Macrothink Institute™

Journal of Biology and Life Science
ISSN 2157-6076
2024, Vol. 15, No. 2

Evaluation of Intercropping and Tobacco Leaf Extract for Management of Fruit Borer (*Helicoverpa armigera*) and Some Associated Beneficial Insects on Tomato in Eastern Hararghe, Ethiopia

Belachew Dabalo

School of Plant Science College of Agriculture and Environmental Science, Haramaya University, Dire Dewa, Ethiopia

Bore Agricultural Research Center Oromia Agricultural Research Institute, Addis Abeba, Ethiopia

Received: April 3, 2024 Accepted: July 17, 2024 Published: July 19, 2024

doi:10.5296/jbls.v15i2.22085 URL: https://doi.org/10.5296/jbls.v15i2.22085

Abstract

Tomato production is challenged by different insect pests among these, fruit borer is the most destructing pests of tomato. To tackle these problems, the study was initiated with the objective to evaluate intercropping and tobacco extract on fruit borer and some associated beneficial insects on tomato in Eastern Hararghe. Head cabbage, common bean, onion, tobacco leaf extract and karate were used as treatments. The experiment was laid out in RCBD with four replications. From these results, significant differences were observed between treatments on larval population per plant and infestation per plant for all insect pests tested and also in population reduction. Tobacco leaf extract highly reduced the population occurrence and infestation level of fruit borer next to karate and followed by onion intercropping. The number of branches, number of fruits, and number of damaged fruits, marketable yield, non-marketable yield, and total yield also showed a significant difference ($P < 0.05$) among the treatments. The number of fruits per plant, marketable yield, and Total yield were the highest on onion intercrops followed by karate and tobacco extracts whereas the lowest number was observed from head cabbage intercrops. Maximum yield and yield traits were recorded on tomato onion intercropping compared to the rests of intercrops while the botanical extract comparably maximized the yields with Karate. Therefore, tomato-onion intercropping and tobacco leaf extract were used as the best alternatives to karate, the synthetic insecticides in the management of tomato fruit borer.

Keywords: Helicoverpa armigera, population reduction, natural enemies, parasitism, yield

1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetables worldwide. The crop is an important source of minerals and antioxidants such as carotenoids, lycopene, vitamin C, E and phenolic compounds with a key role in human nutrition to prevent certain cancer and cardiovascular diseases (Adalid *et al*., 2004). It is widely cultivated in tropical, sub-tropical and temperate climates and thus ranks third in terms of world vegetables production. The world's leading tomato producing and exporting countries are Turkey, Egypt, Italy, Spain, and Morocco (FAOSTAT, 2022).

One of Ethiopia's most significant vegetable crops, tomatoes are mostly grown in the country's northern and central rift valley regions. Ethiopia's commercial tomato output has increased dramatically, according to FAOSTAT (2014), as a result of national agriculture strategies that prioritize the development of high-value cash crops like tomatoes. It is grown primarily for food and profit, both in rain-fed and irrigated environments. Approximately 23,583.75 tons of tomatoes were harvested in Ethiopia during the 2018/2019 Meher season from 4,322 hectares of land, with a productivity of roughly 5.46 t ha-1 (CSA, 2019).

Several production constraints identified for the low level of productivity. Inappropriate agronomic practices and high incidence of diseases and insect pests are among the major constraints of tomato production in Ethiopia (Lemma, 2002). A wide range of insects attack tomato and a major limiting factor in its successful cultivation and yield (Kumar, Ashok, Shivaraju, 2009). Tomato is more susceptible to these pests' attack than other vegetable crops, mainly because of its tenderness and softness. One of the most devastating insect pests is the fruit borer (*Helicoverpa armigera*) which is a serious pest of tomato in both rainy and dry season in the tomato growing countries (Degri and & Samalia, 2014; Tadele, 2016). TFB larvae feed on leaves, stems, buds, inflorescences, fruits and pods and cause damage in the vegetative and reproductive stages of plants lead to substantial economic loss (Mojeni, Asadi, Ganbalani, Shojae, 2005; Murúa, Scalora, Navarro, Cazado, Casmuz, Villagrán, Gastaminza, 2014).

Synthetic insecticides are primarily responsible for controlling the tomato fruit borer. However, the widespread use of pesticides has led to the selection of insecticide-resistant individuals because of the tomato fruit borer's high rate of reproduction and short life cycle (Mohan, Sushil, Bhatt, Gujar, Gupta, 2008; Ahmad, Shafiq, Ahmad, 2013). The reckless and indiscriminate use of non-selective insecticides at high dosages at inappropriate times disturbs the delicate balance of natural ecosystems and has a number of major detrimental effects on pollinators, predators, and parasitoids (Momanyi *et al*., 2012).

Intercropping is an important cultural practice that integrates agricultural operations to reduce pest abundance (Midega, Pittchar, Pickett, Hailu, Khan, 2018; Zarei, Fathi, Hassanpour, Golizadeh, 2019), increase biodiversity and the effectiveness of beneficial insects (Hanumantharaya et al., 2009; Shekhara, Rachappa, Yelshetty, Sreenivas, 2014), improve soil structure and fertilization, and increase crop yields (Tajmiri, Fathi, Golizadeh, Nouri-Ganbalani, 2017).Numerous studies have demonstrated the benefits of crop diversity for TFB management (Reena *et al*., 2009; Ram and Singh, 2010). For instance, Ram and Singh

(2010) discovered that TFB densities reduced in comparison to solitary tomatoes when tomato plants were interplanted in a 2:1 row ratio with coriander (Coriandrum sativum L.) and mustard (Brassica compestris L.). Compared to when chickpea, Cicer arietinum L., was planted alone, Reena *et al*. (2009) observed that the parasitism rate of TFB larvae increased and pod damage decreased when chickpea was interplanted with mustard in a 6:2 row ratio and with linseed in a 4:2 row ratio. Hanumantharaya et al. (2009) found that the quantity of TFB predators, such as Chrysoperla carnea (Stephans) and coccinellids, increased when safflower plants were interplanted with coriander and sorghum (Sorghum bicolor (L.), as opposed to safflower alone. It is preferable to stay away from the health and environmental hazards associated with pesticide use because the fruits are eaten raw in salads. It is necessary to find alternative pest management techniques that are scalable, affordable, effective, and safe for customers. The use of intercropping systems is one of such alternatives to insecticides. Therefore, the objective of this study was to evaluate the potential of intercropping in reducing the population of tomato fruit borer in tomato and abundances of some beneficial insects in Eastern Hararghe, Ethiopia.

2. Materials and Methods

Description of the Study Area

The experiment was conducted at Haramaya University in 2021 at Raree research station using irrigation (located at 42^o3'E and 9^o26'N and 2006 m.a.s.l). It is situated in the semi-arid tropical belt of East Oromiya, Ethiopia and is characterized by a sub-humid type of climate (Mohammed, Mohammed. Kibret, and Diriba, 2016). The mean annual rainfall is 800.9 mm and the mean annual temperature is 23.4^oc. The rainy season of the area is bimodal; the short rainy season stretches from March to May and the main rainy season from July to September. However, it has been observed that the rainfall distribution is frequently erratic, irregular and variable (Robai, Liambila, Kibebew Kibret, 2016).

Treatments and Experimental Design

For the experiment, we used tomato (*Geli-lema* variety) as the main crop intercropped with onion (*Nafis red* variety), beans (*Babile 1* variety), and cabbage (*Copenhagen market* variety) which was collected from Melkassa Agricultural Research Center (EIAR) and besides this, tobacco crude leaf extract was also used as a treatment. The leaf extracts of tobacco were prepared using freshly collected leaf materials and blended using a mortar and pestle. The resulting leaf juice was filtered through muslin cloth and adjusted to have an extract to be sprayed on tomato crop with the rate of one Kilogram (1kg) leaves per one litre of water as the work of Magsi *et al*. (2017) for the stock solution. The solution was diluted by the rate of one (1) litre of water and sprayed to the target plot. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Treatment combinations were tomato + haed cabbage, toamato + common bean, tomato + onion, tomato + tobacco leaf extract, tomato + karate % EC (lambda cyhalothrin) and tomato sole (control).

Field Management

A plot consisted of six rows of 3.6m length and 2.4m width and plot area ($8.64m^2$) with the distance between blocks and plots 1.5m and 1m, respectively. The spacing between rows and plants of tomato was 60cm x 40cm, respectively. The vegetables, namely beans, cabbage and onions were planted between the rows of tomatoes as extra plant population (s). The plot was sized to have six rows of tomato and another five rows of intercrops. Beans were directly sown on the rows allotted to it in the main field.

A fertilizer rate of 200 kg/ha of Di Ammonium Phosphate (DAP) (23- 46-0) and 50 kg/ha of Urea (46-0-0) was applied after a week of transplanting time and 50 kg/ha urea was applied at early flowering stage. All recommended management techniques were applied. Harvesting was done when plants attained physiological maturity. Tobacco leaf extract and Karate 5%Emulsifiable Concentrates (EC) were applied by knapsack sprayer eight (8) times weekly and six (6) times in ten (10) days interval, respectively starting from twenty eighth (28) days of transplanting to first fruit harvesting.

Data Collection

Six (6) plants were selected and tagged from the middle four rows of tomato for the representative samples of each plot. Data were collected on the number of insects per plant, fruits per plant, the number of leaves infested/damaged, and the number of fruit infested/bored by insect pests following the work of Tadele (2016). Counting on caterpillars began after 4 weeks of transplanting and included the number of fruit borer larval holes weekly from the appearance of the fruit to crop maturity by counting the number of larval holes on fruits per plant. Damaged fruits caused by fruit borer are characterized by tunnels or holes inside the fruit and entrance exit holes on the fruit. Undamaged fruits were recognized on the basis of the absence of the fruit borer tunnels or entrance or exit holes (Degri and Samaila, 2014). To evaluate the efficiency of the tested materials, the percentage of reduction of insect pests was calculated as follows: $\%PR = \frac{C-T}{C} X\ 100$ Where c, control; t, treatment; and %PR, percent population reduction. Infestation levels or damages recorded based on Mackenzie *et al*. (1993). Damage on leaves was assessed by counting the number of scars, crumbling, narrowing of apical leaves and corresponding area of damage caused by sap sucking insects and mites rated using a scale of 1 – 5 where, 0-1 = ≤10% no damage; 2= ≤25% slight damage; 3= (25-50% moderate); 4= 50-75% severe); 5= >75% very severe damage

Data on the parasitoids were recorded on the insect specimen/infested leaves and fruit samples were taken from tomato plantations for laboratory rearing until the parasitoids or the adult of the specimens have emerged. In the laboratory, infested leaves and fruits were placed inside a rearing cage covered with a muslin cloth to allow ventilation and left up to the emergence of parasitoid adults (Mahmoud, Mohammed, Mohamed, Khamis, Ekesi, 2020). The sampled tomato leaves and fruits having larvae were served as natural food for larval growth. Emerged parasitoids in rearing cages were preserved in 70% alcohol for identification. Identification of the parasitoids were conducted using identification keys of the morphological characters and referring to published articles, searching and matching with online insect specimen databases, and the help of Senior Entomologists at Haramaya

University. For each parasitoid species, the parasitism rate was determined according to Russell (1987) as follows:

$$\text{Parasitism rate (\%)} = \frac{\text{Parasitoids emerged}}{\text{Host insect emerged + Parasitoids emerged}} x100$$

Data Analysis

Analysis of Variance (ANOVA) on the collected parameters was performed as per the methods described by Gomez and Gomez (1984) using Statistical Analysis System (SAS) computer software version 9.4. (SAS, 2013). Differences among treatment means were compared using Tukey's Studentized range test at 0.05 probability level.

3. Results and Discussion

Population Abundance, Infestation and population reduction of *H. armigera*

In the present study, tomato intercropped with onion and tobacco leaf extracts showed a significant difference on the populations ($F_{a,\, b}$ = 4.87, 3.31; *df* = 15; *p* = 0.0076) and fruit larval holes ($F_{a,\, b}$ = 11.14, 3.31; *df* = 15; $p < 0.001$) of *H. armigera*. Tobacco leaf extracts had the lowest reported larvae population and fruit holes, with onion intercrops coming in second. H. armigera infestation levels decreased as a result of the fewest fruit infestations found on tobacco leaf extracts (3.35), which were statistically comparable to onion (4.45). Thus, tobacco leaf extract showed the greatest population reduction when compared to companion crops and control, with onion intercropping coming in second (figure 1)

In line with this finding, Rahman (2011) evaluated tomato common bean and tomato onion intercropping in tomato fruit borer infestation and found that, in comparison to solitary tomato, high fruit infestation was observed on tomato common bean intercrops and low fruit infestation on tomato onion intercropping. Additionally, compared to a single tomato, Ram and Singh (2010) showed that tomato fruit borer densities decreased on tomato plants intercropped with mustard, Brassica compestris L., and coriander, Coriandrum sativum L., in a 2:1 row ratio. According to Schafer, Zaller, and Köpke (2005), intercropping basil cotton decreased insect pest populations in previous trials. It even resulted in a 50% decrease in the population increase of the pink bollworm, Pectinophora gossypiella Saunders (Lepidoptera: Gelechiidae).

According to a study by Degri *et al*. (2014) on the impact of tomato-maize intercropping, the number of fruit borer larvae holes per plant decreased when tomatoes were intercropped and increased when tomatoes were grown as a single crop. Similarly, Lawal (2016) found that intercropping tomatoes with cowpea, maize, and soy beans greatly decreased the invasion of the Helicoverpa armigera tomato fruit borer. Furthermore, Praveen et al. (2020) assessed the potential damage reduction of the Brinjal fruit borer in relation to various companion crops, including cowpea, onion, garlic, fenugreek, common bean, and coriander. They concluded that the highest percentage of Brinjal fruit borer infestation was found in brinjal + garlic (19.29%), preceded by brinjal + fenugreek (19.96%) and brinjal with onion (21.75%), while 26.58% on a single brinjal plant. On the other hand, a minimum infestation of fruit borer in brinjal + coriander system was recorded by Paul *et al.* (2015).

Journal of Biology and Life Science
ISSN 2157-6076
2024, Vol. 15, No. 2

In reference to botanicals, Rahman *et al*. (2014) examined the effectiveness of four botanical extracts, such as tobacco leaf extract and neem seed kernel extract, on tomato fruit borer. They found that the treated samples with neem seed kernel extract and tobacco leaf extract had the lowest fruit infestation (27.15%) and the highest population reduction (28.68%) compared to the control group. According to Yekkala and Usha (2022), tobacco leaf extract was used to suppress tomato fruit borer and resulted in a lower fruit infestation rate (15.61%) on tomatoes as opposed to the control, which had the highest fruit infection rate (24.46%). According to a study by Sanjay *et al*. (2016), tobacco leaf extract caused 66.67% of the fruit damage reduction caused by the tomato fruit borer, *Helicoverpa armigera* (Hübner), when applied as a botanical insecticide. Furthermore, Shalendra and Ramakant (2021) investigated the bio-efficacy of natural compounds against Helicoverpa armigera in tomato, finding that when sprayed on standing crop, cow urine + tobacco extract 50 ml/l reduced population by 26.47 over control with a mean number of larvae of 0.91. As an alternative to Karate 5% EC, tobacco leaf extracts and onion tomato intercrops have demonstrated consistency in reducing the population of insect pests, leading experts to suggest their inclusion in the integrated management of fruit borer on tomatoes.

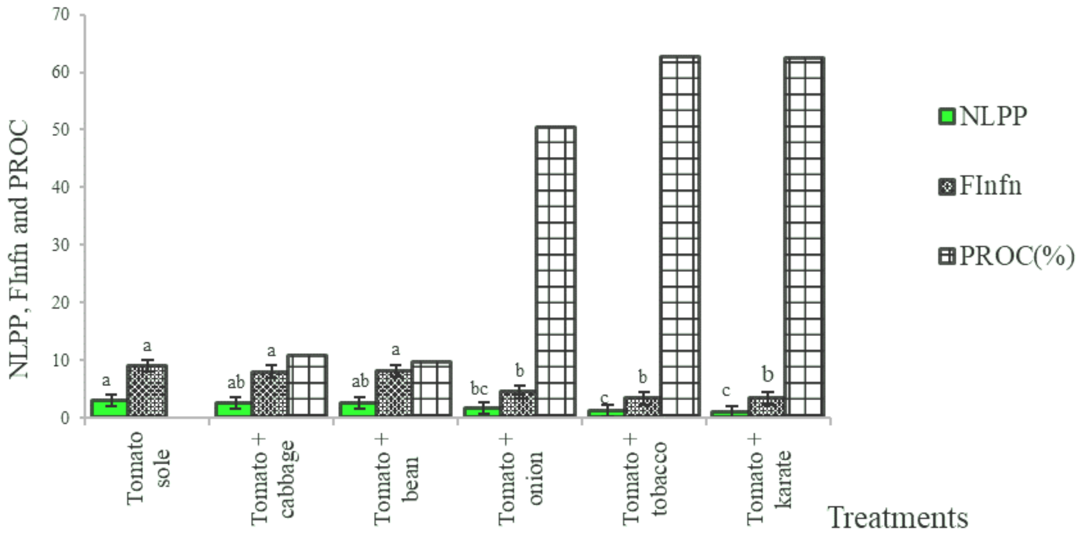

Figure 1. *H. armigera* larval densities, Infestation and population reduction in tomato plantations assessed during the experiment. The figure (1) showed the larval population, infestation level and larval population reductions which were recorded on the author’s tomato experimental field

Note: NLPP, Number of larva per plant; FInfn, fruit infestation; PROC, Population reduction over control (%)

Effect of Intercropping and Tobacco Leaf Extracts on Natural Enemies of Tomato Insect Pests

Table 1. Effect of intercropping and tobacco leaf extracts on occurrences of parasitoids and parasitism rates on insect pests of tomato during the experiment

Treatments	Host Insect	Order: Family: Parasitoids	Parasitism Rate (%)
control	*H. armigera*	Hymenoptera: Braconidae: Braconid wasp.	2.63
Tomato + cabbage		Hymenoptera: Braconidae: Braconid wasp.	5.13
Tomato + bean		Diptera: Tachnidae: *Drino* spp.	2.63
Tomato + onion		Not occurred	-
Tomato + Tobacco		Diptera: Tachnidae: *Drino* spp.	2.63
Tomato + karate		Not occurred	-

Note: The parasitoids were identified in Plant protection laboratory of Haramaya University by the help of Senior Entomologists. The table (1) showed the lists of parasitoids which were observed and identified in the author's experimental field.

Because of its diversity and ability to support a variety of insects that destroy economically significant insects, intercropping is one strategy for preserving natural enemies. The above table (1) regarding the parasitoids of H. armigera showed that species of Drino and Braconid wasps were seen in the research region. Regarding the treatments, Drino species were found in tobacco leaf extracts and common bean intercrops, whereas Braconid wasps were more commonly parasitized on head cabbage intercrops and tomato sole. Consistent with this discovery, Diatte et al. (2016) reported that the parasitoids detected from H. armigera comprised tachinid flies belonging to an undetermined species and Braconid wasps such Meteorus laphygmarum, Apanteles sp., Bracon sp., and Cotesia sp. According to Tarekegn et al. (2020), four tachinid species of larval parasitoids, including Drino sp. (Diptera: Tachinidae), were found parasitizing H. armigera on chickpea. According to Jagdish et al. (2016), there was a higher mean parasitism of C. chlorideae on H. armigera larvae during intercropping as compared to solitary cropping in chickpea coriander intercropping.

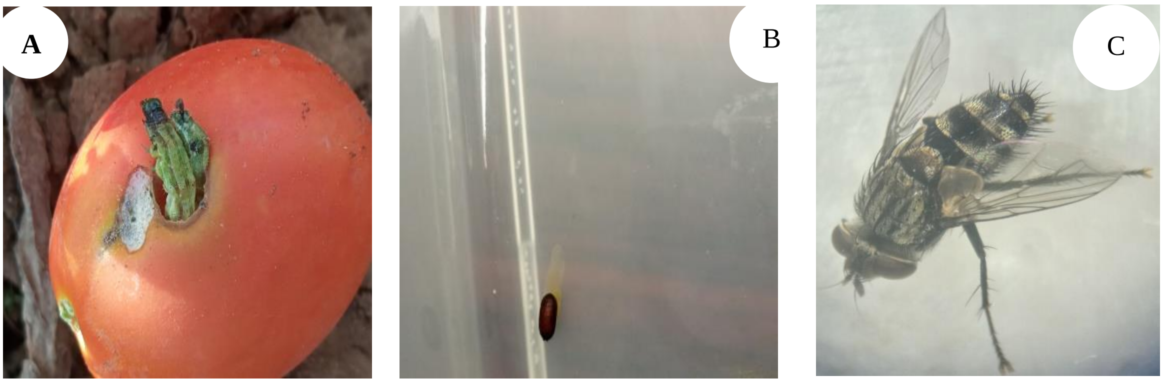

Figure 2. Tachinid fly parasitoids of *H. armigera* retrieved from laboratory-reared larvae of *H .armigera*, A) Parasitized larvae; B) Pupa stage, C) Emerged adult fly (*Drino sp*) of tachinid collected from tomato plantations at Rare farm, HU in 2021

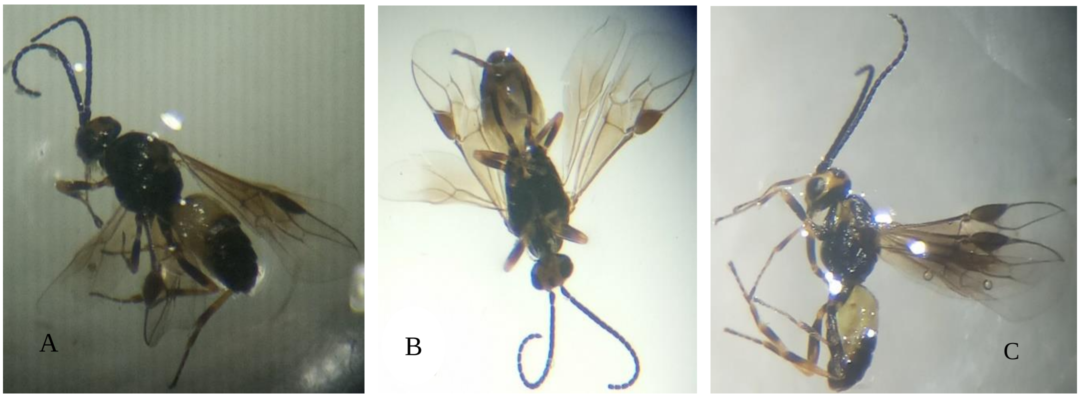

Figure 3. Recorded adult Braconid wasp emerged from parasitized *H. armigera* larvae collected from tomato fruit, HU, Rare research farm in 2021. A) Dorsal view, B) Ventral view), and C) Lateral view. The figures were credited to the author since he published this figure from his own experimental field

Effect of intercropping and botanical extract on yield and yield parameters of tomato

The yield and yield parameters of a crop can be affected by different management practices employed. The summary of yields (Table 5 and 6) showed that all treatments affected the yields.

Table 2. Effect of intercropping and botanical extracts on yield parameters of tomato during January to May in 2021.

Trts	PHPP	NBrPP	NFPP	FW (g)	DF	DP (%)
co	48.55^{a}± 1.83	2.17^{a} ± 0. 32	28.96^{c}± 0.92	82.96^{b}± 1.88	15.21^{a} ±1.17	52.51^{a} ± 3.77
Tcge	44.79^{b} ± 1.00	0.88^{b} ± 0. 14	19.71^{d} ± 1.19	78.97^{b} ± 3.97	7.58^{c} ± 0.26	38.92^{b} ± 2.87
Tbn	49.88^{a} ± 2.57	2.43^{a} ± 0. 11	33.50^{b} ± 1.21	95.45^{a} ± 2.96	11.83^{b}± 0.61	35.45^{b} ± 2.10
Ton	50.13^{a} ± 0.57	2.38^{a} ± 0. 20	38.25^{a} ± 1.42	100.87^{a} ± 4.57	8.58^{c} ± 0.70	22.34^{c} ± 1.12
Toco	51.00^{a} ± 2.77	2.17^{a} ± 0. 41	33.46^{b} ± 1.45	100.28^{a} ± 1.92	7.30^{c} ± 0.60	21.73(^{c} ± 0.96
Tkte	49.42^{a} ± 1.24	1.92^{a} ± 0. 31	33.42^{b} ± 0.69	100.80^{a} ± 4.81	7.28^{c} ± 0.24	21.77^{c} ± 0.32
LSD	3.89	0.63	3.44	8.96	1.86	3.53
CV(%)	5.32	20.88	7.32	6.37	12.78	6.85

The means with the same letters assigned have no significant difference at 0.05 level of significance.

DF, Damaged fruits

DP, Damage percentage

NBrPP, Number of branches per plant

PHPP, Plant height per plant

NFPP, Number of Fruits per plant

FW (g), Fruit Weight in gram

co, control

Tcge, tomato + cabbage

Tbn, Tomato + common bean

Ton, Tomato + onion

Toco, Tomato + tobacco

Tomato + karate

The result yield and yield parameters indicated that intercropping of tomato on number of branches ($F_{a,b}$ = 6.72, 3.31; df = 15; p = 0.0008), number of fruits ($F_{a,b}$ = 19.89, 3.31; df = 15, $p < 0.001$), fruit weight ($F_{a,b}$ = 8.14, 3.31, df = 15, p = 0.0003) and fruit damage ($F_{a,b}$ = 18.04, 3.31; df =15; $p < 0.0001$) and the use of tobacco leaf extract were significantly different among the treatments (Table 2). The tomato intercropped with onion crops produced the largest fruit weight (100.87g), and the fruit damage was lower (22.34%) than on the solitary tomato (52.4%), statistically equivalent to that of tobacco leaf extracts (21.73%). Rahman *et al*. (2014) followed up on this discovery by reporting that when neem and tobacco leaf extracts were applied as insecticides to suppress fruit borer on tomatoes, decreased levels of fruit infection were seen. According to Muhammad *et al*. (2018), neem and turmeric extracts applied to okra plants to control pests resulted in a significant increase in the number of fruits per plant when compared to the untreated control. The effectiveness of several botanicals and their potential to be combined with other pest management strategies for tomatoes were also reported by a number of researchers (Fernando *et al*., 2020; Mansour and Biondi, 2021).

Figure 4. Damage symptoms of fruit borer observed in tomato experimental field at Haramaya University Rare research station in 2021. The figure was credited to the author since he published this figure from his own experimental field

Furthermore, without changing the other tomato plantation development characteristics, the decreased fruit damage seen in the onion-tomato intercropping may have resulted from the suppression impacts of significant insect pest populations. Comparably, intercropping maize and tomato produced lower tomato fruit infestation, which raised fruit weight and productivity over solitary crops (Degri *et al*., 2014). In a related intercropping study, the tomato-common bean intercropping system produced a greater fruit output, weight, and quantity (Abd EL-Guad *et al*., 2014). This could be due to the legume crops' ability to fix nitrogen, which raises soil fertility. More recently, intercropping has been shown to increase the natural enemies of agriculturally significant insect pests in a variety of crops, including sweet pepper (Capsicum annum) and rosemary (Rosmarinus officinalis) (Li *et al*., 2021), potato and maize (Zheng *et al*., 2020), and legume and maize (Udayakumar *et al*., 2021).

Table 3. Mean (±SE) yields of tomato during January to May in 2021

Treatments	**MYtha^{-1}**	**NMYtha^{-1}**	**TYtha^{-1}**
control	19.58^{d} ± 0.45	19.38^{a} ± 1.08	38.96^{c} ± 0.86
Tomato + cabbage	17.19^{d} ± 2.71	12.92^{c} ± 0.70	30.10^{d} ± 2.44
Tomato + bean	25.52^{c} ± 0.91	17.19^{b} ± 1.00	42.71^{b} ± 1.69
Tomato + onion	39.37^{a} ± 0.97	11.35^{cd} ± 0.60	50.73^{a} ± 1.27
Tomato + Tobacco	33.65^{b} ± 0.89	10.00^{d} ± 0.54	43.65^{b} ± 1.43
Tomato + karate	33.85^{b} ± 0.62	10.01^{d} ± 0.52	43.96^{b} ± 0.77
LSD	3.46	2.05	3.16
CV (%)	8.14	10.09	5.02

The means with the same letters assigned have no significant difference at 5% level of significance. CV, Coefficient of variation; LSD, Least Significance Difference

NMYtha^{-1}, Non-marketable yield in tone per hectare

MYtha^{-1}, Marketable yield in tone per hectare

TYtha^{-1}, Total yield in tone per hectare

The marketable yield ($F_{a,b}$ = 38.07, 3.31, *df* = 15, p < 0.0001), non-marketable yield ($F_{a,b}$ = 21.75, 3.31; *df* = 15; p = <.0001) and total yield ($F_{a,b}$ = 29.46, 3.31; *df* = 15; p = <.0001) were also significant among the treatments (Table 3). Maximum (39.37 t/ha) marketable yield and total yield (50.73 t/ha) were obtained from the tomato-onion intercrops followed by tobacco leaf extracts (marketable yield = 33.65 t/ha and total yield = 43.65 t/ha) in comparison to sole tomato (Table 3). Rahman *et al*. (2014) found that neem and tobacco leaf extract sprayed plots produced the maximum yield, which was in line with this conclusion. The current result is also consistent with the findings of Nehal *et al*. (2015), who found that adding eucalyptus oil and garlic extract to tomatoes enhanced their overall output when compared to the control. According to Muhammad *et al*. (2018), neem and turmeric extracts had a favorable effect on the yield and growth of okra crops. According to Hossain *et al*. (2013), the lower frequency of pest infestations can be ascribed to the increased gross and yield produced by these extracts. In a similar vein, Son et al. (2018) found that growing tomatoes with aromatic plants doubled their output compared to growing tomatoes alone. According to Zhou *et al*. (2013), the secret to the increase in crop yield associated with aromatic crops is the release of chemicals that may have an indirect effect on pests by stimulating natural enemies and causing host plant resistance, or a direct effect by masking host plant odors, repelling, or being toxic. Because legumes fix nitrogen from the air, increasing soil fertility and reducing moisture stress on the plant's broad leaves or canopy, legume-tomato intercropping is a compatible cropping practice that, according to this study, also increased tomato yields when compared to sole cropping. Alemayew *et al*. (2016) discovered maize legume intercropping was fruitful and increased yield by 18% compared to maize single crops. This finding is comparable to the current one. According to Khonde *et al*. (2018), maize interplanted with all legumes yielded a larger yield advantage than solitary maize in the same tests. According to Carvalho *et al*. (2012), who researched tomato peppermint and fennel intercropping, head cabbage rivalry for greater area and its canopy as well as fighting for abiotic resources like sunlight, nutrients, and water may affect the output of tomato in head cabbage intercrops. All intercrops did, however, provide an increase in land utilization, which raised the total yield attained per unit area. Compared to single maize, intercropped with all legumes yielded a larger yield advantage.

4. Conclusion

The production of tomatoes is very diminishing upon various constraints of which fruit borers are the leading evils of tomato production. Significant differences were observed between treatments for the insect population per plant and infestation per plant for the H. *armigera*. Tobacco leaf extract caused maximum population reduction and infestation per plant next to Karate 5% EC and onion intercrops suppressed the insect pests at the highest level from the rest of the intercrops. Nicotine contents of tobacco leaf extracts and volatile chemicals of onions caused them to have pesticidal properties which are used in insect pest repellency on the host plant. The number of branches, number of fruits, number of damaged fruits, marketable yield, non-marketable yield, and total yield also showed a significant difference ($P < 0.05$) among the treatments. The number of fruits per plant, marketable yield, and Total yield were maximum on onion intercrops followed by karate and tobacco extracts and the lowest number was recorded from head cabbage intercrops. The yield components in onion intercrops surpassed the other treatments may be on account of onion led to an increase in the uptake of essential nutrients, nitrogen, phosphorus and potassium available in the soil for the tomato and the lower competition between inter-species than intra species and slight fruit damage. The lowest yield components were obtained from head cabbage intercrops which are estimated that interspecific competition is higher than the intraspecific competition and the association favors the performance of head cabbage rather than tomato. Parasitoids associated with fruit borer were observed despite their small numbers and low parasitism rates. Thus, the overall result concluded that intercropping of tomato with onion and tobacco leaf extracts were regarded as a practically sustainable alternative to karate 5% EC and components of the integrated management of *H. armigera* on tomato and to potentially reduce the amount of synthetic pesticides application in crop fields.

5. Recommendations and Study Implications

- Farmers in the research region are advised to try utilizing tobacco leaf extract to lower the population of tomato fruit borer on their tomato crops once it has been shown to be effective against the pest.

- It is advised that farmers in the study area and similar agro ecologies grow tomatoes utilizing tomato onion association rather than synthetic chemicals, as tomato onion intercropping has been found to be the promising crop association to minimize fruit borer population.

- It is advised to conduct more research to determine whether intercropping other fragrant crops with tomatoes can lessen insect infestations on tomatoes. Subsequent research should also be carried out to evaluate the possible effectiveness of other botanical leaf extracts in lowering the population of tomato-pesting insects, such as fruit borers.

- To more properly evaluate the extract's efficacy, it is also advised that future research employing tobacco leaf extract include a wider field and span a longer time period.

Acknowledgments

I would like to thank almighty God for helping me to start and successfully complete this work. Next, would like to thank the Oromia Agricultural Research Institute Bore Agricultural Research Center for the provision of research budget. Also I would like to acknowledge Haramaya University for provision of research materials especially experimental site and laboratory facilities.

Authors contributions

Not applicable. The entire study was conducted by the author.

Funding

Not applicable.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

Open access

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

References

Adalid. A. M., Rosello, S., & Nuez, F. (2004). Breeding tomato for their high nutritional value. *Recreation and Resources Development in Pant Science, 2,* 33-52.

Ahmad, S., Shafiq, A. M., & Ahmad, N. (2013). Acute toxicity and sub lethal effects of the neonicotinoid imidacloprid on the fitness of Helicoverpa armigera (Lepidoptera: Noctuidae). *Int J Trop Insect Sc., 33*, 264-275. https://doi.org/10.1017/S1742758413000246

Alemayehu, A., Tamado, T., Nigusie, D., Yigzaw, D., Kinde, T., & Wortmann, C. S. (2016). Maize-common bean/lupine intercrops productivity and profitability in maize-based cropping system of Northwestern Ethiopia. *Ethiopian Journal of Science & Technology*. https://doi.org/10.4314/ejst.v9i2.1

Carvalho, L. M. de, Oliveira, I. R. de, Almeida N. A., & Andrade, K. R. (2012). The Effects of Biotic Interaction between Tomato and Companion Plants on Yield. Proc. XXVIIIth IHC – IS on Organic Horticulture: Productivity and Sustainability Eds.: I. Mourão and U. Aksoy; *Acta Hort. 933*, ISHS. https://doi.org/10.17660/ActaHortic.2012.933.45

CSA (Central Statistical Agency). (2019). Agricultural Sample Survey 2018/2019: Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Volume-I, Statistical Bulletin 589, Addis Ababa, Ethiopia.

Degri, M. M., & Samalia, A. E. (2014). Impact of intercropping tomato and maize on the infestation of tomato fruit borer (*Helicoverpa armigera*). *Journal of Agriculture and Crop Research*, *2* (8), 160-164. http://www.sciencewebpublishing.net/jacr

Diatte, M., Thierry, B., Dienaba Sall-Sy, & Karamoko, D. (2017). Parasitoid control of the tomato fruitworm, *Helicoverpa armigera*, in smallholder farmer fields in Senegal. *International Journal of Pest Management*. https://doi.org/10.1080/09670874.2017.1346328

FAOSTAT (Food and Agriculture Organization of the United Nations Statistics Division). (2014). Statistical Database of the Food and Agriculture Organization of the United Nations. http://faostat.fao.org

FAOSTAT. (2022). ‘Available online: http://www.fao.org/faostat/en/#data/QC

Fening, K. O., Amoabeng, B. W., Adama, I., Mochiah, M. B., Braimah, H., Owusu-Akyaw, M., Narveh, E., & Ekyem, S. O. (2013). Sustainable management of two key pests of cabbage, *Brassica oleraceae* var. capitata L. (Brassicaceae), using homemade extracts from garlic and hot pepper. *Organic Agriculture*. *3*(3), 163–173. https://doi.org/10.1007/s13165-014-0058-2

Fernando, T. H., Vinádio, L. B., Maurício, U. V., Francine dos, S. G., José, E. P. da S., Renato, R. M., & Virgínia, S. (2020). Plant Acceptance for Oviposition of *Tetranychus urticae* on Strawberry Leaves Is Influenced by Aromatic Plants in Laboratory and Greenhouse

Intercropping Experiments. *Agronomy*. https://doi.org/10.3390/agronomy10020193.

Hanumantharaya, L., Venkateshalu, R. A. B., Basavarajappa, M. P., Somanagouda, G. (2009). Insect pest status of safflower and their natural enemies in Karnataka. *Karnataka Journal of Agricultural Science, 22*, 678-679.

Jagdish, J., Meena, A., & Snehel, C. (2016). Biology and relative parasitization of larval endoparasitoid *Campoletis chlorideae* Uchida on *Helicoverpa armigera* (Hübner) under sole and chickpea-coriander intercropping system. *Journal of Biological Control, 30*(2), 84-90. http://oar.icrisat.org/id/eprint/9921

Khonde, P., Tshiabukole, K., Kankolongo, M., Hauser, S., Djamba, M., Vumilia, K., & Nkongolo, K. (2018). Evaluation of Yield and Competition Indices for Intercropped Eight Maize Varieties, Soybean and Cowpea in the Zone of Savanna of South-West RD Congo. *Open Access Library Journal*. https://doi.org/10.4236/oalib.1103746

Kumar Ashok, C. T., & Shivaraju C. (2009). Bioefficacy of newer insecticide molecules against tomato fruit borer, *Helicoverpa armigera* (Hübner). *The Journal of Agricultural Science*, *22*, 288-289. cabidigitallibrary.org

Lawal, S. A. (2016). Effect of intercropping on the Infestation of Fruit borer (*Helicoverpa Armigera*) And Yield of Tomato. *Journal of Emmanuel Alayande College of Education, 20*(1), 1-7. https://www.researchgate.net/publication/352908941

Lemma, D. (2002). Tomato research experience and production prospects. Research Report-Ethiopian Agricultural Research Organization, No. 43.

Li, X. W., Lu, X. X., Zhang, Z. J., Huang, J., Zhang, J. M., Wang, L. K., … & Lu, Y. B. (2021). Intercropping rosemary (*Rosmarinus officinalis*) with sweet pepper (*capsicum annum*) reduces major pest population densities without impacting natural enemy populations. *Insects, 12*(1), 1-13. https://doi.org/10.3390/insects12010074

Mackenzie, C. L., Cartwright, B., Miller, M. E., & Edilson, J. V. (1993). Injury to onion by *Thrips tabaci* (Thysanoptera: Thripidae) and its role in the development of purple blotch. *Environmental Entomology, 22,* 1266-1277. https://www.researchgate.net/publication/300439766

Magsi, F. H., Syed, T. S., Memon, A. U. R., Bhutto, Z. A., Chang, B. H., Chandio, M. A., ... & Channa, N. A. (2017). Effect of different tobacco extracts on the population build up of sucking complex in okra crop. *120~ International Journal of Fauna and Biological Studies*, *4*(2), 120-123. https://www.researchgate.net/publication/316914763

Mahmoud, M. E., Mohammed, E. S., Mohamed, S. A., Khamis, F. M., & Ekesi, S. (2020). Development and Implementation of a Sustainable IPM and Surveillance Program for the Invasive Tomato Leafminer, *Tuta absoluta* (Meyrick) in Sudan. *Athens Journal of Sciences, 7*(3), 159-174. https://www.atiner.gr/2019fees

Mansour, R., & Biondi, A. (2021). Releasing natural enemies and applying microbial and botanical pesticides for managing *Tuta absoluta* in the MENA region. Phytoparasitica.

Springer Science and Business Media B.V. https://doi.org/10.1007/s12600-020-00849-w

Midega, C. A. O., Pittchar, J. O., Pickett, J. A., Hailu, G. W., & Khan, Z. R. (2018). A climate-adapted push-pull system effectively controls fall army worm, *Spodoptera frugiperda* (J E Smith), in maize in East Africa. *Crop Prot., 105*, 10-15. https://doi.org/10.1016/j.cropro.2017.11.003

Mohammed, U., Kibret, K., Mohammed, M., & Diriba, A. (2016). Soil fertility assessment and mapping of Becheke Sub-Watershed in Haramaya District of East Hararghe Zone of Oromia Region, Ethiopia (MSc thesis. Haramaya University, Haramaya, Ethiopia).

Mohan, M., Sushil, S. N., Bhatt, J. C., Gujar, G. T., & Gupta, H. S. (2008). Synergistic interaction between sublethal doses of *Bacillus thuringiensis* and *Campoletis chlorideae* in managing *Helicoverpa armigera*. *BioControl, 53,* 375-386. https://doi.org/10.1007/s10526-007-9079-z

Mojeni, T. D., Asadi, H. B., Ganbalani, G. N., & Shojaei, M. (2005). Study on bioregional aspects of bollworm, Helicoverpa armigera (Hub.)(Lepidoptera: Noctuidae), in the cotton fields of Golestan province.

Momanyi, G., Maranga, R., Sithanantham, S., Agong, S., Matoka, C. M., & Hassan, S. A. (2012). Evaluation of persistence and relative toxicity of some pest control products to adults of two native trichogrammatid species in Kenya. *BioControl*, *57*, 591-601. https://doi.org/10.1007/s10526-011-9434-y

Muhammad, U., Tariq, N. K., Hazir, R., Daud, M. K., Waheed, M., & Azizullah, A. (2018). Effects of Neem (*Azadirachta indica*) seed and Turmeric (*Curcuma longa*) rhizome extracts on aphids control, plant growth and yield in okra. *Journal of Applied Botany and Food Quality*, *91*, 194-201. https://ojs.openagrar.de/index.php/JABFQ/article/view/8339

Murúa, M. G., Scalora, F. S., Navarro, F. R., Cazado, L. E., Casmuz, A., Villagrán, M. E., ... & Gastaminza, G. (2014). First record of helicoverpa armigera (Lepidoptera: Noctuidae) in Argentina. *Florida Entomologist*, *97*(2), 854-856. https://doi.org/10.1653/024.097.0279

Nehal, M. H., Hussein, M. I., Gadel, H. S. H., Shaalan, H. S., & Hammad, M. A. (2015). Effect of two Plant Extracts and four Aromatic oils on *Tuta absoluta* population and productivity of tomato cultivar, Gold Stone. *Journal of Plant Protection and Pathology*, Mansoura University; 6(6), 969-985. https://dx.doi.org/10.21608/jppp.2015.74529

Paul, S. K., Mazumder, S., Mondal, S., Roy, S. K., & Kundu, S. (2015). Intercropping coriander with brinjal for brinjal fruit and shoot borer insect suppression. *World Journal of Agricultural Sciences, 11*(5), 303-306. https://doi.org/10.5829/idosi.wjas.2015.11.5.1872

Praveen, K. M., Partha, C., Arup, C., Swadesh, B., Tridip, B., Kanu, M., & Sanket, K. (2020). Effect of intercrops on damage potential of major insect pest of brinjal under the Gangetic alluvial zone of West Bengal. *Journal of Entomology and Zoology Studies*; *8*(6), 235-239. http://www.entomoljournal.com/

Rahman, A. K. M. Z., Haque, M. H., Alam, S. N., Mahmudunnabi, M., & Dutta, N. K. (2014).

Efficacy of Botanicals against *Helicoverpa armigera* (Hubner) in tomato. *Scientific Journal of Krishi Foundation, 12*(1): 131-139. https://doi.org/10.3329/agric.v12i1.19868

Rahman, M. M. (2011). *Development of IPM package (S) against Tomato Fruit Borer by utilizing Some Integrated Pest Management Tactics* (Doctoral dissertation, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207).

Ram, S., & Singh, S. (2010). Effect of intercropping of spices, cereal and root crops on the incidence of Helicoverpa armigera (Hub.) in tomato. *Vegetable Science, 37*(2), 164-166.

Robai, N. L., & Kibebew, K. (2016). Climate Change Impact on Land Suitability for Rainfed Crop Production in Lake Haramaya Watershed, Eastern Ethiopia. *Journal of Earth Science & Climatic Change.* https://doi.org/10.4172/2157-7617.1000343

Russell, D. A. (1987). A simple Method for improving estimates of percentage parasitism by insect parasitoids from field sampling of hosts. *New Zealand Entomology, 10,* 38-40. https://doi.org/10.1080/00779962.1987.9722508

Sanjay, K., Hemant, L., Ramawatar, B., & Ramawtar, Y. (2016). Efficacy of botanical insecticides against tomato fruit borer, *Helicoverpa armigera* (Hübner) in tomato, *Lycopersicon esculentum* (Mill.). *Environment and Ecology, 34*(2), 609-613. http://www.environmentandecology.com/

SAS, I. (2013). Base SAS 9.4 procedures guide: statistical procedures. *Cary, NC, USA: SAS Institute Inc*.

Schafer, C., Zaller, J., & Köpke, U. (2005). Cotton-basil intercropping: effects on pests, yields and economical parameters in an organic field in Fayoum. *Egyptian Biological Agriculture & Horticulture, 23*, 59-72. https://doi.org/10.1080/01448765.2005.9755308

Shalendra, P. S., & Ramakant, D. (2021). To study the bio-efficacy of natural compounds against *Helicoverpa armigera* in tomato. *The Pharma Innovation Journal, 10*(10), 1952-1958.

Shekhara, C., Rachappa, V., Yelshetty, S., & Sreenivas, A. G. (2014). Influence of intercrops on activity of natural enemies on Helicoverpa armigera (Hübner) in chickpea. *J Exp Zool India, 17,* 655-658. https://www.researchgate.net/publication/314119412

Son, D., Somda, I., Legreve, A., & Schiffers, B. (2018). Effect of plant diversification on pest abundance and tomato yields in two cropping systems in Burkina Faso: farmer practices and integrated pest management. *International Journal of Biological and Chemical Sciences, 12*(1), 101-119. https://doi.org/10.4314/ijbcs.v12i1.8

Tadele, S. (2016). Evaluation of Improved Tomato Varieties *(Lycopersicon esculentum* Mill.) Performance against Major Insect Pests under Open Field and Glasshouse. *International Journal of Research Studies in Agricultural Sciences,* (2), 1-7.

Tajmiri, P., Fathi, S. A. A., Golizadeh, A., & Nouri-Ganbalani, G. (2017a). Strip intercropping canola with annual alfalfa improves biological control of *Plutella xylostella* (L.) and crop yield. *Int J Trop Insect Sci.*, *37*, 208-216. https://doi.org/10.1017/S1742758417000145

Tarekegn, F., Tebkew, D., Tadele, T., & Mulugeta, N. (2020). Hymenopteran and dipteran larval parasitoid species of the cotton bollworm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in chickpea growing districts of Ethiopia. *Biocontrol Science and Technology*. https://doi.org/10.1080/09583157.2020.1859096

Udayakumar, A., Shivalingaswamy, T. M., & Bakthavatsalam, N. (2021). Legume-based intercropping for the management of fall armyworm, *Spodoptera frugiperda* L. in maize. *Journal of Plant Diseases and Protection*, *128*(3), 775-779. https://doi.org/10.1007/s41348-020-00401-2

Yekkala, N. D., & Usha, Y. (2022). Comparison with botanicals and the bio-agents on Fruit borer, *Helicoverpa armigera* (Hubner) in Tomato. *Journal of Entomology and Zoology Studies*, *10*(2), 223-226. https://doi.org/10.22271/j.ento.2022.v10.i2c.8992

Zarei, E., Fathi, S. A. A., Hassanpour, M., & Golizadeh, A. (2019). Assessment of intercropping tomato and sainfoin for the control of *Tuta absoluta* (Meyrick). *Crop Prot*, *120*, 125-133. https://doi.org/10.1016/j.cropro.2019.02.024

Zheng, Y. Q., Zhang, L. M., Chen, B., Yan, N. S., Gui, F. R., Zan, Q. A., … & Xiao, G. L. (2020). Potato/Maize intercropping reduces infestation of potato tuber moth, Phthorimaea operculella (Zeller) by the enhancement of natural enemies. *Journal of Integrative Agriculture*, *19*(2), 394-405. https://doi.org/10.1016/S2095-3119(19)62699-7

Zhou, H. B., Chen, J. L., Liu, Y., Francis, F., Haubruge, E., Bragard, C., … & Cheng, D. F. (2013). Influence of Garlic Intercropping or Active Emitted Volatiles in Releasers on Aphid and Related Beneficial in Wheat Fields in China. *Journal of Integrative Agriculture*, *12*(3), 467-473. https://doi.org/10.1016/S2095-3119(13)60247-6