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Role of Hunting Spiders in Suppression of Wheat Aphid

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Abstract.- In the present study, we assessed the predatory role of three most dominant hunting spiders (*viz*., *Lycosa terrestris, Pardosa birmanica* and *Oxyopes javanus*) against insect pests of wheat crop in laboratory and field conditions. For laboratory evaluation, both choice and non-choice feeding experiments were performed using three pest species, *Mythimna separate* (Oriental armyworm), *Sesamia inferens* (pink graminous stem borer) and *Sitobion avenae* (aphid). Lab experiments showed that spiders consumed all the prey items offered but in different proportions. Killing rate of aphid (nymph and adult) was higher than other prey types. *Oxyopes javanus* was more voracious predator as compared to *Lycosa terrestris* and *Pardosa birmanica.* Females consumed higher number of prey than males in both choice and non-choice feeding tests. In field, seasonal variation was recorded in the density of aphid and other prey items. It also affects the diet composition of each spider species. The results suggest that spider species residing the wheat fields consume aphid when present in the field and may help in the reduction of aphid populations below the economic injury level.

Key words: Biological control, cereal crop, food preference, spider

INTRODUCTION

Spiders are among the most abundant and diverse generalist predators in agroecosystems. All spiders are predaceous (except *Bagheera kiplingi*) and play a key role in the suppression of the herbivore insect pests (Marc *et al*., 1999; Symondson *et al*., 2002; Nyffeler and Sunderland, 2003). Most of them feed on different insects and show both functional and numerical responses to their prey densities. However, they cannot track one particular prey species for a long time in agroecosystem. Their density independent responses and polyphagy enable them to persist in agroecosystem during the period of low prey density and retard the growth of insect pest population in early crop (Greenstone and Sunderland, 1999; Marc *et al*., 1999; Hole *et al*., 2005). The role of spiders as biological control agents depends on their density in the agroecosystem (Lang *et al*., 1999). High abundance of spiders may reduce herbivore population because of the increased predation rate (Carter and Rypstra, 1995). However, high spider densities also cause intraguild predation and cannibalism that release pest from predation pressure and increase their abundance in the field (Wagner and Wise, 1997; Synder and Ives, 2001).

Spiders usually aggregate in the area where food is abundant (Harwood *et al*., 2003). They maximize their fitness by optimal balancing of nutrients rather than by maximizing of energy consumption (Toft, 1999). So indiscriminate feeding may be disadvantageous to the organisms due to variations in the quality of the prey (Uetz, 1992; Toft and Wise, 1999; Bilde *et al*., 2000). Prey preference is usually based on the quantity and quality of prey available in the feeding patch, age and size of predator, habitat structure and weather conditions (Riechert and Lockley, 1984; Wise, 1993; Pitt and Ritchie, 2002). The compositions of the diet also change with the internal state and experience of the spider (Toft, 2005). In females consumption rate is usually higher than that of males because females require extra energy for reproduction (Walker and Rypstra, 2001). However, the consumption per unit weight and the proportion of food assimilated fluctuate little between the instars and within an instar (Isikber and Copland, 2001).

In wheat fields of Punjab, Pakistan, aphids are the most abundant pest although it rarely crosses economic threshold level. Hashmi *et al*. (1983) reported attack of four species *viz*., *Sitobion avenae* (Fabricius), *Schizaphis graminum* (Rondani), *Rhopalosiphum rufiabdominalis* (Sasaki), and *Rhopalosiphum maidis* (Fitch) on wheat crop of this area. Other pests such as stem borer, *Sesamia*

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inferens Walker and Oriental army worm, *Mythimna separata* Walker cause serious damage occasionally. Yield losses are influenced by the stages of the crop at which attacks of pest occur and environmental conditions of the area. Change in the farming system such as introduction of high yielding varieties, increased use of fertilizers, increased area of irrigated crop, continuous rotation of rice and wheat has increased the losses due to these pests (Sharma *et al*., 2002). These pests decrease productivity of the fields by reducing the quality and quantity of grain yields (Aheer, 2006; Khattak *et al.*, 2007). The natural enemy complex of wheat in Punjab, Pakistan is dominated by many generalist predators which also included spiders. However, their abundance is not sufficient to prove their effectiveness as biological control agent. The aims of the present study were to investigate the predatory efficiency of agrobiont hunting spiders against aphids of wheat crop. For this purpose, choice and non- choice feeding experiments were performed in the lab to assess the quantitative consumption of aphids in the absence and presence of other prey items. Data about predation activity of spider species was also collected from wheat fields. It helps to find out variations in the diet composition of agrobiont spiders with the season and to confirm the inclusion of aphids in the diet in natural conditions.

MATERIALS AND METHODS

For the study, three species of hunting spiders viz., *Lycosa terrestris* (Family Lycosidae), *Pardosa birmanica* (Family Lycosidae) and *Oxyopes javanus* (Family Oxyopidae) were selected due to their high abundance in the wheat fields throughout the crop season (Butt and Sherawat, 2012). For experiments, only adult spiders were collected alive from the wheat fields during January through April using sweep net and suction device. Spiders were singly stored in the 50 ml plastic cups containing sand, crumpled paper towel and leaves for shelter and moisture. Muslin cloths wrapped around the mouths of each cup and held tight by rubber bands. Spiders were kept at temperature 22 to 32°C, 55–65% humidity and a light: dark cycle of 14:10 h. No specimen was used more than once in the experiment.

To determine the killing potential of these spiders, only 1st and 2nd instar larvae of *Mythimna separata* (armyworm) and *Sesamia inferens* (pink graminous stem borer), and 4th nymphal instar and apterous adult of *Sitobion aven*ae (aphid) were used as prey. These insects are common pests of the wheat fields in the study area. Larvae of *S. inferens* and *M. seperata* were obtained from the laboratory of Agriculture Department, Sheikhupura. However, aphids (nymphs and adults) were collected from the wheat fields and kept alive in the laboratory on the wheat plants till used in the experiments.

No-choice feeding tests

Feeding experiment was conducted in the laboratory with six types of prey (*i.e.*, larvae of first or second instars of stem borer or armyworm, nymph or adult of aphids) to assess the killing potential of agrobiont spider species. Before laboratory experiment, spiders were fed with a mixture of insects collected from the wheat fields to the satiation level and then starved for four days to standardize the hunger levels. Single starved spider was placed in a container (12.5 cm diameter, 3.25 cm height) and only one type of food was provided in excess (10 specimens). For one experiment, 30 spiders of one species were used and experiment repeated twice at different time. The container was examined after 24 h and numbers of dead prey items were recorded. In control containers (n = 10), ten specimens of each prey type were placed separately but without spider. Mortality data of 24 h was used to assess the natural mortality rate in prey during same time.

Choice feeding tests

This test was performed to assess the predatory preference of agrobiont spiders in the presence of different types of prey. The procedure was similar as described in non-choice feeding experiment. However, in the test single starved spider was exposed to mixture of all preys types mentioned earlier. Ten specimens of each prey type were placed in the container and dead specimens were recorded after 24 hours.

Fields observations for the predators

To record the diet composition of spiders in the field, direct observations (separately for each species by a single observer) were made from January through April 2010. For this purpose, two wheat fields approximately 500 meters apart were selected. These fields were not treated with any insecticides or herbicides. All the predators were diurnal so data was not recorded at night. In the field, observations were conducted for 1 h at following times: 06:00, 09:00, 12:00, 15:00, and 18:00 per day. Observer walked in the field randomly and if he found a spider with a prey, he tried to identify the prey to the order level. If possible spider was captured and brought to the laboratory for the identification of the food present in its chelicerae. To record the variation in the abundance of aphids, 30 tillers were randomly selected in the field during a trapping session and the number of aphids present per tiller was recorded.

Statistical analyses

Before any statistical analyses, normality of the data was checked using Kolmogorov–Smirnov test. The differences in the predation rates of spiders for different prey in choice and non choice feeding experiments were assessed using ANOVA. To find which of the three hunting spiders was most active in killing or consumption of pests, Tukey's test was used. Wilcoson signed-rank test was used to compare the monthly diet of three spider species in the fields. To assess seasonal variation in the diet of a species Friedman test was applied. The difference in the feeding preferences of male and female spiders was checked using paired *t*- test.

RESULTS

Non- choice feeding test in laboratory

Results showed that in the laboratory each hunting spiders consumed all types of prey offered to them (Table I). However, aphid nymph was the most consumed diet of all species (F5, 54 = 18.64 for *L. terrestris*, 15.35 for *P. birmanica* and 21.47 for *O. javanus,* P< .01). The feeding potential of *O. javanus* was more than *L. terrestris* (t = -6.90; P = 0.000) and *P. birmanica* (t =-4.71; P = 0.00). However, no difference was observed in the consumption rate of *L. terrestris* and *P. birmanica* (t = 1.80; P = 0.08). Consumption rate of females of all spider species was higher than males in the studied spider species (t = -4.32; P =0.002 for *L. terrestris*; t = -3.80; P = 0.004 for *P. birmanica* and t = 4.54; P = 0.001 for *O. javanus*).

Choice feeding test in laboratory

Prey preferences of three hunting spiders are similar as based on the choice feeding experiments. All the spiders prefer to feed on aphid nymph as compared to other available prey (Table II). A significant low consumption of all food items was recorded in this experiment as compared to non-choice feeding experiments. The comparison of the pest-killing rate of three species showed *O. javanus* to be the most active hunters than other species (F2, 87 =122.85; P < 0.001 for males and F2, 87 =158.65; P < 0.001 for female). Killing rate of females was higher than males spiders in all species (t = -3.32; P = 0.009 for *L. terrestris*; t = -2.98; P = 0.015 for *P. birmanica* and t = -3.62; P = 0.006 for *O. javanus*).

Field observations

During the study, 98 specimens of *L. terrestris,* 54 of *P. birmanica* and 140 of *O. javanus* were observed in the field with the food. Most of them were captured and brought to the laboratory for the identification of prey. Results indicated that Homoptera, Diptera, and Collembola constitute main prey of three hunting spiders during study period (Table III). Data showed seasonal change in the food pattern of all the spider species (S = 21.17, P = 0.007 for *L. terrestris*, S = 17.53, P = 0.025 for *P. birmanica* and S = 21.69, P = 0.003 for *O. javanus*). In January, collembolan was major food of the lycosid spiders. With the change in the season, homoptera (aphid) and diptera become abundant in the diet. However, *O. javanus* appear in the field in February and mainly consume homoptera and diptera individuals. Other preys consumed by hunting spiders include: Coleoptera, Dermoptera, Hymenoptera, Lepidoptera, Orthoptera, and others (unidentifiable). Aphid population starts to appear in the field in January and reached at peak during 2^{nd} and 3^{rd} week of March. This also appears in the diet of the studied

Table I.- Mean number of prey killed by different sexes of hunting spiders after 24 h of exposure in non- choice feeding experiment

Predator	Sex	Stem borer 1st instar	Stem borer 2nd instar	Army worm 1st instar	Army worm 2nd instar	Aphid nymph	Aphid adults
Lycosa terretris	Female	6.3 ± 0.3	4.2± 0.4	5.2 ± 0.3	4.8 ± 0.5	7.5 ± 0.5	5.4 ± 0.5
	Male	5.0± 0.4	4.2 ± 0.4	4.1 ± 0.5	3.9 ± 0.4	6.2 ± 0.5	4.8 ± 0.6
Pardosa birmanica	Female	6.7 ± 0.3	5.2 ± 0.3	6.7 ± 0.3	5.6 ± 0.3	8.2 ± 0.2	6.2 ± 0.5
	Male	5.1 ± 0.5	4.6 ± 0.3	6.0 ± 0.2	4.3 ± 0.3	7.5 ± 0.3	5.4 ± 0.5
Oxyopes javanus	Female	8.2 ± 0.6	7.7 ± 0.5	7.5 ± 0.4	6.2 ± 0.6	9.5 ± 0.1	7.1 ±0.6
	Male	6.3 ± 0.5	6.5 ± 0.6	6.4 ± 0.6	5.4 ± 0.6	8.2 ± 0.8	5.2 ± 0.6

Table II.- Mean number of prey killed by different sexes of three hunting spiders after 24 h in choice feeding experiment

Predator	Sex	Stem borer 1st instar	Stem borer 2nd instar	Army worm 1st instar	Army worm 2nd instar	Aphid nymph	Aphid adults
Lycosa terretris	Female	1.0± 0.2	0.5±0.2	0.1 ± 0.1	0.0± 0.00	4.6± 0.4	2.7 ± 0.1
	Male	0.8 ± 0.1	0.4 ± 0.1	0.1 ±0 .1	0 .0± 0.00	3.2± 0.5	2.3 ± 0.2
Pardosa birmanica	Female	1.5 ± 0.2	1 ± 0.1	1.2 ± 0.1	0.8 ± 0.3	5.5± 0.4	3.2 ± 0.2
	Male	0.9 ± 0.1	0.3 ± 0.1	0.5 ± 0.2	0.4 ± 0.1	3.9± 0.5	1.8 ± 0.1
Oxyopes javanus	Female	2.9 ± 0.2	0.8 ± 0.2	1.0 ± 0.1	0.6 ± 0.2	6.8± 0.8	4.2 ± 0.6
	Male	2.3 ± 0.1	0.6 ± 0.2	0.5 ± 0.1	0.2 ± 0.1	4.2± 0.6	3.4 ± 0.7

Table III.- Percent composition of various insect orders in the diet of the three hunting spiders in the wheat fields.

Insect order	*L. terrestris*	*P. birmanica*	*O. javanus*
Homoptera	25.3	21.9	35.1
Diptera	14.5	13.8	20.8
Lepidoptera	3.4	4.7	2.5
Orthoptera	3.4	2.4	3.3
Hymenoptera	5.7	7.5	5.8
Coleoptera	10.5	7.3	10.4
Collombola	21.3	30.1	0.0
Dermaptera	1.0	1.6	2.1
Unidentified	14.9	12.2	20.0

March. This also appears in the diet of the studied species. However, monthly diet composition of the three hunting spiders did not differ statistically in March and April (Wilcoson signed-rank test, P>0.05).

DISCUSSION

The food spectrum of the ground living spiders, such as wolf spiders (Lycosidae), consist of prey species of different trophic level including herbivore insect pests of crop like aphids, detrivore, conspecifics, and other predators (Wise, 1993; Oelbermann *et al*., 2008). Studies have reported spiders as main predators of aphid in wheat crop and other cereals (Sunderland *et al*., 1987; Kajak, 1995; Nyffeler and Sunderland, 2003). Nyffeler and Benz (1982) reported that in agroecosystem aphid constituted 25% of the diet of lycosid spiders. In the present study, all the three hunting spiders consumed aphids (both nymphs and adults) in more number as compared to other food items offered in both choice and non choice feeding experiments. Toft and Wise (1999) reported that aphids are poor quality prey that allowed neither growth nor development of the spiders. That is why spider prefers other food sources to maintain their population in the field (Bilde and Toft, 1997; Beck and Toft, 2000). In the present study, spiders killed all types of offered prey in both choice and no choice feeding experiments. In the choice feeding experiment, the number of aphid killed was low as compared to non-choice feeding experiments. This showed that the availability of high quality prey (larvae of stem borer and armyworm) result in a decrease in the control of aphids. Some previous studies also reported decrease in the predation of spiders on the aphids in the presence of alternative prey (Bilde and Toft, 1997; Nyffeler and Sunderland, 2003), while some studies denied it (Sunderland *et al*., 1985, 1986; Toft, 2005). Lycosid spiders preferred mix diets even if some single prey types were highly available (Wise, 1993). Consumption of low quality prey depends on the nutritional balance of the spiders. Those spiders which were nutritionally balanced consumed three times more aphid than nutritionally imbalanced spiders (Mayntz and Toft, 2001). Toft (1995) also reported that hunger level of spider has no effect on the consumption rate of aphid. Although pure aphid diet has little or no effect on growth and development of spiders but it is not useless as food. In starved conditions, pure aphid diet increase survivorship in linyphiid and lycosid spiders. Thus, in a situation of low food availability, aphid consumption helps to maintain spider population in the agricultural fields.

The studied species are hunting spiders but *L. terrestris*, and *P. birmanica* (Lycosidae) live on ground in the cracks of soil between the crop rows, while *O. javanus* (Oxyopidae) live on foliage. The prey types used in the experiments were mainly foliage dwellers and approximately of equal size. Although, lycosids are predominately hunter on the ground, field observations and gut content analysis proved that some of them can climb to the foliage and hunt herbivore pest species (Pollet and Desender, 1987; Sunderland *et al*., 1987; Nyffeler and Benz, 1988). Winder *et al*. (1994) reported that a large number (37–348 m^{-2} day^{-1}) of aphids (dead and live) falls on the ground and remain available to the ground spiders. Lycosids are not scavengers so available dead aphid are useless to them. Live aphids return to the crop canopy in just 5.7 minutes. So their availability is continuous but low to lycosid spiders on the ground. *L. terrestris* and *P. birmanica* in this study also climbed to wheat plant and capture prey there. However, the movement of *P. birmanica* was restricted to the lower part of the plant (pers. obs.). Similarly, the specimens of *O. javanus* were also captured from the ground surface. So three studied species have similar ability to catch prey in the field.

Field studies showed that Diptera constitute major part of the food after the aphids in all the three hunting spiders. Some other studies also reported that diptera is a high nutritional value food for the spiders and makeup 25 -32 % of the food of wolf spiders (Nyffeler AND Benz, 1988) Although lycosid spiders in the long term may suffer from nutrient deficiency when feeding exclusively on *Drosophila melanogaster* (Toft and Wise, 1999; Oelbermann and Scheu, 2009). Therefore, predator shift to alternate prey such as collembolan when pest species are of low quality which affect their pest control potential (Bilde and Toft, 1997; Bilde *et al*., 2000). Tahir and Butt (2009) reported that *O. javanus* consumed more Lepidoptera in rice fields than *L. terrestris* and *P. birmanica* in the same study area. But in this study, no significant difference was recorded in the proportion of Lepidoptera in the diet of three hunting spiders. This might be due to the difference in abundance and diversity of Lepidoptera in rice and wheat fields.

Female spiders were voracious predators and consume more insect pests than the males under the similar conditions. Females usually need more energy for oviposition and brood care, while males need only the essential energy for survival (Kim, 1992). This finding supports the hypothesis of males as time minimizers and females as energy maximizers (Walker and Rypstra, 2001). In present study also, females of each spider species consumed more prey than males. All these three species of spider will reproduce in the coming months after hibernation, so for them main goal may be to store energy for reproduction.

The consumption of prey in the field and laboratory could not be correlated with each other. In the laboratory, consumption of wheat pests was higher as compared to the field data. The use of enclosed arena for the experiments altered the abiotic conditions experienced by the animal. Such changes included radiation, air and ground temperature, wind speed and relative humidity. It also increases prey – predator encounter rate and decreased cover for the prey organisms, cannibalism and intraguild predation. However, this study has shown that the studied spiders have potential to influence the density of wheat aphids in the field but still needs to prove that it actually happens in natural field conditions. The consumption rate of aphid was low in the field data but studied spider species had high abundance in field. This increased their interaction with the pest population and caused its suppression. Along with these species, a large assemblage of the spider was recorded in the wheat fields (Butt and Sherawat, 2012) which suggested that they will be helpful in controlling even those pests which are not beneficial for these predators. During the period, when preferred prey is scarce, feeding of spider on alternative foods facilitate to maintain high spider density in the fields. This behavior of spiders is important for the biological control of insect pests in the fields.

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