Evaluation of intercropping for the management of onion thrips (*Thrips tabaci*) at Ribb and Koga irrigation schemes in Western Amhara, Ethiopia

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Abstract:

Field experiments were conducted in 2013/14 and 2014/15 cropping seasons to evaluate different spatial arrangement of intercrops such as carrot (*Daucus carota*) and snap bean (*Phaseolus vulgaris*) with onion for the management of onion thrips (*Thrips tabaci*) on onion. Thrips damage incidence was determined in percentages and severity estimated on a scale of 1-5. Unmarketable and marketable bulb yield was determined at physiological maturity. All agronomic managements were equally applied to all plots and data were collected and subjected to analysis of variance using SAS statistical software and significant treatment mean differences were separated by using least significance difference at 5% significance level. All spatial arrangements of intercropping onion with snap bean and carrot significantly ($p \leq 0.05$) reduced thrips population by up to 54% at Koga and 76% at Rib; consequently the two intercrops did significantly ($p \leq 0.05$) reduced thrips damage severity at both locations. Intercropping onion with carrot and snap bean significantly ($p \leq 0.05$) increased marketable onion bulb yield at Koga and Rib, whereas the effect of these intercrops on unmarketable yield didn't show significant ($p > 0.05$) difference at Rib. Hence a 1:2 spatial arrangements of onions with snap bean and 1:3 of onion and carrot can be utilized in the management of onion thrips.

Keywords: Damage levels, Population, Spatial arrangement, Thrips

INTRODUCTION

Onion (*Allium cepa* L.) is one of an important vegetable produced across a wide range of latitudes in Africa, Asia, Europe and North America (Rabinowitch and Currah 2002). In Ethiopia, small-scale farmers grow onions and supply to the domestic market (CSA 2013).

Consumption of onions has been increasing significantly in the world partly because of the health benefits onions possess (Havey et al. 2004, Wang et al. 2006). Onions are also rich in flavonoids and alkenyl cysteine sulphoxides which play a part in preventing heart disease and other ailments in humans (Gareth et al. 2002, Havey et al. 2004, Javadzadeh A., et al. 2009).

Major factors limiting onion production are diseases and insect pests (Rabinowitch and Currah 2002, Muendo and Tschirley 2004). Onion thrips (*Thrips tabaci*) which is considered to be the most economically important pest of onion worldwide (Trdan et al. 2005) is responsible for causing considerable reduction in yield (Brewster 1994, Nawrocka 2003, Trdan et al. 2005). In Ethiopia, thrips are present in all onion growing areas and can cause up to 37% loss in yield (Waiganjo et al. 2008). Previous studies (Abate, 1986) showed that thrips numbers were highest in the hotter parts of the year (February through April), and lowest in the rainy seasons (June through August). Yeshitila Merene (2005) studied the population fluctuation of the onion thrips in 2004 in the northeastern part of the Amhara region, and reported a similar result. The population density of thrips was low during the rainy and cooler months of August to November and high during the months of February to April.

Currently, growers manage thrips by applying insecticides several times in a growing season. However, most insecticides are ineffective because a large number of thrips are always protected between the inner leaves of the onion plant and the pupal stage is hidden in the soil. In addition, *Thrips tabaci* is a very prolific species with many overlapping generations (Nault and Shelton 2010, Alimousavi et al. 2007, Shelton et al. 2006). It was reported that the efficacy of insecticides to control thrips was declining through time (Tsedeke Abate, 1983; Tsedeke Abate and Gashawbeza Ayalew, 1994; Gashawbeza Ayalew, 2005).

Development of resistance by onion thrips to most commonly used insecticides has been reported (Martin et al. 2003). Besides increasing the cost of production, the use of pesticides has negative effects on the environment and human health which is attributed to high chemical residues (Burkett-Cadena et al. 2008). Therefore, there is need to integrate the use of chemicals with other methods of control such as cultural practices (Dejene 2006) and use of resistant varieties in the management of thrips and other pests of onion. One sustainable method of managing pests is intercropping (Trdan et al. 2006, Finckh and Karpenstein-Machan 2002), a system in which a plant species (the intercrop) is grown specifically to reduce pest damage on a main crop. Intercropping is an important cultural practice that has been utilized in the management of weeds, insect pests and diseases in many crops worldwide (Trdan et al. 2006, Finckh and Karpenstein-Machan 2002). It is traditionally practiced by subsistence farmers in developing countries as a crop production system (Sodiya et al. 2010). The system is characterized by minimal use of pesticides and increases land productivity (Ullah et al. 2007). However, there are limited studies done in Ethiopia on management of thrips in onions using different spatial arrangement of intercrops. This study was therefore undertaken to evaluate the effectiveness of different spatial arrangements of intercrops for the management of thrips in onions fields.

MATERIALS AND METHODS

Experimental Design and Layout

Field experiments were carried out under irrigation conditions (November to April) at Koga and Rib irrigation schemes for two warm growing seasons 2013/14 and 2014/15. Treatments consisted of three different spatial arrangements (1:1, 1:2 and 1:3) of intercrops carrot *(Daucus carota*) and snap beans *(Phaseolus vulgaris*). Controls consisted of pure stands of onion variety Bombay red.

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Plot size was 5 m * 6 m; spacing between plots was 1 m and between blocks was 1.5 m. On each plot where intercropping was done, one row of onion was alternated with one to three rows of intercrop with a spacing of 30 cm * 10 cm for onion, 45 cm * 10 cm for carrot, 45 cm * 20 cm for snap bean.

Assessment of Thrips Population and Damage

Assessment of thrips population was done by random destructive sampling of 5 plants per plot from the border rows of each plot. Silvery patches characteristically caused by thrips on onion leaves were used to assess thrips damage starting from the fourth week after transplanting to physiological maturity of the crop (four times). Incidence of thrips damage was determined by counting the number of damaged plants over the total number of plants per one row segment on three central rows per plot. Thrips damage severity was determined by randomly sampling ten plants from the inner rows of each plot. The percentage of leaf surface showing thrips damage was assessed based on a scale of 1 - 5 (Smith et al. 1994) where 1 = no damage, 2 = up to 25%, 3

= 26-50%, 4 = 51-75% and 5 = >75% damage. Leaf width (mm) were measured at full growth stages of the crop, whereas plant height (cm) was measured two times at vegetative and harvest stage, by taking samples from the inner rows.

Assessment of Bulb Yield

Harvesting was done by hand at physiological maturity when 50-80% of the foliage had fallen over and the tops and roots were cut off. The bulbs from each plot were weighed and marketable bulbs that were greater than 3 cm diameter separated and graded. Bulb length and diameter (mm) were measured at harvest time. The bulb yield for each spatial arrangements of intercrop treatment was converted into quintal per hectare.

Data Analysis

Data was checked for its distribution before statistical analysis. Analysis of variance (ANOVA) was performed using SAS 9.1.3 software package. Treatment means were separated using the Fisher's protected LSD test at 5% probability level. Regression analysis was made to find the relations of thrips population with yield and other associated parameters using SAS and the Minitab 14.

RESULTS AND DISCUSSION

Thrips Population

All intercropping with their respective spatial arrangements' significantly ($p \leq 0.01$) reduced thrips population at both locations Koga and Rib (Table 1). At Koga, the minimum thrips population of about 45% was observed on carrots (ratio 1:3) and about 44% on snap beans (ratio 1:1). At Rib, it was 44% and 56%, respectively (Table 1), the trend was similar at both locations. Previous reports suggest similar trends (Alamu et al. 2002). Intercrops reduce population of pests, preserve beneficial insects, reduce labor costs, control weeds and stabilize yields. Otherwise when temperatures are high, *Thrips tabaci* is a very prolific species with overlapping generations per season (Bergant et al. 2005; Alimousavi et al. 2007).

Table 1. Effect of spatial arrangements' of intercrops on mean number of thrips per sampled plants and their associated damages (%)

Spatial arrangements'	Thrips population		Incidence (%)		Severity	
	Koga	Rib	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	48.70[c]	55.67[bc]	20.07[B]	4.67[b]	3.67[b]	3.67[b]
1 : 2/ Onion : Carrot /	45.27[c]	57.93[bc]	35.42[B]	7.33[b]	3.00[c]	2.67[cd]
1 : 3/ Onion : Carrot /	44.80[c]	43.73[c]	22.43[B]	5.33[b]	2.00[d]	2.00[d]
1 : 1/Onion : Snap bean/	43.77[c]	56.40[bc]	23.61[B]	6.00[b]	3.33[bc]	3.00[bc]
1 : 2/Onion : Snap bean/	67.27[b]	69.20[b]	16.53[B]	6.33[b]	3.00[c]	2.67[cd]
1 ; 3 /Onion : Snap bean/	56.07[bc]	59.53[b]	20.07[B]	5.33[b]	2.00[d]	2.00[d]
Sole onion	88.40[a]	126.13[a]	63.75[A]	18.67[a]	5.00[a]	5.00[a]
CV (%)	17.60	19.79	38.12	37.85	9.40	12.59
Significance	***	***	**	***	***	**

*Where: *** = showed highly significant difference, values with the same letter showed no significant differences at P=0.05*

Relatively high temperatures and lack of rainfall have been associated with increase in onion thrips population, while high relative humidity and rainfall reduce thrips population (Hamdy and Salem, 1994). However, this study showed that intercropping onion with snap bean and carrot significantly reduced thrips population. Maximum (63.46 and 58.75 %) protection were recorded on 1:3 spatial arrangements' of carrots at Koga and Rib respectively (Table 2).

Table 2. The relative efficacy (%) of spatial arrangements of intercrops on the reduction of thrips population

Spatial arrangements of intercropping	Locations	
	Koga	Rib
1 : 1/Onion : Carrot/	49.07	22.93
1 : 2/ Onion : Carrot /	50.67	36.54
1 : 3/ Onion : Carrot /	63.46	58.75
1 : 1/Onion : Snap bean/	54.07	21.69
1 : 2/Onion : Snap bean/	51.24	34.40
1 : 3 /Onion : Snap bean/	76.13	54.86
Sole onion	-	-

This could have been due to visual and physical interference of thrips by the intercrops. Physical interference could cause attraction of thrips to intercrops instead of onions thereby resulting in reduction of their population on onions (Alston and Drost 2008, Trdan et al. 2006). Carrot foliage hide the onions from thrips view (Uvah and Coaker, 1984). Thrips injury to intercrops is not as economically damaging as injury to onions (Alston and Drost 2008). The reduction could also be attributed to reduced food concentration in a mixed ecosystem with non-host plants thereby reducing the rate of multiplication of thrips. Ramert and Lennartson (2002) reported that insects are attracted to and concentrated on their food plant resources which are more apparent in a simple monoculture system.

Damage Variables

Incidence: Silvery patches on experimental plants were considered as damage symptoms of thrips. All intercropping arrangements significantly ($p \leq 0.01$) reduced thrips damage incidence at both locations; the sole grown onion gave the highest damage incidence of about 18%. This may be associated with the thrips population per plant during the growing stage of the crop (Table 1).

Severity: Similarly, intercropped plots had significantly lower thrips damage severity (Table 1). At both locations, the highest mean severity of 5% was recorded on sole grown plants. The significant differences in thrips damage severity among the treatments indicates that the level of the ratio of the spatial arrangements of intercrops with onions and its influences on thrips population. Muthomi J.W. et al., (2012) reported that the three vegetable (Carrot, French bean and Spider plant) intercrops significantly ($p \leq 0.05$) reduced thrips damage severity, with spider plant having the greatest reduction of up to 15.7%.

Plant Growth and Development

Plant height: At Koga, plant height was significantly varied between treatments at harvest, but not at the vegetative stage. A minimum height (45.47 cm) was recorded on plots that received no intercrops. However there was no significant difference obtained between spatial arrangements' of intercrops (Carrot and Snap bean) except a 1:3 /Onion: Snap bean/ at harvest stage at Koga irrigation scheme. At Rib, it was significant regardless of plant growth stage, however a minimum heights (38.83, 42.63 cm') were recorded on sole planted onions than the intercropped followed by a 1:1/Onion: Carrot/ which was (46.03, 51.80 cm'), maximum height (53.47, 62.23 cm') were recorded on plots that received a 1: 3 /Onion: Snap bean/ spatial arrangements' of intercrops at vegetative and harvest respectively (Table 3).

Table 3. Effect of spatial arrangements' of intercrops on plant height (cm) of onions

Spatial arrangements'	Vegetative stage		Harvest stage	
	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	43.80	46.03^{bc}	52.93^{a}	51.80^{b}
1 : 2/ Onion : Carrot /	38.93	46.27^{ab}	51.80^{a}	55.87^{ab}
1 : 3/ Onion : Carrot /	42.60	51.00^{ab}	52.53^{a}	56.00^{ab}
1 : 1/Onion : Snap bean/	43.33	48.33^{ab}	53.20^{a}	55.47^{ab}
1 : 2/Onion : Snap bean/	40.60	48.47^{ab}	52.47^{a}	54.93^{ab}
1 : 3 /Onion : Snap bean/	38.87	53.47^{a}	49.47^{ab}	62.23^{a}
Sole onion	32.00	38.83^{c}	45.47^{b}	42.63^{c}
CV (%)	11.22	8.65	5.11	9.41
Significance	NS	*	*	*

*Where: values with the same letter showed no significant differences at P=0.05, NS = stands for non- significance * = stands for significant*

Yield and Yield Components

Bulb size: Generally, onions grown in intercrops had higher bulb length and bulb diameter than sole grown onions at both locations (Table 4). At Koga, bulb length was statistically the same in all intercrop combinations. However at Rib, plots intercropped with carrots had less bulb length. Bulb diameter was more or less the same in all intercrop combinations at Koga. However at Rib, 1:3 ratio of carrots and snap beans had significantly higher bulb diameter.

As Haider Karar *et.al*.,(2014) reported, maximum population 160.2/ plant, bulb weight 27.0 g and bulb diameter 7.0 mm were recorded from unprotected plots. Whereas, in case of protected plots the population remained 12.2 /plant, bulb weight 40.9 g and bulb diameter was 13.8 mm.

Table 4. Effect of spatial arrangements' of intercrops on the bulb sizes of onions

Spatial arrangements'	Bulb lengths(mm)		Bulb diameter (mm)	
	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	53.00^{ab}	52.40^{c}	33.17^{ab}	53.73^{b}
1 : 2/ Onion : Carrot /	58.80^{a}	54.20^{bc}	33.19^{ab}	56.80^{b}
1 : 3/ Onion : Carrot /	56.93^{a}	59.43^{a}	34.41^{a}	61.70^{a}
1 : 1/Onion : Snap bean/	56.20^{a}	57.73^{ab}	33.87^{a}	49.60^{c}
1 : 2/Onion : Snap bean/	58.13^{a}	56.67^{abc}	33.32^{ab}	56.47^{b}
1 ; 3 /Onion : Snap bean/	53.00^{ab}	54.60^{abc}	31.24^{bc}	61.53^{a}
Sole onion	48.80^{b}	40.77^{d}	30.67^{c}	45.63^{d}
CV (%)	6.23	5.32	3.98	3.84
Significance	*	***	*	***

*Where: values with the same letter showed no significant differences at P=0.05, * = stands for significant & *** = stands for highly significant*

Bulb yield: At Koga, plots intercropped with 1:2 of snap bean and 1:3 carrot gave significantly higher marketable yield than sole grown onions (Table 5). Other combinations did not vary significantly. At Rib, 1:3 ratios of both intercrops had significantly higher marketable yield than the sole plants. Unmarketable yield did not show some discernible pattern but it generally tended to be high on sole grown onions than on intercropped onions.

Table 5. Effect of spatial arrangements' of intercrops on marketable and un-marketable yield (qt/ha) of onions

Spatial arrangements'	Marketable yield		Un marketable yield	
	Koga	Rib	Koga	Rib
1 : 1/Onion : Carrot/	144.57^{bc}	112.67^{d}	6.00^{b}	0.00 (0.71)
1 : 2/ Onion : Carrot /	145.23^{bc}	152.43^{c}	9.23^{a}	0.33 (0.57)
1 : 3/ Onion : Carrot /	171.67^{ab}	233.77^{a}	7.90^{ab}	0.33 (0.57)
1 : 1/Onion : Snap bean/	134.67^{bc}	99.10^{d}	8.10^{ab}	0.00 (0.71)
1 : 2/Onion : Snap bean/	207.23^{a}	184.23^{b}	7.90^{ab}	0.10 (0.32)
1 ; 3 /Onion : Snap bean/	147.57^{bc}	236.10^{a}	7.10^{b}	0.43 (0.66)
Sole onion	122.23^{c}	114.00^{d}	10.90^{a}	0.10 (0.32)
CV (%)	17.87	8.59	20.48	8.79
Significance	*	***	*	NS

*Where: values with the same letter do not show significant differences; NS = stands for non- significance, numbers in the parenthesis are transformed values of the corresponding number, * = stands for significant & *** = stands for highly significant*

Correlations analysis

The unmarketable yield was significantly positively correlated with thrips population whereas bulb diameter and lengths was significantly but negatively correlated with unmarketable yield. Although not significant the damage percentages showed positive correlations with thrips population; however bulb length and bulb diameter showed highly significant negative correlations with thrips population (Table 6).

Table 6. Correlations between various dependent variables recorded during the growth period

	UMY	MY	DS	BD	BL	DP	NT
Un-marketable yield (UMY)	1.000	-0.222 NS	0.134 NS	-0.452 *	-0.016 *	0.115 NS	0.452 *
Marketable yield (MY)		1.000	0.045 NS	0.304 NS	0.301 NS	-0.488 *	-0.031 NS
Damage (DS)			1.000	-0.215 NS	-0.268 NS	0.241 NS	0.308 NS
Bulb diameter (BD)				1.000	0.643 ***	-0.113 NS	-0.712 ***
Bulb length (BL)					1.000	-0.246 NS	-0.558 ***
Damage percentage (DP)						1.000	0.199 NS
Number of thrips (NT)							1.000

** = stands for significant, *** = stands for highly significant, NS = stands for not significant.*

Regression Analysis

The regression analysis was done between different yield and yield related parameters'. Bulb length was regressed with thrips population and showed that as thrips population increases the bulb length decreases with the regression equation (BL=222-3.01TP), however the coefficient of determination (R^2) is low (R^2=42.4%) (Figure 1).

The thrips population were also regressed with bulb diameter and plant heights and showed that as the thrips population increases the bulb diameter and plant heights decreased with its respective regression equation and coefficient of determinations (Figures 2, 3 & 4).

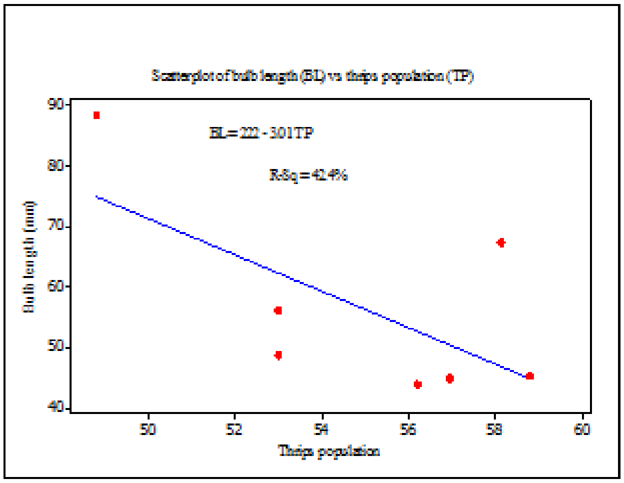

Figure 1. Regressions between bulb length (BL) vs thrips population (NT) at Koga

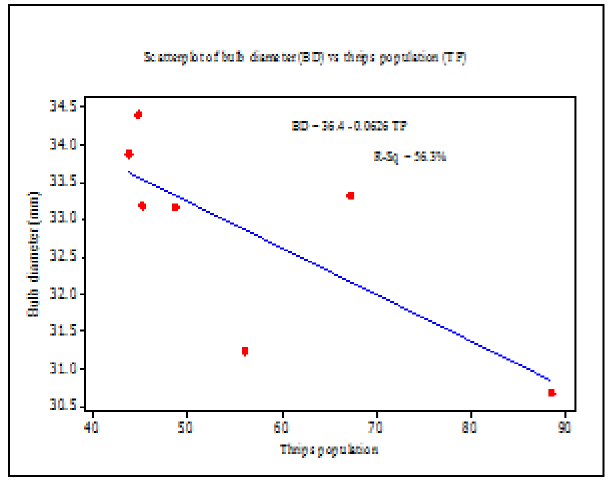

Figure 2. Regressions between bulb diameter(BD) vs thrips population (TP) at Koga

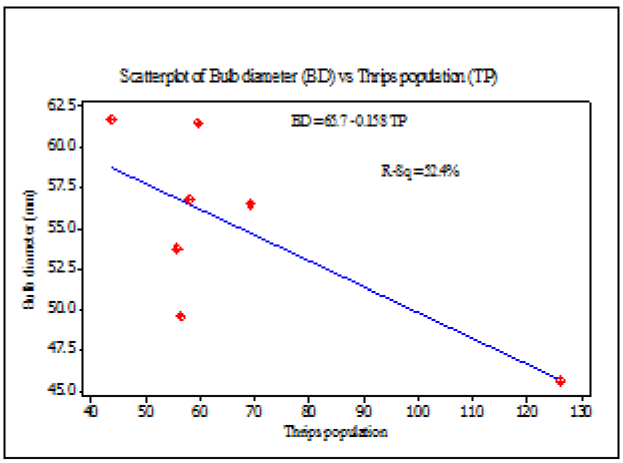

Figure 3. Regressions between bulb diameter(BD) vs thrips population (TP) at Rib

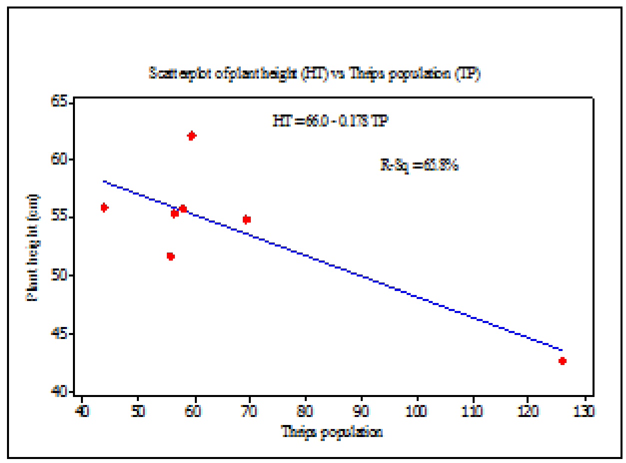

Figure 4. Regressions between plant height (HT) vs thrips population (TP) at Rib

Intercropping of onions with spider plant and carrots reduce onion bulb yields (Trdan et al. 2006, Kabura et al. 2008); however our intercropping was not affecting the recommended spacing's to the main crop (Onion). This study showed that thrips population and damage on onion can be significantly reduced when the inter crops are spatially arranged to 1:2/onion: carrots/ and 1:3 /onion with snap bean/.

Intercrops offer an alternative to the use of chemicals thereby reducing the development of resistance that has been reported in many of the currently registered insecticides (Shelton et al. 2006, Nault and Shelton 2010, Diaz-Montano et al. 2011). Intercrops not only reduce pest populations but they also preserve beneficial insects, reduce labor costs incurred in application of pesticides, control weeds and stabilize yields (Alamu et al. 2002).

CONCLUSIONS

The direct and indirect damage on onions by thrips was reflected by the plant height, leaf width, bulb sizes, etc. Damage levels varied because of different spatial arrangements of intercrops (carrots and snap beans) with onions. The significant reduction in thrips population and damage in the onion-carrot and onion-snap bean intercrops with their spatial arrangements (1: 2 and 1:3) showed that this arrangement can be utilized for the integrated management of this economically important pest of onion and can be taken as an alternative to insecticides for small holder farmer.

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