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Research Article

Effect of additive intercropping kidney bean *Phaseolus vulgaris* with some aromatic plants on *Thrips tabaci* population

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Abstract: Intercropping is defined as the simultaneous cultivating of two or more crops together at the same time within a field. It has many advantages like pest population reduction, which increases crop yield. This study compared the impact of additive intercropping kidney bean *Phaseolus vulgaris* L. with some aromatic plants on *Thrips tabaci* Lindeman, 1889 population. The treatments included kidney bean sole crop, 100 + 50 kidney bean + coriander *Coriander sativum* L., 100 + 50 kidney bean + ajwain *Carum copticum* L., 100 + 50 kidney bean + basil *Ocimum basilicum* L., and 100 + 50 kidney bean + dill *Anethum graveolens* L. There were six sampling dates at weekly intervals after onion thrips emergence on the leaves. Kidney and bean leaves were collected on each sampling date, and the number of thrips larvae or adults was recorded. Results showed that the intercropping system significantly influences the onion thrips population. The minimum and maximum thrips per leaf were recorded in kidney bean + basil mixed and kidney bean sole crop treatments (0.208 and 0.540 Thrips/leaf). Moreover, there was a significant negative relationship between the number of thrips and kidney beans yield. The highest yield was recorded in kidney bean + basil treatments (2756 kg/ha). Besides, intercropping increased the Land Equivalent Ratio (LER) of bean monoculture. For instance, all intercropping treatments had higher LER than kidney bean monoculture. Among the intercropping treatments, the kidney bean + basil treatment had the highest LER (1.433). Finally, intercropping kidney beans with some aromatic plants could be an eco-friendly strategy in integrated pest management.

Keywords: Conservation, LER, Monoculture, Polyculture, Sustainable agriculture

Introduction

Kidney bean *Phaseolus vulgaris* L. is a major grain legume consumed worldwide for its edible seeds and pods (Heuzé, 2013). Because of its high protein content (20–25%), complex carbohydrates (50–60%), and a good source of vitamins, minerals, and poly-unsaturated fatty acids, it is one of the most globally essential legume crops for human nutrition (Rehman *et al.*, 2001).

Thrips tabaci L. (Thysanoptera: Thripidae) is a severe global pest of many economically important crops worldwide (Waiganjo *et al.*, 2008). During the high infestation, its population may reach upto100 individuals/plant (Ullah *et al.*, 2007). Thrips direct feeding causes leaf whitening (blast), leaf curling, and twisting,

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leading to plant stunting. Besides direct injuries, it serves as a principal vector of different diseases (e.g., tospoviruses and *Alternaria porri*) and causes yield loss (Riley *et al.*, 2011; Gill *et al.*, 2015).

Several ecofriendly control tactics have been developed to reduce thrips damage in field vegetable crops (Riley and Pappu, 2004; Rueda *et al.*, 2007). However, more selective insecticides have been introduced into crop protection recently. This development helped overcome insecticide resistance problems (Rueda *et al.*, 2007). Besides increasing the cost of production, pesticides have some adverse effects on the environment and human health, attributed to high chemical residues (Burkett-Cadena *et al.*, 2008). The rapid resistance development by onion thrips to the most commonly used insecticides has been reported frequently (Martin *et al*., 2003; MacIntyre Allen *et al.*, 2005). Therefore, it is necessary to integrate the use of chemicals with other control tactics such as cultural practices to keep the *T. tabaci* population below the economic damage.

Intercropping has been developed to minimize the reliance on pesticides and reduce pest densities (Midega *et al*., 2018; Zakka *et al*., 2018). It is defined as growing more than one crop in the same field simultaneously, where plants coexist throughout the whole period or at least during a prominent part of their cycle (Ferreira *et al*., 2014). This intercropping system is a fundamental agronomic technique to prevent pest population outbreaks and keep it below the economic injury level (Malik *et al*., 2003).

Intercropping is considered an essential component of crop production systems in developing countries (Sodiya *et al.*, 2010). It can provide numerous benefits to cropping systems through increasing total yield and land-use efficiency (Dhima *et al.*, 2007), improving biodiversity and yield stability of cropping systems (Lithourgidis *et al.*, 2006), enhancing light, water, and nutrient use (Lithourgidis *et al.*, 2007), controlling weeds, insects, or diseases (Vasilakoglou *et al.*, 2008), increasing soil fertility and conservation of natural predatory fauna (Rao *et al.*, 2012).

Medicinal plants are considered a source of health products, essential oils, and other natural aroma chemicals in the national and international markets (Sujatha *et al*., 2011). These plants have a particular position in traditional medicine. Aromatic plants (AP), produce high amounts of volatile secondary metabolites; thus, they are potential candidates for testing intercropping designs aimed at interfering with or masking host plant odors to disturb host selection by insect pests (Sujatha *et al*., 2011). Several studies have emphasized the use of medicinal plants such as okra *Abelmoschus esculentus* L. (Muoneke and Mbah, 2007), chili pepper *Capsicum frutescens* L. (Uddin and Odebiyi, 2011), saffron *Crocus sativus* L. and three species of chamomile *Matricaria chamomilla, Tanacetum parthenium, and Anthemis nobilis* (Naderi Darbaghshahi *et al*., 2012) in intercropping systems.

Several studies have demonstrated that intercropped repellent plants or trap plants can be effective alternative methods to reduce pest pressure on the primary crop (Tang *et al.*, 2013). Onion and clover intercropping causes a reduction in the onion thrips population and higher onion yield (Trdan *et al.*, 2006). Chilies intercropped with garlic and onion showed lower pest infestation levels and a higher yield (Aswathanarayanareddy *et al*., 2006). Analysis of 207 case studies involving 287 pest species showed a pest population reduction of 52% in polyculture cases compared with monocultures (Andow, 1991).

The kidney bean is often a suitable companion crop in intercropping systems due to its non-aggressive and short growth cycle (Dawo *et al*., 2009). Growers manage thrips by applying insecticides several times in a growing season. However, most insecticides are ineffective because of the cryptic lifestyle of onion thrips, and many thrips individuals are always protected between the inner leaves of the onion plant. Moreover, *T. tabaci* is a prolific species with many overlapping generations (Nault and Shelton, 2010). Therefore, the current study aimed to evaluate the impact of additive intercropping kidney beans with some aromatic plants on the thrips population.

Materials and Methods

Experimental site

The field experiment was conducted on the Malekabad Research Farm (Alashtar, Lorestan province, Iran; 33°83' N latitude, 48°24' E longitude, 1620 m above mean sea level), in 2020. Irrigation was scheduled for every 6-7-days. The study was conducted under clay soil conditions characterized by pH = 7.5, 0.95% organic matter, 0.88, 9.5, and 190 mg kg^{-1} available N, P, and K, respectively. According to soil analysis and common recommendations for kidney bean production in the area, phosphorus was added once during bed preparation at 80 kg ha^{-1} as a superphosphate-triple. 100 kg ha^{-1} nitrogen (based on urea, like ammonium nitrate) was divided into three equal parts and applied to the experimental plots after seedling emergence, weeding, and pod filling (top-dressed). Ultimately, all treatments received the same fertilization regime regarding soil analysis results. This site has an average annual precipitation of 440.30 mm and is classified as a semi-arid climate. The yearly mean temperature of the region is recorded at 12.7 °C, and during the experiment was 21.67 °C.

Design and cultivation practices

The experiment was carried out in a randomized complete block design (RCBD) with five treatments and three replications. The size of plots was 3 × 2.5 m. The treatments included kidney bean sole crop *Phaseoulus vulgaris* L. c. v. Dadfar, 100 + 50 kidney bean + Coriander, 100 + 50 kidney bean + Ajwain, 100 + 50 kidney bean + Basil, and 100 + 50 kidney bean + Dill (intercropping pattern) was as additive series; in this intercropping, one crop is the main or base crop, and another is intercrop. Also, the population of accompanied plant crops is less than their recommended pure stand). Local cultivars of additive intercropped plants were used in the study. The density of kidney beans was 20 plants/$m^{2,}$ and coriander, ajwain, basil, and dill were sown between kidney bean rows (one row in between) at 8, 6, 10, and 20 cm distance from each other on the ridge, respectively (Fig. 1).

After sterilization by Rosalaxyl 72%, WP (Ridomil-Mancozeb) for 15 min, kidney beans and other intercropped seeds were planted at the stack side (width ca. 50 cm) on 24 May 2020. Kidney bean seeds were sown at a depth of 5 cm, and seeds of four additive intercropped plants were sown at 1 cm soil depth. Irrigation and weed control were carried out as required. After bean pod ripening, yield per hectare was calculated, and the Land Equivalent Ratio (LER) regarding seed yield was evaluated according to equation 1.

$$LER = \frac{Yb}{Ya} \qquad \text{equation 1}$$

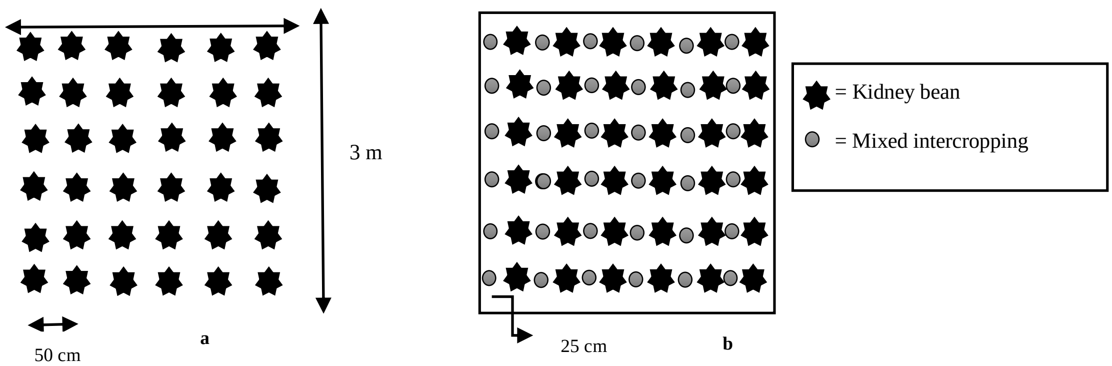

Figure 1 Schematic illustration of kidney bean sole plot (a) and mixed intercropping between kidney bean lines plots (b).

Where Y_b is the kidney bean yield in intercropping and Ya is the yield in sole-crop treatment.

LER < 1, meaning less than expected (adverse)

LER = 1, meaning the same as monoculture

LER > l, meaning more than expected (favorable)

According to equation 1, if LER is greater than one, the multiple-crop system works, but sole-crop cultivation will be more profitable if LER is less than one.

Sampling method

Samples were taken once the onion thrips emerged in the plots, and there were six sampling dates at weekly intervals. Because of the marginal effect, no sample was taken from lines one and six and 50 cm up and down the plots. Onion thrips sampling randomly selected six plants and four leaves from the middle part in four geographical directions in each sampling period. The kidney bean leaf was selected as the sampling unit. After transfer to the laboratory, both lower and upper leaf surfaces were examined under a digital loop (40x magnification).

Statistical analysis

Data normality was checked, and if the distribution met the normality requisite, the number of thrips among treatments was tested by one-way analysis of variance (ANOVA). Means were compared using Tukey's multiple range test at $p < 0.05$. Moreover, the Pearson correlation coefficient test assessed the relationships between independent variables.

Results

Effect of intercropping on thrips population

It was revealed that intercropping components significantly influenced the thrips population ($F = 4.51$, df = 4, 8, $P < 0.05$). Mean comparison showed the highest (0.540 thrips/leaf) and the lowest (0.208 thrips/leaf) number of thrips in sole kidney bean and 100 + 50 kidney bean + basil treatments (Fig. 2).

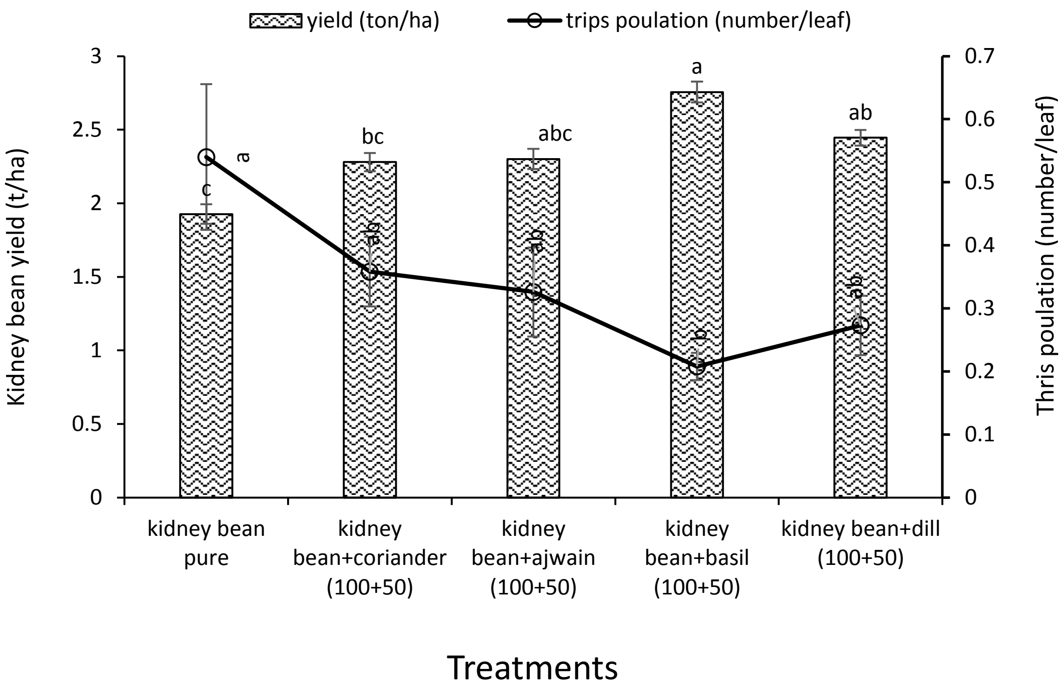

Figure 2 Mean ± SE comparisons of thrips population and kidney bean yield at experimental treatments (Tukey at 5%).

Accordingly, all intercropping treatments have a lower thrips population than kidney bean monoculture. However, there were no significant differences between other intercropping treatments (e. g., kidney bean + coriander, kidney bean + ajwain, and kidney bean + dill) in the thrips population (Fig. 2).

Kidney bean yield and Land Equivalent Ratio (LER)

Analysis of variance showed that kidney bean yield (F = 17.87, df = 4,8, P < 0.01) and LER (F = 17.14, df = 4,8, P < 0.01) are significantly influenced by intercropping. Mean comparisons concerning kidney bean yield showed a significant difference between sole cropping and Multiple-crop treatments (Fig. 2).

In all intercropping treatments, the yield was more than kidney bean sole culture (1926 kg/ha). Moreover, among the intercropped treatments, the highest kidney bean actual seed yield (2756 kg/ ha) was obtained from 100 + 50 kidney bean + basil treatment, and the lowest belonged to 100 + 50 kidney bean + coriander (2280 kg/ha) (Fig. 2). As shown in figure 2, there is no yield difference between sole kidney bean, kidney bean + coriander, and kidney bean + ajwain treatments.

The LER of all intercropping treatments was more than one, which indicated an advantage of intercropping over kidney bean monoculture (Fig. 3). Also, a 100 + 50 kidney bean + basil ratio among intercropped treatments had a higher value (1.433 per unit of land). Similar to the thrips population, there was no difference between three intercropping treatments (kidney bean + coriander, kidney bean + ajwain, kidney bean + dill) and sole cropping of kidney bean in terms of LER (Figs. 2 and 3).

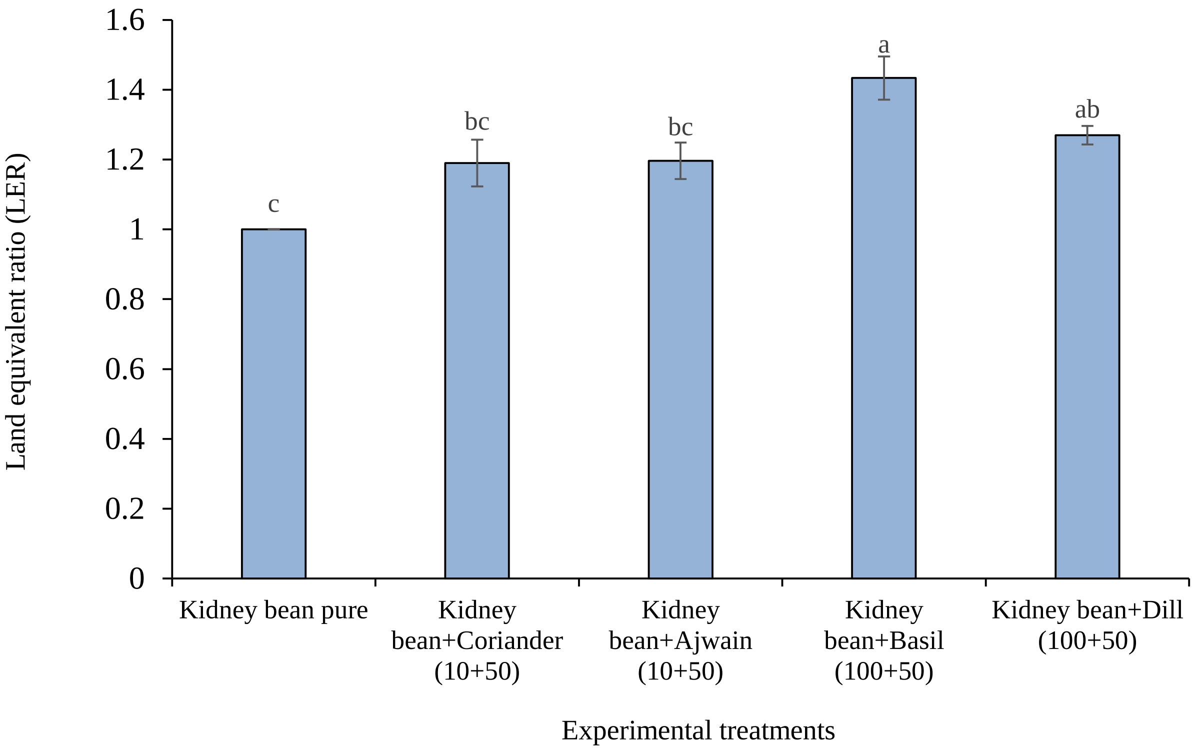

Figure 3 Mean ± SE comparisons of Land Equivalent Ratio (LER) (Tukey 5%) at different experimental treatments.

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The relationship between the onion thrips population and kidney bean yield

In the present study, the correlation test results show that the relationship between kidney bean yield and the number of thrips was significantly negative, which means treatments with high yield have a lower thrips population (Table 1).

Table 1 Correlation coefficient between onion thrips population and yield at different intercropped treatments.

	Thrips population	Yield	LER
Thrips population	1	-0.717 **	-0.027 *
Yield		1	0.951 **
LER			1

** and * are significant at 1% and 5% probability levels, respectively.
LER: Land Equivalent Ratio.

Consistently, the number of thrips per leaf and yield in sole cropping of kidney beans were 0.54 and 1.926 t/ha, respectively; by contrast, all intercropping treatments had a lower thrips population with higher outputs (Fig. 2). The treatment 100 + 50 kidney bean + basil with 0.208 thrips per leaf and 2.756 (t/ha) yield showed the highest performance (Fig. 2).

Discussion

It is widely known that diversifying agriculture systems (*e.g.,* through intercropping) prevents pest outbreaks and increases the sustainability of agroecosystems (El-Wakeil *et al.,* 2020). Intercropping brings species diversity to the cropping systems and makes the systems more resilient against environmental perturbations, thus enhancing food security (Frison *et al*., 2011).

In an investigation of crop species diversification's impact on the presence of 198 pest species, a decrease in their number was confirmed in 59% of cases (Risch *et al*., 1983). Intercropping with non-preferred hosts, which affects the pest's ability to discriminate between volatiles and disrupt host plant findings, may reduce damages to preferred host plants.

Finch and Collier (2000) discussed how both chemical and visual stimuli affect insects' behavior during the period before accepting a plant as a suitable host (theory based on appropriate/inappropriate landings). Two central hypotheses for the intercropping mode of action are the resource concentration hypothesis and the natural enemies hypothesis. The first one emphasizes decreasing pest availability and retention in the preferred crop (Van Driesche *et al*., 2008). Finding a host plant may be more difficult when non-host plants surround it. However, the outcomes are varied because of variations in the plant species selected for intercropping.

The underlying mechanism most likely involves the repellent chemicals hypothesis (Uvah and Coaker, 1984), in which the volatile organic compounds (VOCs) emanate from aromatic plants interfere with the ability of a herbivore to find a host plant, feed, migrate and breed, collectively preventing pest population build-up (Finch *et al.* 2003). Indeed, VOCs have insecticidal, antifeedant, and repellent effects on insect arthropods (Song *et al.,* 2010).

Several studies have demonstrated that the odors from aromatic plants are most effective at repelling, feeding, and mating pests on host plants (Lu *et al*., 2007; Tajmiri *et al*., 2017; Midega *et al*., 2018; Zarei *et al*., 2019).

One study showed that compared with the non-intercropped plots, the cotton-basil intercropping system significantly reduced total pest infestation and led to a 50% reduced abundance of the pink bollworm *Pectinophora gossypiella* Saund. Basil, known for its repellent effect on various insect pests (Schader *et al.,* 2005; Basedow *et al*., 2006), also affected the movement and abundance of the beneficial epigeic fauna (*e. g*., Coleoptera, Araneae, Gryllidae). Aharoni *et al.* (2003) indicated that the volatile organic compounds emitted from plant tissues could directly affect herbivore physiology and behavior due to their potentially toxic, repellent, or deterrent properties. Bennison *et al.* (2001) found that rosemary *Rosmarinus officinalis* L. has repellent effects on

Frankliniella occidentalis (Pergande) (Thysanoptera: Thripidae).

Allam *et al. (*2009), studied the effect of intercropping of aromatic plants on the population of three main pests and their associated predators with three bean varieties at Fayoum and Gharbia Governorates, Egypt. They proved that each mint, fennel, and black cumin significantly reduced the *Tetranychus urticae* population on *P. vulgaris*. A significantly higher thrips population was observed in the monocropping system rather than in mixed cropping (Pankeaw *et al.*, 2011). Intercropping onion crops achieved up to 15.7% thrips reduction with spider plants *Chlorophytum comosum* Thunberg. (Gachu *et al.*, 2012).

Gombac and Trdan (2014) also found the least thrips damage to leek plants when intercropped with birdsfoot trefoil *Lotus corniculatus* L. Other intercropping systems that have significantly reduced thrips population and plant infestation include leek with clover (Belder *et al.*, 2000), leek with carrot, and clover with French bean (Kucharczyk and Legutowska, 2002). Thrips injury in the carrot-onion mixed cropping system is not as economically damaging as injury to the monoculture of onions (Alston and Drost, 2008). The current study results align with the previous documents; thus, aromatic plant volatiles was responsible for decreasing *T. tabaci* population as thrips adults were supposedly being repelled by volatiles from non-host plants.

The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with monoculture cropping (Mucheru-Muna *et al.,* 2010). Yield increase occurs because environmental factors such as light, water, and nutrients are more efficiently absorbed and converted to crop biomass by the intercrop over time and space. This could be assigned to differences in competitive ability for resources between crops, which originate from the character variations of the mixed crops such as canopy development rates, final canopy size (width and height), a photosynthetic adaptation of canopies to irradiation conditions, and root taking depth (Tsubo *et al.,* 2001).

The more efficient resource exploitation in mixed cropping happens because of inconsistency in resource exploitation temporally and locally (Echarte *et al.,* 2011). Akhtar *et al*. (2015) reported increased productivity of 35.24 to 62.64% in the maize-leafy vegetables intercropping system. Similarly, Islam *et al*. (2014) reported 11.17 to 26.67% yield increase in the brinjal-leafy vegetables/legume intercropping system, and Ahmed *et al*. (2013) found 28 to 45% yield advantages in okra-leafy vegetables intercropping design.

It has been proposed that LER is an index of combined yield to evaluate the effectiveness of all intercropping combinations (Willey and Osiru, 1972). Hayder *et al.* (2003) reported that the LER range was 1.39 to 1.52 in intercropping of corn with soybean. In the intercropping system, root interaction could increase the root activity and microbial quantity in the rhizosphere (Zhang, 2013). Interspecific interaction between species in the rhizosphere can also enhance nutrient availability and uptake in intercropping (Li *et al.,* 2010).

Mixed cropping than monocrops reduced production risk when one cultivated crop in a mixed system. It also reduces disease and pest incidences (Lithourgidis et al., 2011; Vasilakoglou et al., 2008), severe drawbacks of the monocropping system. Moreover, it also helps the farmers to maximize water use efficiency (Yang et al., 2011), maintain soil fertility (Ilany et al., 2010), improve soil conservation, minimize soil erosion, provide resistance against lodging, enhance weed control (Corre-Hellou et al., 2011).

Trdan *et al.* (2006) also obtained similar results of thrips suppression and higher onion bulb yield when onion was intercropped with white clover. Therefore, it can be stated that a mixture of several plants could be investigated as an alternative and a more profitable approach to pest management. The significant reduction of the thrips population on kidney beans with these aromatic plants intercrop in the current study concurs with previous findings by Waiganjo *et al*. (2007).

Finally, our results showed that the intercropping system reduced the thrips population. Additionally, all intercropped treatments had higher yield and LER than common bean sole-crop culture; however, chemical control is still the most common method against thrips. We propose that intercropping should be considered with other thrips control strategies within an IPM context.

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Statement of Conflicting Interests

The authors state that there is no conflict of interest.

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تأثیر کشت مخلوط افزایشی لوبیا *Phaseolus vulgaris* با تعدادی از گیاهان دارویی بر جمعیت تریپس پیاز *Thrips tabaci*

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چکیده: کشت مخلوط به‌صورت کشت هم‌زمان دو یا چند محصول زراعی در کنار یکدیگر در یک مزرعه تعریف می‌شود. این روش مزایای زیادی از جمله کاهش جمعیت آفات را در پی دارد که متعاقباً سبب افزایش عملکرد خواهد شد. این مطالعه با هدف مقایسه اثر کشت مخلوط افزایشی لوبیا *Phaseolus vulgaris* L. با تعدادی از گیاهان دارویی شامل گشنیز، زنیان، ریحان و شوید روی جمعیت تریپس پیاز *Thrips tabaci* L. انجام شد. تیمارها شامل کشت خالص لوبیا قرمز، کشت ۵۰ + ۱۰۰ لوبیا قرمز + گشنیز، کشت ۵۰ + ۱۰۰ لوبیا قرمز + زنیان، کشت ۵۰ + ۱۰۰ لوبیا قرمز + ریحان و کشت ۵۰ + ۱۰۰ لوبیا قرمز + شوید بود. پس از ظهور نخستین علائم تغذیه تریپس پیاز، نمونه‌برداری در شش مرحله با فاصله یک هفته انجام شد. برگ‌های جمع‌آوری شده در هر تاریخ نمونه‌برداری به آزمایشگاه منتقل و تعداد لاروها و حشرات کامل تریپس در تیمارهای مختلف ثبت شد. نتایج نشان داد که جمعیت تریپس به‌صورت معنی‌داری تحت تأثیر سیستم کشت مخلوط است. کم‌ترین و بیش‌ترین تعداد تریپس‌ها در هر برگ به‌ترتیب در تیمارهای کشت مخلوط لوبیا قرمز + ریحان و تیمار لوبیای خالص (۰/۲۰۸ و ۰/۵۴۰ تریپس در هر برگ) ثبت شد. به‌علاوه، یک رابطه منفی و معنی‌دار بین تعداد تریپس‌ها و عملکرد لوبیا برقرار بود بدین‌صورت که کم‌ترین تعداد تریپس با ۰/۲ در هر برگ و بیش‌ترین میزان عملکرد با ۲۷۵۶ کیلوگرم در هکتار در تیمار کشت مخلوط لوبیا + ریحان ثبت شد. هم‌چنین، مشخص شد کشت مخلوط سبب افزایش شاخص LER (Land Equivalent Ratio) در مقایسه با تک‌کشتی لوبیا قرمز می‌شود. برای نمونه، در تمام تیمارهای کشت مخلوط شاخص LER نسبت به تک‌کشتی لوبیای قرمز بالاتر بود که در این میان، تیمار لوبیا قرمز + ریحان دارای LER بیش‌تری بود. درنهایت، کشت مخلوط لوبیا با تعدادی از گیاهان دارویی می‌تواند به‌عنوان یک راهبرد دوستدار محیط‌زیست در مدیریت کنترل آفات (IPM) مورد توجه قرار گیرد.

واژگان کلیدی: تک‌کشتی، چندکشتی، LER، حفاظت، کشاورزی پایدار

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