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Effects of wheat-oilseed rape intercropping and fertilizers on the population density of *Sitobion avenae* and its natural enemies

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Abstract

According to a field experiment at Research Farm of Tabriz University, Tabriz, Iran, during 2010-2011, four cropping system and two types of fertilizer were used to determine the effects of wheat-oilseed rape intercropping on the population density of wheat aphid, *Sitobion aveana* (Fabricius, 1775) and its natural enemies. The results showed that the decreasing of wheat aphid population density was in agreement with increasing of its natural enemies particularly ladybird, *Coccinella septempunctata* L., 1758 and common lacewing, *Chrysopa carnea* (Stephens, 1838). It was concluded that wheat-oilseed rape intercropping could control *S. avenae* especially under narrow wheat strips and high ratio of oilseed rape to wheat strips. Fertilizer treatments and their interaction with cropping systems had no significant effect on population density of wheat aphid and common lacewing, but the interaction of fertilizer with cropping system treatments was significant for population density of ladybird at the anthesis complete stage as 8:3 treatment (wheat: oilseed rape) under 50% chemical plus biological fertilizer had the highest mean number of ladybird.

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Introduction

Planting large monocultures of genetically homogeneous crops often lead to adaptations of herbivores to plant defenses (Altieri and Rosset, 1995). Concentrated plant resources in monocultures enable herbivorous insects to locate their host plants more easily than in diverse plant stands (Root, 1973). Increasing biodiversity in agro-ecosystems can result in a hierarchy of benefits for pest management (Gurr *et al.,* 2003). The presence of non host plants in intercrops creates physical, chemical and behavioral barriers to invasion and colonization of the crop by pests (Altieri and Lectourn, 1982; Kostal and Finch, 1994). Additionally, the provision of floral 'resource subsidies' for predators and parasitoids (Tylianakis *et al.,* 2004) can enhance natural-enemy effectiveness through aggregation, sex-ratio changes, increases in longevity, fecundity, parasitism rates and ultimately can reduce pest populations (Wratten *et al.,* 2002).

Both oilseed rape, *Brassica napus* L., 1753 and wheat, *Triticum aestivum* L., 1753 are planted as monoculture in many countries, however intercrops of the two species offer the potential benefits in integrated pest management. At the time of blooming, the flowers added valuable resources to numerous species of bees and natural enemies. In fact, adding flowers to an agroecosystem for the enhancement of beneficial insect populations has shown promise as a strategy to enhance biological control. These floral resources can provide enough floral nectar and pollen to enhance natural enemy fitness (Landis *et al.,* 2000; Irvin and Hoddle, 2007).

Aphids are small insect herbivores renowned as pests of agriculture, horticulture and forestry. They inflict economic damage directly by feeding and indirectly by transmitting plant viruses (Blackman and Eastop, 2007). The wheat aphid, a monoecious species completing its life cycle on members of the Poaceae family, lives on the leaves of Poaceae before heading, then it moves on the ears (Vereijken, 1979; Reimer, 2004).

The studies of Zhang and Li (1996) on cotton - wheat intercropping showed that cotton monoculture had significantly more aphids and mites (*Allothrombium ovatum,* Zhang and Xin, natural enemy of aphid) than intercropped fields. They suggested that the intercropping reduced aphid migration. Strip intercropping of wheat and alfalfa significantly increased the egg and larval densities of the mite *(Allothrombium ovatum)* as well as the percentage of wheat aphid *(Macrosiphum avenae)* which was parasitized by larval mites compared to the monoculture of wheat (Ke-Zheng *et al.,* 2007). The investigation's results of Wang *et al.,* (2008) on wheat-oilseed rape and wheat-garlic intercropping showed that the population density of *S. avenae* in wheat-oilseed rape and wheat-garlic intercropping fields was significantly lower than that of in wheat monoculture fields. The population density of ladybird (natural enemy of wheat aphids) and the ratio of ladybird to *S. avenae* were higher in wheat-oilseed rape intercropping.

Increases in the production cost, and the hazardous nature of chemical fertilizers for the environment has led to a resurgence of interest in the use of biofertilizers for enhanced environmental sustainability, lower cost production and good crop yields. Plant growth-promoting rhizobacteria (e.g. *Azotobacter chroococcum* as free living nitrogen fixing bacteria and *Bacillus megatherium* as phosphate dissolving bacteria) have been successful in promoting the growth of crops such as canola, soybean, lentil, pea, wheat and radish have been isolated (Glick, 1995; Timmusk *et al.,* 1999). Better growth of plants and improved yield depends upon balanced fertilization, which in turn has indirect effect on pests. Khattak *et al.,* (1996) reported that application of nitrogen alone increased the aphid infestation, whereas nitrogen and phosphorous in combination suppressed the aphid attack.

In the previous studies the effects of cropping systems included mono and inter cropping of wheat-oilseed rape and chemical fertilizer on related pest and natural enemies were assessed as alone, so there is no information about combined effect of wheat-oilseed rape intercropping and chemical and biological fertilizers on target insects. Therefore in this projects our objects were evaluate the effects of wheat monoculture and wheat-oilseed rape intercropping under chemical and biological fertilizers application on wheat aphids and its natural enemies.

Material and methods

Experimental sites

A field experiment was conducted during winter season of 2010-2011 at Research Farm of Tabriz University, Tabriz, Iran (Latitude, X: 46° 17´ E; Y: 38° 05´ N, Altitude 1360m a.s.l.).

Experimental design and treatments

The factorial set of treatments was arranged with in RCBD (randomized complete block design) in 3 replications with 4 cropping systems (A_1: sole cropping of wheat, A_2: strip intercropping of wheat-oilseed rape with 8 rows of wheat and 3 rows of oilseed rape, A_3: strip intercropping with 12 rows of wheat and 4 rows of oilseed rape and A_4: strip intercropping with 16 rows of wheat and 5 rows of oilseed rape) and 2 fertilizer types (B_1: 100% chemical fertilizer and B_2: 50% chemical plus biological fertilizer). Chemical fertilizers included Triple superphosphate and Urea and biofertilizers were Barvar2 (include phosphate dissolving bacteria) and Nitrazhin (include free living nitrogen fixing bacteria). For B_1 and B_2 treatments, 100kg/ha of Triple superphosphate (46% P) and 200kg/ha Urea (46% N) as well as half of these quantities plus biological fertilizers were used, respectively. Triple superphosphate was applied at sowing time but Urea was used equal-splitted at stages sowing time, stem elongation time and before anthesis. Biofertilizers applied at sowing time as seed inoculation. The seeds of wheat (cultivar: Alvand) and oilseed rape (cultivar: Okapi) were

simultaneously sown by hand on 15 Sep. 2010. Plot size in each cropping system was different (A_1: 15m^2 A_2: 22.5m^2 A_3: 30m^2 and A_4: 35m^2) and consisted of different number of rows of 5m length, spaced 20cm apart for both plant.

Sampling method

The sampling method was followed with a modification of the procedure detailed by Wang *et al.,* (2009). The number of aphids and its predators were recorded at 4-day intervals from 20 May to 18 June from each plot. Ladybirds (all stages) and common lacewing (larval stage only) on all wheat plants within a one square meter covering five rows of wheat were counted and identified. Sampling of *S. avenae* was adopted a "Z" sampling pattern. Three sampling sites were chosen from each plot. Within a sampling site, ten wheat tillers were randomly selected and were used as a sampling unit, 3 units (30 wheat tillers) were sampled from each plot, and the number of *S. avenae* was counted on all tillers.

Data analysis

The obtained data for density of studied insects were transformed by SQRT(X+0.5) and were analyzed using ANOVA with SAS 9.1 software and means were compared using LSD test. Excel software was used to draw figures.

Results

Variance analysis of the data showed that population densities of wheat aphid, ladybird and common lacewing were affected by cropping systems at the anthesis complete stage (247 days after sowing) and soft dough stage (271 days after sowing) of wheat (Table 1). Fertilizer treatments had no significant effect on density of mentioned insects, but cropping systems×fertilizers interaction was significant on density of ladybird at anthesis complete stage (Table 1).

The abundance of aphids was significantly lower in strip intercropping than that of wheat sole cropping at two growth stages of wheat. At the anthesis complete stage, the mean numbers of wheat aphid were 149.00, 68.67, 46.83 and 96.5 in sole cropping of wheat, 8:3 (A_2), 12:4 (A_3) and 16:5 (A_4) row proportions of wheat-oilseed rape intercropping systems, respectively. (Fig. 1). The highest number of aphid was obtained in sole cropping which had no significant difference with A_4, but it had significant difference with A_2 and A_3.

Table 1. Analysis of variance results for population densities of wheat aphid, ladybird and common lacewing at two wheat growth stages, affected by cropping systems and fertilizers.

		MS					
S.O.V	df	Wheat aphid		Ladybird		Common lacewing	
		S_1	S_2	S_1	S_2	S_1	S_2
Block	2	1.042	5.597	0.022	0.613	0.069	0.461
Cropping system	3	38.456*	51.115**	1.083**	4.311**	0.595**	1.141*
Fertilizer	1	15.089	6.365	0.504	1.283	0.065	0.277
Crop. Sys.×Fertil.	3	5.901	9.894	0.771*	0.373	0.065	0.956
Error	14	9.055	8.501	0.181	0.446	0.064	0.306
Total	23	---	---	---	---	---	---
CV (%)	---	33.92	27.19	23.01	25.23	16.41	30.73

*Statistically significant at $p<0.05$. **significant at $p< 0.01$.

S_1: Anthesis complete stage.

S_2: Soft dough stage.

Predators of wheat aphids were identified as ladybird, *Coccinella septempunctata* and common lacewing, *Chrysopa carnea*. Mean number of ladybird was highest in A_2 (6.00) that it had no significant difference with A_3 and A_4 at the anthesis complete stage. The lowest number of ladybird was observed in A_1 (1.67) (Fig. 2). Also, maximum number of common lacewing was achieved in A_3 (3.83) that it had no significant difference with A_2 (Fig. 3). The lowest number of lacewing was observed in A_1 and A_4 at this stage (Fig. 3).

At the soft dough stage of wheat, mean number of *S. aveana* in sole cropping (232.83) was significantly higher than all of those intercropping systems (Fig. 1) that followed by A_4 (97.67), A_2 (94.00) and A_3 (88.33). At the same stage, A_2 with 10.67 and A_3 with 12.67 mean number of Ladybird had significant difference with A_1 and A_4 (Fig. 2). Similarly, mean number of lacewing was lower in A_1 and A_4 than those of A_2 and A_3 (Fig. 3).

Interaction of cropping system×fertilizer on mean number of ladybird at anthesis complete stage of wheat (Fig. 4) showed that A_2B_2 with 8.67 ladybirds on one square meter had the highest mean number compared to other treatments followed by A_3B_2. The lowest mean number was belonged to A_1B_2 (1.5). In A_1 and A_4 under B_1 treatment, density of ladybirds was more than that of B_2 treatment, in contrast, in A_2 and A_3 under B_1 treatment density of ladybird was lower than that of B_2 treatment (Fig. 4).

Discussion

The experimental results demonstrated that strip intercropping of wheat-oilseed rape can effectively to control of *S. avenae* population density. This reduction of *S. avenae* population density can be attributed to abundance of natural enemies due to increase of biodiversity. It suggests that the increasing biodiversity make suitable niche for natural enemies which induce biocontrol of pests (Andow, 1991; Stiling *et al.,* 2003). The addition of second plant can benefit for natural enemies by providing them with favorable microclimate (shelter) (Thomas *et al.,* 1992; Hossain *et al.,* 2002), a source of alternative hosts or prey (Mathews *et al.,* 2004), or a supply of plant-based foods (i.e., nectar and pollen) (Wackers *et al.,* 2007). For example Zhang and Li (1996) found that the strip cropping resulted in a moister, shadier soil surface microclimate which caused adult female mites to lay more egg pods. As well as the non-furrowed areas of the intercropped fields could provide a more suitable habitat for mites overwintering (Zhang *et al.,* 1994).

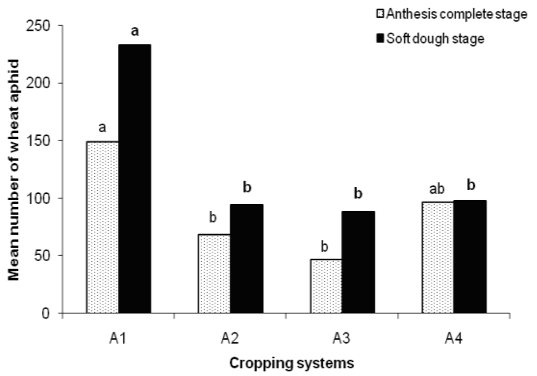

Fig. 1. Mean number of wheat aphid in different cropping systems.

(A_1: sole cropping of wheat, A_2: strip intercropping of wheat-oilseed rape with 8 rows of wheat and 3 rows of oilseed rape, A_3: strip intercropping with 12 rows of wheat and 4 rows of oilseed rape and A_4: strip intercropping with 16 rows of wheat and 5 rows of oilseed rape). Different letter (s) indicating different at $p \leq 0.05$.

It is possible to control wheat aphids by using floral plants to design an ideal intercropping system. The addition of floral resources can enhance the survival, fecundity, longevity and behavior of natural enemies in order to increase their effectiveness (Kozár *et al.,* 1994; Landis *et al.,* 2000; Tylianakis *et al.,* 2004; Berndt and Wratten, 2005). *Chrysopa carnea* adults on the other hand are not predacious but feed primarily on pollen, nectar and honeydew (Principi and Canard 1984; Hogervorst *et al.,* 2007).

Our results showed that different row ratio of intercropping gave different results. At the mentioned two growth stages, although the mean number of wheat aphid in A_4 (16:5 combination of wheat-oilseed rape) was lower than that of sole crop, A_4 was not as profitable as A_2 (8:3 row ratio) and A_3 (12:4 row ratio) to decrease population density of wheat aphid (Fig. 1). These results are in agreement with Lavandero *et al.,* (2006) findings that showed the number of parasitoids decreased significantly with the distance from the flowers. Field experiments showed that parasitism declined exponentially with increasing distance from floral patches, reaching zero beyond 14 m (Tylianakis, 2004). When wheat and oilseed rape were intercropped in wide strips, mutual inhibition was observed, as the mean number of each predator species was less than those of the narrow strips of intercropping. As the row number of wheat was reduced to 12 and 8, the profit of oilseed rape became greater than that of 16 wheat rows.

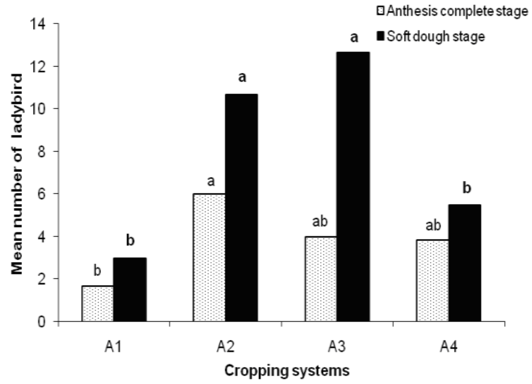

Fig. 2. Mean number of ladybird in different cropping systems.

Therefore, intercropping systems gave a control advantage for wheat aphid. The results showed that the peak abundance of ladybird and lacewing accorded with the lowest population density of aphids (Figs. 1-3). Similar result was recorded by Wang *et al.,* (2009), whereas, the densities of *S. avenae* were significantly higher on the monoculture system than on either the 8:2 intercropping system (eight rows of wheat with two rows of oilseed rape) or the 8:4 intercropping system (eight rows of wheat with four rows of oilseed rape). The mean number of predators of *S. avenae* was significantly higher in two intercropping systems than those in the monoculture system. Wheat-oilseed rape intercropping conserved more predators than that of in wheat monoculture fields.

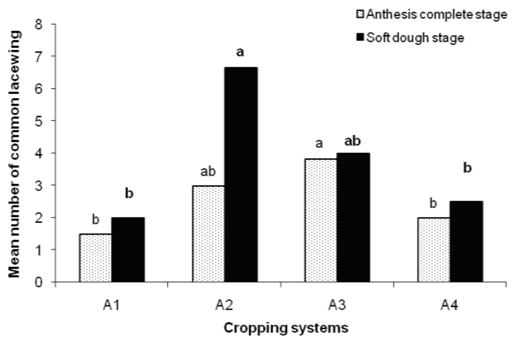

Fig. 3. Mean number of common lacewing in different cropping systems.

Increasing rate of *S. avenae* on wheat is strongly affected by the growth stage of the host plant, in that the highest rate observed by feeding on ears at the milky-ripe stage (Vereijken, 1979). At the present study, nearly, the almost of under studying insects were observed at high density at soft dough stage in comparison with another stage (Fig. 1-3), but the increased of natural enemies in A_2 and A_3 were higher than those of the other treatments (Fig. 1 and 2).

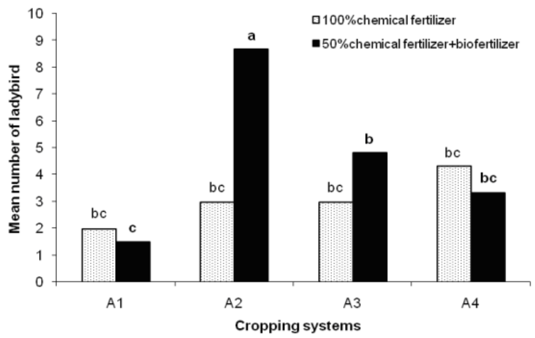

Fig. 4. Effect of cropping systems at different types of fertilizer on mean number of ladybird at anthesis complete stage of wheat.

On the basis of this research, fertilizers had no significant effect on population of wheat aphid and its natural enemies (Table 1). The 3 rows of oilseed rape and 8 rows of wheat combination under 50% chemical fertilizer plus biofertilizer had the best effect on ladybird population (Fig. 4) that it is in agreement with the results of Archer *et al.,* (1995) and Ge *et al.,* (2003). According to Singh *et al.,* (1995) an increase in the level of nitrogen application resulted in an increase in the infestation of Indian mustard by *Lipaphis erysimi*, while significant reductions in infestation were observed due to addition of phosphorus and potassium.

Therefore, it was suggested that intercropping systems cause to increase crop diversity in the agroecosystems which significantly affect on the abundance of insect herbivores and their natural enemies. Population density of wheat aphid in the two intercropping systems was significantly lower than those of the sole cropping of wheat. There were more predators in wheat-oilseed rape intercropping systems compare to wheat sole cropping. Thus, it can be concluded that strip intercropping of wheat and oilseed rape in 8:3 and12:4 row ratios resulted the maximum increasing in the natural enemies of wheat aphid as well as decreasing of population density of this important pest.

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