90**	**115**
Cabbage	92	95	98.83	99.67	100	100	100
Carrot+lettuce	93.5	95.33	99.17	99.67	100	100	100
Untreated	93.67	95.83	99.5	100	100	100	100
Lettuce	92.5	95.5	99.17	99.33	100	100	100
Lamda-cyhalothrin	93.5	96.33	99.67	100	100	100	100
Cabbage+carrot	92.67	95.83	99	99.83	100	100	100
Cabbage +lettuce	92.67	95.83	99	99.5	100	100	100
Carrot	93.5	95.83	99	100	100	100	100
Significance level	NS	NS	NS	NS	NS	NS	NS

NS=No significant difference (P > 0.05) on thrips infestation

Table 7. Effect of intercropping on yield and yield components of onion

Intercropping onion with	Bulb length (cm)	Bulb diameter (cm)	Bulb weight (g)	Biomass yield (g)	Marketable bulb yield (t/ha)	Gross return (ETB/ha)
Cabbage	4.55[ab]	5.75[abc]	88.40[cde]	93.91[cd]	24.53[c]	281823[ab]
Carrot +lettuce	4.69[a]	6.26[a]	111.77[ab]	115.82[ab]	35.52[a]	278138[b]
Untreated	4.39[bc]	5.52[bc]	89.87[cd]	92.61[cd]	34.21[a]	239714[c]
Lettuce	4.43[bc]	5.39[c]	90.17[cd]	94.88[cd]	28.17[bc]	307344[a]
Lamdacyhalothrin	4.21[c]	5.39[c]	76.19[e]	81.41[d]	27.76[bc]	194583[d]
Cabbage+carrot	4.69[a]	5.99[ab]	100.22[bc]	104.59[bc]	26.77[bc]	300990[ab]
Cabbage+lettuce	4.39[bc]	5.53[bc]	83.19[de]	87.87[d]	23.54[c]	306341[a]
Carrot	4.71[a]	6.15[a]	116.49[a]	121.28[a]	31.87[ab]	232266[c]
MSD(p<0.05)	0.24	0.55	12.75	16.66	5.29	28196
CV (%)	2.61	4.68	6.62	8.26	8.93	5.17

MSD (5%) =Minimum significant difference at (P ≤ 0.05), CV (%) = Coefficient of variation in percent. Means with the same letter(s) within a column are not significantly different at 5% level of significance using Tukey. The Gross return ETB/ha was calculated from the yield obtained from each crop multiplied by its field price value at harvesting time. Onion 7 birr/kg, cabbage 3.50 ETB /kg, lettuce 1.75 ETB /plant, carrot 8 ETB /kg and the cost of insecticide (500 ETB/l) and its total application cost (420 ETB) was subtracted from the insecticide treated treatments reported that intercropping onion with carrot and spider plant significantly ($P < 0.05$) reduced onion bulb yield. Kabura et al. [22] indicated that onion planted as a monocrop had higher total and marketable yield than the onion-pepper intercrop. Intercropping onion with *Lacy phacelia* also resulted in reduced onion yield [21]. The marketable yield reduction in onion was compensated by yield of the vegetables.

In the current study, the highest gross income per unit area was recorded on onion intercropping compared to onion treated and untreated sole cropping (Table 7). Onion intercropped with lettuce and onion with lettuce + cabbage gave significantly ($P < 0.01$) higher gross income 307,344 and 306,341 ETB ha^{-1} respectively, followed by onion intercropped with cabbage + carrot 300,990 ETB ha^{-1}. This could be due to the diverse species within the same plot that had different prices at the harvesting season. However, the lowest gross return per hectare was recorded from the insecticide treated control 194,583 $ETBha^{-1}$. Intercropping onion with vegetables had value addition over the onion sole cropping and diversifies the production and decreases the cost of production.

Similar to the present findings, [12] concluded that intercropping of onion with carrot or tomato was suitable for the management of onion thrips infesting onion with higher economic return. Aswathanarayanareddy et al. [23] indicated that chili intercropped with onion, garlic, brinjal, bhendi, marigold, maize and beans were significantly superior, to others with lesser infestation of whitefly, thrips, aphids, jassids, and pod borers with higher yield than sole crop of chili.

4. CONCLUSION

The study showed that onion-vegetable intercropping significantly reduced *T. tabaci* population and thrips damage severity. On the other hand, it enhanced thrips natural enemies and the gross gain per hectare (production per unit area). The highest *T. tabaci* population percentage reduction was obtained from onion intercropped with cabbage + carrot (63.81%) and onion with cabbage only (58.47%). Predatory thrips *(Aeolothrips sp.)* were observed on onion intercropped plots and were totally absent in the chemical treated plots. Therefore, the onion-vegetable intercropping practice is suitable in onion production, especially for small-scale farmers who do not have adequate resources for purchasing insecticides. This system would also be very ideal for integrated pest management with organic vegetable production, in which chemical application is required and also avoids human and environmental hazards due to pesticides. Growing of multiple crops in intercropping system reduced insect pests, encouraged beneficial insect population, and increased the productivity per unit of land. It allowed crop diversification as well as reduced financial risk in the event of crop failure.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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