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Seasonal and Phenological Relationship Between Spiders and Sucking Insect Pests in Spring and Fall Maize Crops

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Key words
Maize, Leafhoppers, *Araneae, Pyrilla perpusilla*, Predator pray interaction, Maize seasons

ABSTRACT

The cultivation of maize (*Zea mays* L.) holds significant agricultural and economic importance in Pakistan, ranking as the third most valuable cereal crop after wheat and rice. To develop sustainable integrated pest management strategies, identifying insect pests and their natural predators is essential component of IPM. For this, a field experiment was carried out during spring and fall season maize field crop at the Plant Breeding and Genetics Research Area of the University of Agriculture Faisalabad. The research focused on the seasonal and phenological relationship between spiders attacking insect pests in maize field. Using a random plant sampling method, data on nymphal and adult stages of insect pests and their natural enemies were collected weekly through visual observation. Graphpad prism 5.01 version was used to present mean numbers (±SEM) per 100 maize plants, as a result, in spring season, leafhopper reached their highest mean population (118.55±21.51) per 100 maize plants on April 20th at reproductive growth stage but in fall season, at reproductive growth stage leafhoppers reach their peaked population (27.08±6.78) per 100 maize plants on October 13th. Among natural enemies, spiders (*Araneae*) reached their peak population (34.40±12.36) per 100 maize plants on May 11th at the end week of reproductive stage in the spring season, however, in fall season; spiders reached their peak population (17.76±2.82) per 100 maize plants on September 29th at vegetative growth stage. The outcome of this study emphasis the farmers' attention at reproductive stage in fall season. These findings would provide the gateway for future sustainable pest management strategies in maize cropping ecosystem in Pakistan.

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INTRODUCTION

Maize (*Zea mays* L.) being queen of cereals due to its remarkable yield potential, retains a significant position among cereal crops after wheat and rice in Pakistan. Maize contributes 3.0 % to the value added in agriculture and 0.7 % to the country's GDP. In the 2022-23 season, maize cultivation expanded by 4.1 %, covering 1,720 thousand hectares, resulting in a 6.9 % increase in production to 10.183 million tonnes compared to the previous year. It gives around 0.6 percent to gross domestic production and 3.4 % to the additional value in farming (GOP, 2023). After rice, corn has become the powerful cereal crop for its food and feed value (Alam *et al*., 2018).

Core growing areas of maize are in the districts of Sahiwal, Okara, Toba Tek Singh, Chiniot, and Faisalabad (Naqvi *et al*., 2014). In Pakistan, the highest production of maize is in Punjab, accounting for approximately 85%, followed by Khyber Pakhtunkhwa followed by around 15% in Baluchistan and Sindh contribute slightly more than 1% each to the overall production (GoP, 2023). The loss of arable land, excessive use of agrochemicals, and yield losses caused by pests have all been blamed for reduction in yields. Globally, pests and pathogens reduce maize yields by 16–41% (Savary *et al*., 2019), and global warming will inevitably result in an increase of 10–25% in the losses (Deutsch *et al*., 2018).

Pyrilla perpusilla Walker (Hemiptera: Lophopidae) is widely distributed one of the most destructive sugarcane pests in the Punjab province. In addition to sugarcane, it also feeds on wheat, barley, oats, maize, and a number of grasses (Rahman and Nath, 1940). Both nymphs and adults feed on the sap from the leaves, with the nymphs causing the most significant damage (Ganehiarachchi and Fernando, 2000). The hopper extracts phloem sap from the leaves and secretes honeydew on the foliage, which promotes the growth of sooty mold. This direct and indirect damage diminishes photosynthesis, thereby reducing both the yield and quality of maize (Butani, 1964; Bindra and Brar, 1978; Kumar and Yadav, 2006). In Pakistan, it remains active year-round, completing 3 to 4 generations annually, with peak activity occurring from July to September. Early infestations have a detrimental impact on yield, while late infestations decrease the sucrose content (Puri and Siddharth, 2001). The corn leafhopper caused directly 25-30% annual yield losses during the vegetative stage (Cunha *et al*., 2023), by laying endophytic eggs in the leaves and by removing sap with their piercing-sucking mouthparts and by transmitting several maize pathogens, like bacteria and viruses, indirectly (Virla *et al*., 2021). Researchers have investigated spiders as potential biological control agents against leafhoppers (Beyer, 1922; Howell and Pienkowski, 1971). Spiders known as generalist predators of sugarcane pyrilla are commonly present in agroecosystems worldwide (Riechert and Lockley, 1984; Michalko *et al*., 2019). However, no data is available on interaction of spiders with prevalent leafhopper and pryilla insect pests especially after the introduction of fall armyworm in Pakistan. Therefore, this study aims to advance the baseline data for sustainable integrated pest management in maize fields by providing insights for effective forecasting, monitoring, and timely control measures in response to changing climate conditions and cropping patterns. This study is focused on seasonal fluctuations, maize growth stages, and specific sampling dates. It examined the phenological and seasonal dynamics in maize fields, with particular attention to the abundance of spiders that prey on leafhoppers in maize field crops during the spring and fall seasons.

MATERIALS AND METHODS

Study area

A survey of experiments was conducted during the spring and fall seasons in the experimental research area of Department of Plant Breeding and Genetics at the University of Agriculture Faisalabad (UAF) (31° 26' 17" N and 73° 3' 59" E). Seeds of different genotypes were provided by the Department of Plant Breeding and Genetics at UAF and were manually planted at a depth of 3-4 cm on ridges. Standard agronomic practices were followed with guidance provided from the local extension staff of the Punjab Agriculture Department.

Experimental design

The total experimental field area 0.18 hectares (70.49m × 25.15m) was divided into 16 blocks -each at a distance of 0.79 meters to ensure optimal plant growth and air circulation and facilitate easier access for monitoring and data collection. The distance between the 1st controlled block to 2nd block was 1.82 meters. The spacing between beds was 0.68 meters, and the bed width was 0.79 meters. The hybrids were distributed across the blocks as follows: blocks two to seven each had seven hybrids, blocks six and seven contained eleven hybrids, block eight featured nine hybrids, and blocks nine, thirteen, and seventeen had 17 hybrids. Block ten, twelve, fourteen, fifteen, and sixteen accommodated 18 hybrids each (Supplementary Fig. 1).

Sampling

Through open field survey, a random sampling approach was used to collect insect data from 531 plants during the spring season and 562 plants in the fall season. Weekly sampling was conducted in the morning time from each plant (as a whole) and was examined visually for all insect stages except eggs of the foraging insect during three maize crop stages (i) vegetative growth stage (ii) reproductive growth stage and (iii) maturity growth stage. Leafhoppers, sugarcane pyrilla (*Pyrilla perpusilla*) and spiders (*Araneae*) were recorded throughout the vegetative, reproductive and maturity growth stages of the maize crop for two growing seasons. Morphological characteristics of above-mentioned insects were identified using a compound microscope (magnification 40-1000x) by using the classification key. Data were recorded on data sheets and collected where necessary for further identification. In spring season, the vegetative stage occurred from March 30th to April 6th, the reproductive stage from April 13th to May 11th, and the maturity stage from May 18th to May 25th. During the fall season, the vegetative stage was from September 2nd to October 13th, the reproductive stage from October 20th to November 10th, and the maturity stage from November 16th to November 24th.

Data analysis

The weekly field collected data were transferred to MS Excel and processed by converting it into mean numbers (±SEM) per 100 plants. Leafhopper and sugarcane pyrilla with their natural enemy - spiders were computed for data analysis through GraphPad Prism 5.01 version. The X-axis of the graph represented the sampling dates of maize, while the Y-axis displayed the averages of insect pest and predator. Comparison of three maize growth stages (vegetative, reproductive and maturity growth stages) for all sampling parameters (maize insect pests and predator) during spring and fall seasons were carried out using a One-way analysis of variance with Bonferroni's Multiple Comparison Test by GraphPad Prism version 5.01. A probability level of $P<0.05$ was considered as indicating statistical significance separately inside each season of the study. In this study, we employed generalized linear mixed models (GLMMs) to analyze the population dynamics of insect pests and their natural enemies in maize fields. With repeated measurements, different sampling times (dates) and locations were treated as random effects while treatments were fixed effects. A Poisson distribution was used for the count data, and the logit function was applied.

RESULTS

Seasonal population dynamics and abundance of insect pests

Overall, the densities of maize leafhoppers do not differ significantly between the spring and fall seasons ($P = 0.308$), but they do vary significantly depending on the specific dates ($P<0.001$) (Table II).

Maize leafhoppers

The population of maize leafhoppers was monitored from March 16th to May 25th during the spring season through weekly visual observations. The leafhopper was first observed in a maize field on March 30th. Over the following two weeks, this population steadily increased on April 6th and April 13th.The population then reached its peak on April 20th. Subsequently, there was a decline, observed on April 27th. The lowest mean population dynamics was recorded on May 11th and remained at zero until the final observation on May 25th (Fig. 1A). The abundance of leafhopper was more dominant during the reproductive growth stage on 20th April when compared to the vegetative (6th April) and maturity (25th May) growth stages. Moreover, the percentage of leafhoppers per 100 plants varied significantly, with values of 17.22% for vegetative, 82.56% for reproductive and 0.22% for maturity growth stages. The highest percentage (82.56%) of leafhoppers were on April 13th –to May 11th during the reproductive growth stage. Conversely, 17.22% was observed during the vegetative stage March 30th to April 6th. Notably, only a few leafhoppers were noted on May 18th to25th during maturity growth stage (Table III).

Table I. Repeated measures one way ANOVA (at 95% confidence intervals) results for the effects of maize growth stages (vegetative, reproductive and maturity growth stages) and seasons, on the population density of maize leafhopper, sugarcane pyrilla (*Pyrilla perpusilla*) and natural predator, spiders (*Araneae*) in Research Area under the study.

Factors	Sampling insects	df	F	P
Spring and fall seasons	Leafhopper	20	1.26	0.308
	Sugarcanen pyrilla (*Pyrilla perpusilla*)	25	1.025	0.374
	spider (*Araneae*)	20	0.187	0.831

Table II. Repeated measures ANOVA (at 95% confidence intervals) results for the effects of sampling seasons and dates on the population density of maize leafhopper, sugarcane pyrilla (*Pyrilla perpusilla*) and natural predator, spiders (*Araneae*) in research area under study.

Factors	Df	F	P	df	F	P	df	F	P
Seasons	20	1.26	0.308	25	1.025	0.374	20	0.187	0.831
Dates	19	25.96	<0.001	19	15.56	<0.001	19	4.61	<0.001

During fall season, population of leafhopper was observed during September 2nd to November 6th during weekly visual observation. The leafhoppers were first observed in a maize field on September 2nd. In the following weeks, the population gradually increased on September 9th, 22nd and 29th. Leafhoppers reached their peak on October 13th. The number of leafhopper decreased over the following two weeks on October 20th, 17th and remained at zero until the final observation on November 24th (Fig. 1A). The abundance of leafhoppers was more dominant during the vegetative plant growth stage when compared to other growth stages. The percentage of leafhopper per 100 plants differed significantly with values of 86.19% vegetative, 13.81% for reproductive and 0% for periods of maturity growth stages. The vegetative stage (September 2nd to October 13th) stood out with the highest percentage of leafhopper (86.19%), while in the maturity stage (November 16th to 24th) leafhoppers were entirely absent (Table III).

Sugarcane pyrilla

The densities of sugarcane pyrilla do not differ significantly between the spring and fall seasons ($P = 0.374$) (Table I). They do vary significantly depending on the specific dates ($P<0.001$) (Table II). The population of sugarcane pyrilla (*P. perpusilla)* was observed during April 6th to May 25th in spring season through weekly visual observation. The highest recorded population was on April 20th (Fig. 1B). The abundance of *P. perpusilla* was more dominant during the reproductive plant growth stage April 20th compared to the vegetative and maturity growth stages. Significant variations of Sugarcane pyrilla were observed across vegetative, reproductive and maturity growth stages. The percentages per 100 plants were 6.35% during vegetative, 79.50% during reproductive and 14.15% at maturity growth stages. It worth mentioning that the reproductive stage (April 13th to May 11th) stood out with the highest percentage of *P. perpusilla* (79.50%), while the vegetative stage (March 30th to April 6th) had the lowest percentage (6.35%) (Table III).

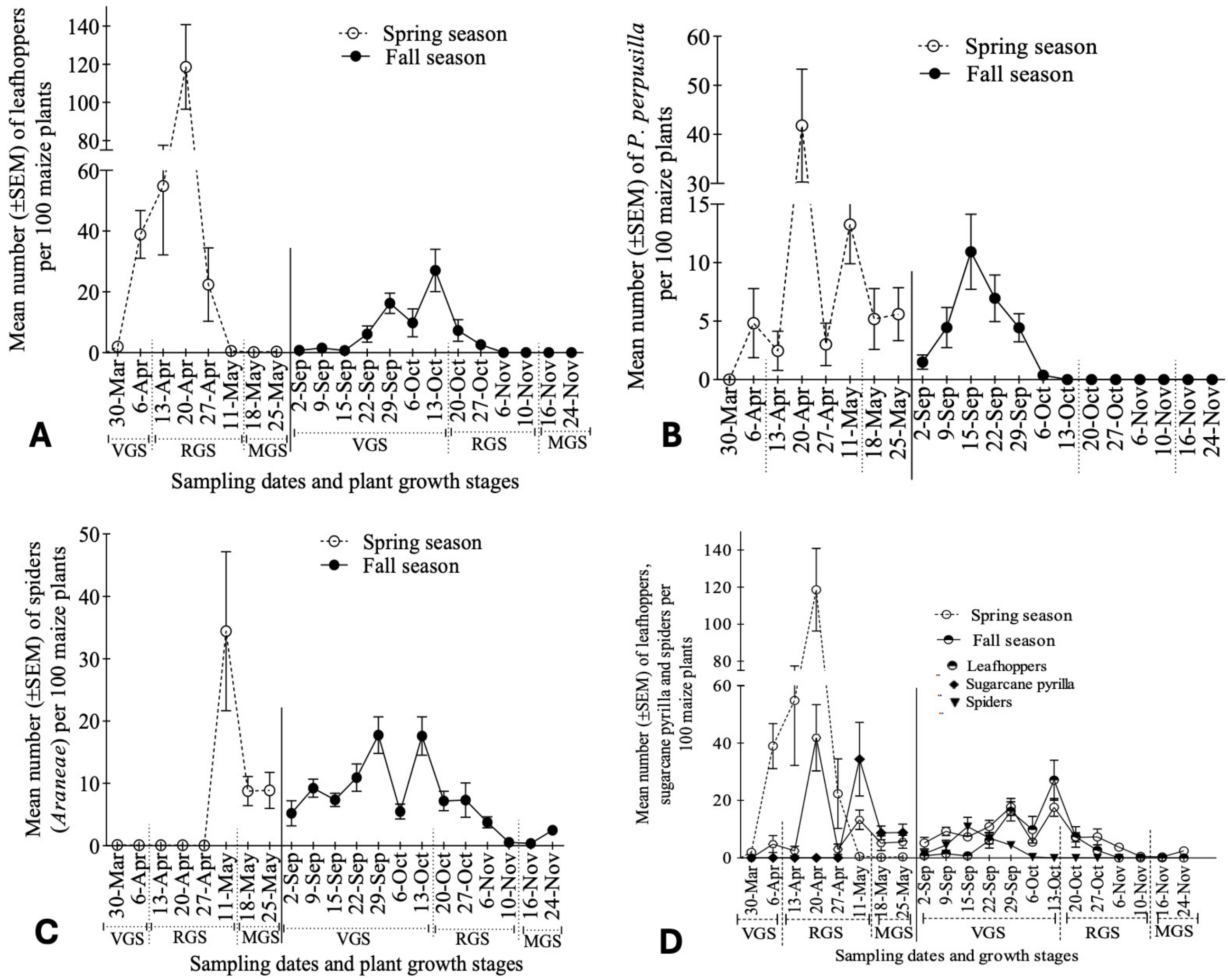

Fig. 1. Individual and combined seasonal mean (±SEM) population dynamics of (A) leafhoppers, (B) sugarcane pyrilla (*Pyrilla perpusilla*) , (C) spiders (*Araneae*) and (D) insect pests and their predator per 100 maize plants in spring and fall season recorded at the vegetative growth stage, reproductive growth stage and maturity growth stages in maize open field survey conducted in the research area.

Table III. Total counts and percentage guilds of insect pests and its predator per 100 plants observed during spring maize season in research area under study.

Insects and growth stages	Spring season	Fall season
Sucking insect pests		
Leafhopper	3804.63 (65%)	1156.41 (37%)
Vegetative growth stage	655.02 (17.22%)	996.77 (86.19%)
Reproductive growth stage	3141.11 (85.56%)	159.64 (13.81%)
Maturity growth stage	8.49 (0.22%)	(0.0%)
Total	3804.63	1156.41
Sugarcane pyrilla (*Pyrilla perpusilla*)	1219.17 (21%)	474.01 (15%)
Vegetative growth stage	77.39 (6.35%)	396.77 (83.71%)
Reproductive growth stage	969.26 (79.50%)	77.23 (16.19%)
Maturity growth stage	172.52 (14.15%)	0.00 (0%)
Total	1219.17	474.01
Predator		
Spider (Araneae)	839.61 (14%)	1520.81 (48%)
Vegetative growth stage	3.12 (0.37%)	1177.43 (77.42%)
Reproductive growth stage	554.4 (66.04%)	300.52 (19.76)
Maturity growth stage	282.08 (33.59%)	42.85 (2.82%)
Total	5863.41 (100%)	3151.23 (100%)

Sugarcane pyrilla (*P. perpusilla*) was observed during September 2nd to November 24th in fall season. The *P. perpusilla* was reported for the first time in maize field plants on September 2nd. The population of *Pyrilla* reached its peak on October 6th. The number of sugarcane pyrilla decreased over the following two weeks on October 27th, and remained at zero until the final observation on November 24th (Fig. 1B). Furthermore, the percentage of sugarcane pyrilla per 100 plants differed significantly with values of 83.71% during vegetative, 16.19% during reproductive and 0% during maturity growth stages. It is worth mentioning that the vegetative stage (September 2nd to October13th) stood out with the highest percentage of sugarcane pyrilla (83.71%), while in the maturity stage (November 16th to 24th) pyrilla were entirely absent (Table III).

Spiders

In maize fields, spider densities show no significant difference between the spring and fall seasons ($P = 0.831$) (Table I). However, they do vary significantly across different dates ($P<0.001$) (Table II). Population dynamics of spider (Araneae) was observed during April 27th to May 25th in spring season through weekly visual observation. Spider (Ctenidae: Araneae) was first observed in a maize field on April 27th which reached its peaked on May 11th. For the following two weeks, it gradually decreased on May 18th, and on May 25th (Fig. 1C). The abundance of spiders was notably more dominant during the reproductive plant growth stage when compared to the vegetative and maturity growth stages. Furthermore, the percentage of spiders differed significantly, with values of 0.37% for vegetative, 66.04% for reproductive and 133.59% during maturity growth stages. It is worth mentioning that the reproductive stage stood out with the highest percentage of spiders (66.04%), while the vegetative stage had the lowest percentage (0.37%), (Fig. 1B).

During fall season population dynamics of Spider was observed during September 2nd to November 24th.Spiders were first observed in a maize field on September 2nd, which reached its peak on September 29th. In the following four weeks, the population gradually declined on October 6th, October 13th, October 20th, and October 27th eventually reaching zero and remaining at that level until the final observation on November 24th. The population reached its highest point on September 29th during the vegetative growth stage (Fig. 1D). The abundance of spiders was notably more dominant during the vegetative plant growth stage when compared to the reproductive and maturity growth stages. Furthermore, the percentage of spiders per 100 plants differed, with values of 77.42% for vegetative, 19.76% for reproductive and 2.82% for maturity growth stages. It is worth mentioning that the vegetative stage stood out with the highest percentage of spiders (77.42%), while the maturity stage had the lowest percentage (0.37%) (Table III).

DISCUSSION

Maize, a vital crop in the agricultural landscape, is no exception to the challenges posed by insect pests. Throughout its growth stages, from sowing to maturity, maize faces relentless attacks from various insect pests. These pests wreak havoc on all parts of the maize plant, targeting the roots, stems, leaves, tassels, silks and even the grain itself. The damage inflicted by these pests can be substantial, leading to reduced crop yields and economic losses. Our study on the population dynamics of leafhopper in two cropping seasons showed the population of leafhopper in the spring season to be much larger than the fall season. Maize leafhopper and sugarcane pyrilla (*Pyrilla perpusilla*) were more dominants during the reproductive growth stage on April 20th when compared to the vegetative and maturity growth stages. Spiders, known as generalist predators, are commonly present in agro ecosystems worldwide (Michalko *et al*., 2019; Reichert and Lockley, 1984). In our observations of seasonal population dynamics, significant shifts were noted between the spring and fall seasons among spider's leafhoppers, and sugarcane pyrilla. During the spring season, spiders constituted a minor portion of the total population at 14%, while leafhoppers and sugarcane pyrilla were more prevalent, comprising 65% and 21% respectively. However, a dramatic change was observed in the fall season. Spiders emerged as the dominant predators, increasing to 48% of the total population, whereas the populations of leafhoppers and sugarcane pyrilla declined to 37% and 15%, respectively.

These statistics suggest an inverse relationship between spider and leafhopper populations. Researchers have investigated spiders and other arachnids are potential biological control agents against leafhoppers (Beyer, 1922; Howell and Pienkowski, 1971). As the spider population increased rapidly in the fall, the leafhopper population decreased significantly. This could imply that spiders play a regulatory role in controlling leafhopper populations, likely through predation. The increase in spider numbers might have contributed to the reduction in leafhopper numbers, highlighting the potential impact of predatory dynamics on population control within this ecosystem. Similarly, the decrease in sugarcane pyrilla, though less pronounced, might also be influenced by the increased presence of spiders.

The data highlights the importance of seasonal variations and predator-prey interactions in shaping the population structure of these species. The marked increase in spider population and simultaneous decrease in leafhopper and sugarcane pyrilla populations during the fall season emphasizes the ecological role of spiders as natural pest controllers. Therefore, early detection of sucking insect pests is crucial for effective pest management but delaying the first pesticide application to the maximum extent possible can yield significant benefits. Thus, promoting sustainable agriculture and reducing environmental impact.

CONCLUSION

Future studies shall emphasize on the evaluation of yield losses or damage by leafhoppers in both seasons of maize field crops. The main pest sugarcane pyrilla because of its strong resilience turned its attention to maize as a primary host. As a result, it was noticed that sugarcane pyrilla migrated to maize fields as an alternate host plant. These findings could be utilized for the zooning of cropping patterns in Punjab province of Pakistan.

DECLARATIONS

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IRB approval

Ethical Committee of the Department of Zoology, University of Jhang approved the study (Ref.No.UOJ/ Ethical Committee/04, Dated: 19 /03 /2024).

Supplementary material

There is supplementary material associated with this article. Access the material online at: https://dx.doi.org/10.17582/journal.pjz/20240611071658

Statement of conflict of interest

The authors have declared no conflict of interests.

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