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

Onion thrips (Thrips tabaci) is considered as the most economically important pest of onion worldwide. Field experiments were conducted in 2013/14 and 2014/15 cropping seasons to assess 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 spatial arrangements of intercropping onion with snap bean f gl ka faa fldq h ((- m l dnk h gh md lagf q nh lg -, l Cg f /. l Ja 3 gfk i m fldq l lo g afl ghk a ka faa fldq h ((- m l dnk e k n dq l gl dg lagfk Afl ghh af gfagf o d gl f kf h f ka faa fldq h ((- af k e c l d onion bulb yield at Koga and Rib. Hence, both 1:2 and 1:3 spatial arrangements of onions with snap bean and as well as with carrot can be utilized for the management of onion thrips.

Keywords: *Damage levels; spatial arrangement; Thrips population,*

Introduction

Onion (*Allium cepa* L.) is one of the important vegetables 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 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 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*) is considered as 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 study Tsedeke Abate (1986) showed that thrips numbers were highest in the hotter parts of the year (February through April), and lowest in the rainy season (June through August). Yeshitila Merene (2005) studied the population fluctuation of the onion thrips in 2004 in the Showa Robit district of Amahara region, and reported a similar result. The population density of thrips was low during the rainy season 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 hiding 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 a need to integrate the use of chemicals with other methods of control such as cultural practices (Dejene 2006) and use of resistant varieties for 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 for the management of weeds, insect pests and diseases in many crops worldwide (Trdan et al. 2006; Finckh and Karpenstein-Machan 2002). Sodiya *et al. (*2010) reported that subsistence farmers in developing countries traditionally practice intercropping as a crop production system. 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 assess the effectiveness of different spatial arrangements of intercrops for the management of onion thrips in onions fields.

Material and Methods

Experimental Design and Layout

An experiment was carried out under irrigation condition (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*). Pure stands of onion variety Bombay red was considered as controls. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Plot size was 5 * 6 m; spacing between plots and blocks was 1 m and 1.5 m, respectively. 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 * 10 cm for onion, 45 * 10 cm for carrot, 45 * 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, where as plant height (cm) was measured two times at vegetative and harvest stages, 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 30 mm 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 normal distribution before statistical analysis. Due to zero data recorded on unmarketable yield, then it was transformed using square root $\left(\sqrt{n+0.5}\right)$ transformation method before analyses. 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. The correlation and 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 intercrops with their respective spatial arrangements' significantly ($p \leq 0.01$) reduced thrips population at Koga and Rib. 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) while at Rib, it was 44% and 56%, on the same ratio of carrots and snap bean, 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, as Bergant et al. (2005) and Alimousavi *et al. (*2007) explained, when temperatures are high, *Thrips tabaci* is a very prolific species with overlapping generations per season.

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]
Mean	56.32	66.94	28.83	7.67	3.14	3.0
CV	17.60	19.79	38.12	37.85	9.40	12.59
Significance	***	***	**	***	***	**

***= showed highly significant difference, values with the same letter showed no significant differences at $P \leq 0.05$.

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 on both locations (Table 2). This could have been due to visual and physical interference of thrips by the intercrops. Physical interference could cause thrips attraction to intercrops instead of onions thereby resulting in reduction of their population on onions (Alston and Drost 2008; Trdan *et al*. 2006). Uvah and Coaker, (1984) reported that carrot foliage hides the onions from thrips view. Alston and Drost, (2008) studied the thrips injury to intercrops and found that the effect was not as economically damaging as onions. 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.

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	-	-

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 indicate the level of the ratio of the spatial arrangements of intercrops with onions and its influences on thrips population. Muthomi *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 inters crops (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) (46.03, 51.80 cm), this was reflected by thrips population, where maximum population were recorded on plots that received sole planted onions. 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}
Mean	40.02	47.49	51.12	54.13
CV	11.22	8.65	5.11	9.41
Significance	NS	*	*	*

Values with the same letter showed no significant differences at $P \leq 0.05$, NS = stands for non-significance symbol (*) = stands for significant at $P \leq 0.05$.

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 ratios of carrots and snap beans had significantly higher bulb diameter. As Haider Karar *et.al*. (2014) reported, maximum population (160.2/ plant) gave bulbs with a bulb weight of 27.0 g and bulb diameter of 7.0 mm 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]
Mean	54.98	53.69	32.84	55.07
CV	6.23	5.32	3.98	3.84
Significance	*	***	*	***

Values with the same letter showed no significant differences at P=0.05, * = stands for significant; *** = stands for highly significant P≤0.05.

Bulb yield: At Koga, plots intercropped with 1:2 of snap bean and 1:3 carrots 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 discernible pattern but it generally tended to be high on sole grown onions than on intercropped onions.

Effects of onion thrips on the yield of onions was reported by different authors: Brewster (1994), Nawrocka (2003) and Trdan *et al. (*2005) describing thrips are responsible for causing considerable reduction in yield. Waiganjo *et al. (*2008) also reported the yield loss studies done in Ethiopia, indicating the occurrence of thrips in all onion-growing areas that can cause up to 37% loss in bulb yield of onions.

Intercropping of onions with spider plant and carrots reduce onion bulb yields (Trdan *et al.* 2006; Kabura *et al.* 2008); however, in this experiment intercropping was not affecting the recommended spacing's of the main crop (Onion). The result showed that thrips population and damage on onion significantly reduced, when the inter crops are spatially arranged to 1:2 /onion: carrots/ and 1:3 /onion with snap bean/. Different scholars: Shelton et al. (2006), Nault and Shelton (2010) and Diaz-Montano et al. *(*2011) reported that intercrops offer an alternative to the use of chemicals thereby reducing the development of resistance that has been reported in many of currently registered insecticides. Another scholar Alamu et al. (2002) also reported that 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.

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

Spatial arrangements'	Marketable yield (qt/ha)		Un marketable yield (qt/ha)	
	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)
Mean	153.31	161.76	8.30	0.26
CV	17.87	8.59	20.48	8.79
Significance	*	***	*	NS

Values with the same letter do not not show significant differences; NS = stands for non- significance, numbers in the parenthesis are transformed values of the corresponding number, symbol (*) = stands for significant; *** = stands for highly significant at $P \leq 0.05$.

Correlations analysis

The unmarketable yield was significantly positively correlated with parameters thrips population, damage percentage and damage severity, however it was only significant at thrips population parameter than others, whereas the yield determining factors (bulb diameter and bulb length) were significantly negatively correlated with unmarketable yield, although not significant, these parameters showed positive correlations with marketable yield. The negative correlation results between bulb length and bulb diameter with damage percentages and damage severity was not significant, however bulb length and bulb diameter showed a negative correlations with damage percentages and highly significant negative correlations with thrips population. This was due to the direct and indirect damages of thrips in the course of onion plant growth exerting major impact on the bulb yield of onions (Table 6).

Table 6. Correlations between various agronomic dependent variables

	UMY	MY	DS	BD	BL	DP	TP
UMY	1.000						

MY	1.000	0.045	0.304	0.301	-0.488*	-0.031
DS		1.000	-0.215	-0.268	0.241	0.308
BD			1.000	0.643***	-0.113	-0.712***
BL				1.000	-0.246	-0.558***
DP					1.000	0.199
TP						1.000

* = stands for significant; *** = stands for highly significant UMY=unmarketable yield, MY=marketable yield, DS= damage severity, BD=bulb diameter, BL= bulb length, DP=damage percentage, TP= Thrips Population.

Conclusion

Different spatial arrangements of carrots and snap beans within the rows of onions were compared, the thrips population and its associated direct and indirect damage on onions was reflected by the plant height, leaf width, bulb sizes, etc. it was found that damage levels varied due to different spatial arrangements of intercrops (carrots and snap beans) with onions. Both a 1:2 and 1:3 spatial arrangements showed minimum thrips population and lower level of damage percentages' and higher relative efficacy to check the thrips population increase than other spatial arrangements as well as sole onion planted plots. Hence, these arrangements could be utilized for the integrated management of this economically important pest of onion. It can also be taken as an alternative to the use of insecticides for smallholder farmers that intern reduces the repeated use and risk of developing pesticide resistances, as well as polluting the environment.

References

Alamu JF, Olarewaya JD, Coker A.A. (2002). Profitability assessment of tomato and pepper produced under Fadana development program in Kaduma state. *Nigerian Journal of Horticultural Science* 6(1):44-48.

Alimousavi SA, Hassandokht MR, Moharramipour S. (2007). Evaluation of Iranian onion germplasms for resistance to thrips. *International Journal of Agriculture and Biology* 9: 897-900.

Alston, D.G., and Drost, D. (2008). Onion Thrips (Thripstabaci). Utah State University Extension Publication ENT- 117-08PR.

Bergant K, Trdan S, Znidari D, Repinsek D, Kajfez-Bogataj L. (2005). Impact of climate change on developmental dynamics of Thrips tabaci (Thysanoptera: Thripidae): *Environment and Entomology* 34: 755- 766

Brewster JL. (1994). Onions and other vegetable alliums, CAB International, Wallingford, UK

Burkett-Cadena M, Kokalis-Burelle N, Lawrence KS, van Santen E, Kloepper JW. (2008). Suppressiveness of root-knot nematodes mediated by rhizobacteria. *Biological Control* 47: 55-59.

CSA (Central Statistical Agency). (2013). Agricultural Sample Survey. Volume III. Report on Area and Production (Private Peasant Holdings, Meher Season). Addis Ababa.

Diaz-Montano J, Fuchs M, Nault BA, Fail J, Shelton AM. (2011). Onion Thrips (Thysanoptera: Thripidae): A global pest of increasing concern in onion. *Journal of Economics and Entomology* 104(1):1-13

Finckh MR, Karpenstein-Machan M. (2002). Intercropping for pest management. In: Pimentel D (ed.) Encyclopedia of pest management. Taylor and Francis Press, London,UK, p 423

Gareth G, Laurence T, Timothy C, Brian T, Brian S. (2002). Onions - A global benefit to health. *Phytotherapy Research* l6: 603 – 615

Gashawbeza Ayalew. (2005). Comparison among some botanicals and synthetic insecticides for the control of Onion thrips (*Thrips tabaci* Lind.) (Thysanoptera: Thripidae) (Abstract). P-38. Paper presented at the thirteenth Annual Conference of the Crop Protection Society of Ethiopia (CPSE), CPSE, Addis Ababa, Ethiopia.

Haider Karar, Ghulam Abbas, Asifa Hameed, Ghayour Ahmad and Amjad Ali. (2014). Losses in Onion (Allium cepa) Due to Onion Thrips (Thrips tabaci) (Thysanoptera: Thripidae) and Effect of Weather Factors on Population Dynamics of Thips. *World Applied Sciences Journal* 32 (11): 2250 2258. DOI: 10.5829/idosi.wasj.2014.32.11.2751

Havey MJ, Galmarini CR, Gokce AF, Henson C. (2004). QTL affecting soluble carbohydrate concentrations in stored onion bulbs and their association with flavor and health-enhancing attributes. *Genome* 47: 463–468.

Javadzadeh A, Ghorbanihaghjo A, Bonyadi S, Rashidi MR, Mesgari M, Rashtchizadeh N, Argani H. (2009). Preventive effect of onion juice on selenite-induced experimental cataract. *Indian Journal of Ophthalmic* 57(3):185-189.

Kabura BH, Musa B, Odo PE (2008). Evaluation of the yield components and yield of onion (Allium cepaL.)- pepper (Capsicum annum L.) intercrop in the Sudan savanna. *Journal of Agronomy* 7 (1): 88-92.

Martin NA, Workman PJ, Butler RC. (2003). Insecticide resistance in onion thrips(*Thrips tabaci*) (Thysanoptera: Thripidae). New Zealand. *Journal of Crop and Horticultural Science* 31: 99-106

Muendo KM and Tschirley D. (2004). Improving Kenya’s domestic horticultural production and marketing system: Current competitiveness, forces of change, and challenges for the future. Tegemeo Institute of Agricultural Policy and Development, Egerton University, Kenya.

Muthomi J.W., Gachu S.M., Narla R.D., Nderitu J.H., Olubayo F.M., Wagacha J.M. (2012). Management of thrips (Thripstabaci) in bulb onion by use of vegetable intercrops. *International Journal of Agricultural Science* Vol. 2(5): 393-402,

Nault BA. and Shelton AM. (2010). Impact of insecticide efficacy on developing action thresholds for pest management: a case study of onion thrips (Thysanoptera: Thripidae) on onion. *Journal of Economics and Entomology* 103: 1315-1326.

Nawrocka B (2003) Economic importance and the control method of Thrips tabaci Lind. on onion. IOBC/WPRS *Bulletin No. 26, pp. 321-324.*

Rabinowitch HD and Currah L. (2002). Allium crop science: Recent advances. CAB International Wallington, UK, pp. 551.

Ramert BM and Lennartsson, DG. (2002). The use of mixed species cropping to manage pests and diseases – theory and practice. Proceedings of the COR Conference, Aberystwyth, UK 26- 28th March 2002.

Shelton AM, Zhao JZ, Nault BA, Plate J, Musser FR, Larentzaki E. (2006). Patterns of insecticide resistance in onion thrips (Thysanoptera: Thripidae) in onion fields in New York. *Journal of Economics and Entomology* 99: 1798-1804.

Smith CM, Khan ZR, Pathak M.D. (1994). Techniques for evaluating insect resistance in crop plants. CRC Press, Boca Raton, Florida, USA.

Sodiya AS, Akinwale AT, Okeleye KA, Emmanuel J.A. (2010). An integrated decision support system for intercropping. International Journal of Decision Support System Technology 2: 51-66.

Takele Dejene 2006. Assessment of species composition of thrips on onion and their management using mulching. MSc thesis, Alemaya University of Agriculture, Alemaya, 66 pp.

Trdan S, Vali N, Zezlina I, Bergant K, Znidar D. (2005). Light blue sticky boards for mass trapping of onion thrips, Thrips tabaci Lindeman (Thysanoptera: Thripidae), in onion crops. *Journal of Plant Disease and Protection* 12: 173-180.

Trdan S, Znidari D, Vali N, Rozman L, Vidrih M. (2006). Intercropping against onion thrips, ThripstabaciLindeman (Thysanoptera: Thripidae) in onion production: on the suitability of orchard grass, lacy phacelia, and buckwheat as alternatives for white clover. *Journal of Plant Disease and Protection* 113: 24–30.

Tsedeke Abate (1983). Insecticidal control of onion thrips, Thripstabaci, in the Awash Valley, Ethiopia. *Ethiopian Journal of Agricultural Sciences* 5: 32-43.

Abate T. 1986. A review of vegetable insects and mite pest management research in Ethiopia . In: *A review of Crop Protection Research in Ethiopia*. ed. Tsedeke Abate, pp. 479-494. Proceedings of the First Crop Protection Symposium, 4-7 February 1985, Institute of Agricultural Research (IAR), Addis Ababa, Ethiopia.

Tsedeke Abate and Gashawbeza Ayalew. (1994). Progress in vegetable pest management research 1985-1992. P. 187-193. In: E. Herath and L. Dessalegne (eds.). *Horticulture Research and Development in Ethiopia.* Proceedings of the Second National Horticultural Workshop,1-3 December 1992, IAR/FAO, Addis Ababa, Ethiopia.

Ullah A, Ashraf-Bhatti M, Gurmani Z.A, Imran M. (2007). Studies on planting patterns of maize (Zea mays L.). Facilitating legumes intercropping. *Journal of Agricultural Research* 45: 113-118.

Uvah, I. I. I., and T. H. Coaker. (1984). Effect of mixed cropping on some insect pests of carrots and onions. *Entomological Experment Application* 36: 159-167.

Waiganjo MM, Mueke JM, Gitonga L.M. (2008). Susceptible onion growth stages for selective and economic protection from onion thrips infestation. *Acta Horticulture* 767: 193-200.

Wang B, Lin S, Hsiao W, Fan J, Fuh L, Duh P. (2006). Protective effects of an aqueous extract of Welsh onion green leaves on oxidative damage of reactive oxygen and nitrogen species. *Food Chemistry* 98: 149–157.

Yeshitila Merene. (2005). Study on Population ecology and yield loss of onion thrips (*Thrips tabaci*) on onion in Showa Robit district of Amahara region. M.Sc. Thesis, Addis Ababa University, Ethiopia.