POPULATION DYNAMICS OF PREDATORY COCCINILIDS IN CEREAL CROPS OF DISTRICT FAISALABAD

Nazia Ehsan[*] and Rana Naureen

Department of Zoology, Wildlife and Fisheries, Faculty of Sciences, University of Agriculture Faisalabad, Pakistan;

[*]**Corresponding author's e-mail address: nazia.ehsan@uaf.edu.pk**

Pakistan's population extremely relies on cereals for their daily food requirements. Cereal crops are vulnerable to many pest species particularly aphids. In the wake of economic well-being and food security these bio-weapons must be controlled. In that context biological control by predators is a sustainable management strategy to solve ecological problems with environmental concerns. This study was aimed to identify Coccinellids as potential predators of aphids and their spatio-temporal organization patterns in cereal crops that would help in developing biological control program in this area. A survey at large scale was conducted to assess the abundance of predatory Coccinellids in cereal crops with respect to seasonal rhythms in district Faisalabad. A total of eighteen Coccinellid predator species were identified representing fourteen, eleven and six species in wheat, maize and rice crops, respectively. The dominant Coccinellid species encountered was *Coccinella septemptunctata.* Coccinellid predator's density was greater 80.6% in wheat than in maize 13.54% and rice 5.74% crops. Highest value of H' (1.6760) was estimated for maize and least for wheat (1.0585) crop. Evenness (E) was observed to be greater in rice 0.8068 cropland while highest value of dominance (D) 0.5989 was determined in wheat. Mean period of maximal diversity and abundance for Coccinellidae was early spring as maximum abundance 52.04% was recorded in February and March 2016 only. The data of these months together yielded 37.12% of Coccinellid abundance compared with rest of months. Species abundance decreased with higher rainfall, warmer temperature while increased with higher air moisture. Significant variations in richness and abundance among sites, crops and months are concordant. As these species occurred at high densities in the fields enough to reduce aphid damage in the cereal crops. Therefore, the spatial and temporal organization patterns of Coccinellids, as revealed in this study might be helpful in developing the natural biological control strategy against pests for regulation of the cereal agro-ecosystem.

Keywords: Coccinellids, insect infestation, biological control, predators, cereal crops, bio-weapons

INTRODUCTION

Food security is an important concern in Pakistan (FAOSTAT, 2013). Agriculture is the backbone of Pakistan's economy and prime benefactor to food security (GoP, 2015; Chandio *et al*., 2016). Population of Pakistan depends exceedingly on cereals for their daily demand of food energy. Cereals deal with 47 percent of entire caloric supply and 46 percent protein supply per capita (FAO, 2011).

Wheat is Pakistan's dietary staple and one of the four main agricultural crops grown on an area of around 9.0 million hectares during winter. Rice ranks second among the staple food grain crops in Pakistan (Anonymous, 2018). The third most important cereal crop of Pakistan is maize (corn) due to its multiple uses for domestic, commercial and industrial purposes. The average yield of wheat, rice and maize in Pakistan is 70, 61 and 82%, respectively which is lower than the average yields obtained internationally (Aslam, 2016).

There are various constraints for low crop yields including agronomic, irrigation management, environmental, technological, institutional and socio-economic as well as pests and plant diseases (Khan, 2012). Wheat, maize, rice, cotton and sugarcane crops are frequently attacked by pests and insects that are managed inappropriately resulting low crop yields (Anonymous, 2012).

Yield losses due to insect infestation occurred in all regions of Pakistan. Temperature and higher relative humidity being conducive to insect growth cause higher yield losses (Highley *et al.,* 1994). Both biological and chemical control measures have been used in order to control cereal crops pests (Meehan *et al*., 2011). Natural bio-control provided by predators, parasitoids or pathogens is instrumental to oversee pest population at all trophic levels that can affect the structure of agro-ecological community (Brosius *et al.,* 2007; Costamagna *et al*., 2007).

Order Coleoptera is the most species-rich group of organisms at present that bears a large group of predators (Bouchard *et al*., 2009). They are well known as efficient biological control agents of aphids (Neved and Honek, 2012). Approximately 4000 species of family Coccinellidae have been reported throughout the world (Michand, 2001). Coccinellidae is the most studied group of insects and major generalist predators

of order Hemiptera such as aphids and scale insects (Batary *et al.,* 2007; Ruby *et al.,* 2011; Caballero-López *et al*., 2012) that are serious pests of agricultural crops (Batary *et al.,* 2007; Ruby *et al.,* 2011) while some are prey specific and habitat specialist.

Predacious Coccinellids fauna is of considerable practical and scientific importance being natural enemy of phytophagous insect pests (Joydeb *et al.*, 2015). Several studies reported that most of the species showed high feeding potential, foraging activity and reproductive efficiency, which are the characteristics of effective biocontrol agent used in IPM (Arhex and Corley, 2003; Kohno, 2003). The extensive changes that occurred during the process of agricultural intensification had repercussions on natural enemy communities (Tuck *et al.,* 2014).

Climate change influences the diversity and abundance of Coccinellid species through changes at lower trophic levels (Soares *et al*., 2017) in particular the well noted increase in temperature and altered rainfall patterns are driver of native ladybird Coccinellid communities and an important factor in synchronizing their lifecycles (Abbott *et al*., 2014; Facey *et al*., 2014; Clissold *et al.,* 2015).

Herein, the main goal of present research was to explore the predatory fauna of family Coccinellidae and spatio-temporal segregation of predators' diversity and abundance in cereal crops in order to adopt some efficacious well-being strategies as biological control.

MATERIAL AND METHODS

Survey was executed in selected cereal crops wheat, maize and rice for collection of data throughout the Faisalabad district.

***Study area*:** District Faisalabad is in the central Punjab of Pakistan. The average maximum temperature is 35°C and minimum temperature is 1°C. Temperature during summer reaches above 40°C except some occasional relief from monsoon rains. The average rainfall recorded during 2015-16 was 400 mm (Anonymous, 2016). An extensive survey was carried out in the selected cereal crops from 23 different sites oriented towards five directions in the cultivations situated 15 km to 40 km away from the center of city. An area of about 23-24 acres for each crop was sampled while taking 1 acre for each crop from each site. Samples were collected from 4 GB Ram Diwali, Rasulpur, Dera Arayian, Thathian, Roshan wala, Dasuha, Dalowaal, Dijkot, Nawababad, Naya Lahore, Painsra, Soha, Mansooran, Makkuana, Manawala, Awagat, Haripur, Nanakpur, Chokera, Narwala Bangla, Nathu, Fanepur and Aminpur Bangla.

***Collection of samples*:** Efforts to sample Coccinellid predators were carefully tailored to suit a situation and taking into account the nature of predator and plant type. Prior information was collected about the irrigation system and time of irrigation for each crop. Sampling events were conducted in conventionally managed cereal cropland where there were no insecticides applied to the field during the study period. Sampling was conducted fortnightly for a period of about one year from June 2015 through May 2016. Sampling of Coleopteran species was executed from cereal crops at dawn when maximum foraging was seen. Insect fauna for wheat was taken in December January, February, March, April and May while for maize and rice it was sampled in June, July, August, September, October and November.

Samples were collected from crop fields by different sampling methods. Four quadrats with the size of 1 m x 1 m were set randomly in crop fields of one acre each. Sweep-nets were used to collect aerial and foliage fauna (Coccinellids). As many as 5 sweeps were made by walking through vegetation forming a figure of eight (Ruby *et al*., 2011) within quadrats. Number of sweeps was kept constant during each sampling tour. Moreover, direct hand picking was also employed to collect foliage fauna. A total of 22 sampling trips were executed in different localities for a period of one year.

***Identification of specimens*:** The collected specimens of order Coleoptera were identified up to species level in relation to the accessible taxonomic keys provided by Brunetti (1978), Borror and Delong (2005), Rafi *et al.* (2005), Shunxiang (2010) and the Fauna of British India by Talbot (1978) and online identification keys available on different web-sites. Research laboratories and museum were also consulted.

***Preservation of specimens*:** Each specimen pertaining to a species was washed and then preserved in separate glass vials filled with 30% alcohol along with few drops of glycerin.

***Monthly data of environmental variables*:** In order to explain the possible effects of environmental factors' fluctuations and of the most relevant environmental variables which could have influence on the distribution of predatory Coccinellids among the three studied habitats (Butterfield *et al*., 1995), the climatic data of environmental variables as temperature, relative humidity, rainfall, and wind speed for the study sites was taken fortnightly and verified by metrological data from meteorological department of University of Agriculture, Faisalabad.

***Data analyses*:** Species diversity index, richness and evenness of family Coccinellidae was calculated using Shannon-Weiner diversity index, which is an estimable tool for computation of diversity of ecological communities (Magurran *et al*., 1988). Moreover, Tukey's test was applied to compare diversity among crops (Inayat *et al*., 2010) as given by Hutcheson (1970). Relationships between natural species distribution in the cereal crops and environmental factors viz. temperature, relative humidity, rainfall and wind speed was determined by Canonical Correspondence Analysis (CCA) using CANOCO (version 4.5A) (Cajo and Braak, 2003). The 'R' values in CCA ordination biplot represented positive or negative correlation between axes.

RESULTS

The results of extensive survey in cereal crops of wheat, maize, and rice revealed diversity and abundance dynamics of Coccinellid predators. An aggregate of 3087 adult predators from 18 species of family Coccinellidae was captured in the cereal crop fields. The faunal composition comprised of *Anatis labiculata, Brumoides suturalis, Cheilomenes sexmaculata, Chilocorus circumdatus, Coccinella novemnotata, Coccinella septempunctata, Coccinella transversalis Cycloneda.munda, Epilachna.indica, Harmonia axyridis, Hippodamia convergens, Hippodamia variegata, Micraspis allardi, Psyllobora vigintiduopunctata, Scymnus nubilus, Scymnus posticalis, Oenopia sauzeti* and *Stethorus gilvifrons* species. Fourteen, eleven and seven of the total eighteen Coccinellid species captured in wheat, maize and rice crops respectively, proving poor knowledge of Coleopteran fauna in rice cropland.

The supernumerary predator species was *C. septempunctata* with 1968 specimens and with 63.6% share in all Coccinellid species of which, 58% specimens were found from wheat, 4.4% from maize and 1.25% specimens from rice. Second most abundant species was *C. sexmaculata* (10.85%) of which 6.38, 3.21 and 1.26% specimens were sampled from wheat, maize and rice, respectively. *C. transversalis* was another abundant species with 8.02% specimens followed by *H. variegata having* 8.22% specimens while rest of fourteen species had abundance less than 3%. The lowest number of specimens 0.03% of each *C. munda* and *C. circumdatus* were captured from the three cereal crops of area (Fig. 1). *A. labiculata, C. circumdatus* and *C. novemnotata* remained as the rare species with only one specimen each. In addition to that most of the captured predaceous Coccinellid individuals (80.6%)) were present in wheat croplands followed by maize 19.08% and least 14.94% in rice crop (Table 1).

From the total of 18 species 14 were captured only in wheat cropland with relative abundance 80.6%. Wheat was the most species rich crop when compared with other two crops. *C. circumdatus, H. convergens, P. punctata, S. nubilus, S. posticalis* and *S. gilvifrons* were captured only in wheat cropland. The dominant Coccinellid encountered was *C. septempunctata*, a widespread generalist predator species. *C. septempunctata* was particularly prevalent in wheat with 1801 specimens and 58.34% relative abundance while *C. circumdatus* proved as rare species with one specimen only (Fig. 1).
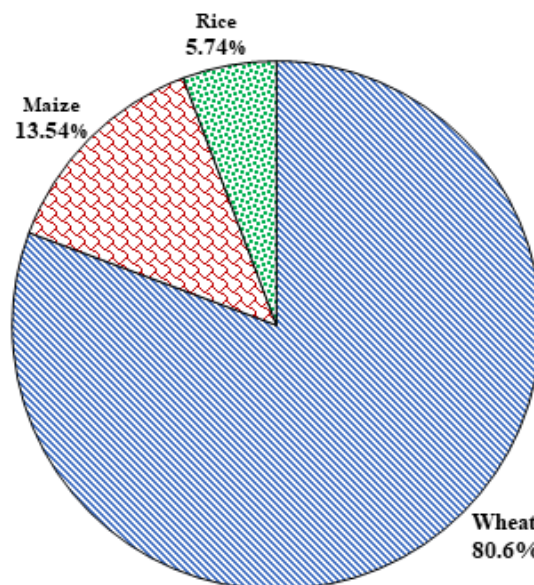

Figure 1. Percentage relative abundance of Coccinellids.

Maize cropland proved as less diversified area compared to wheat with particular reference to Coccinellid species richness as only 11 species were found in maize cropland. *B. suturalis, C. sexmaculata, C. novemnotata, C. septempunctata, C. transversalis, C. munda, O. sauzeti, H. axyridis, H. variegate, M. sallardi, P. punctata* predatory species were captured in maize crop with relative abundance 13.54% altogether (Table 1). *C. sexmaculata* was dominant with 99 specimens and 3.21% relative abundance whereas *C. novemnotata* and *C. munda* were rare species of maize cropland. *C. munda, O. sauzeti* and *E. indica* were unique to maize cropland (Fig. 2b).

Rice cropland proved as species poor with reference to richness of predatory Coccinellids as only seven species out of eighteen were collected from rice cropland. *A. labiculata, B. suturalis, C. sexmaculata, C. novemnotata, C. septempunctata, C. transversalis, H. variegate* and *M. allardi* occurred in rice crop and that constitute relative abundance 5.74% (Table 1). *B. suturalis* was more prevalent in rice cropland with 59 specimens and 1.91% relative abundance whereas *A. labiculata* and *C. novemnotata* were least abundant. Moreover, *A. labiculata* was the only species captured from rice cropland and nowhere else (Fig. 2c).

Diversity Index H' was computed as 1.3285 for Coccinellid data from all cereal crops whereas highest value of H' (1.6760) was estimated in maize followed by rice 1.5699 and least for wheat 1.0585 crop. Evenness (E) was observed greater in rice 0.8068 cropland than in maize 0.6990 and wheat 0.4011 croplands respectively while highest value of Dominance 0.5989 was observed in wheat compared to maize 0.3010 and rice 0.1932 crops. Table 2 presents the difference between diversity indices of Coccinellids among three crops.

Accordingly, diversity of ladybird beetles was significantly different among all cereal crops. Floral and faunal association of Coccinellid species as exhibited in CCA ordination biplot revealed 79.8% variations in the distribution of Coccinellid species within all selected cereal crops. Figure 3 shows that some species were associated more with their respective crops.

Table 3 presents comparison computed via Tucky's contrast test for diversity indices of aphids among three crops. Accordingly, diversity and abundance of aphids was significantly different between wheat and maize as well as wheat and rice while non-significant difference was found between diversity and abundance of maize and rice crops.

Predatory Coccinellids richness showed variations among months as abundance was higher 29.26% only in March (Fig. 4) followed by February (22.78%), April (16.36%), January (9.73%), October (9.37%), September (6.81%), December (2.17%), August (0.95%), May (0.22%) and least in July (0.03%). *C. septempunctata* richness was higher with peaks in activity in February and March of 2016. These sample periods together yielded 37.12% of the total abundance compared with samples from 12.60, 0.13, 0.00, 0.03, 0.29, 1.75, 2.82, 0.52, 1.65 and 6.83% for February, March, April, May, June, July, August, September, October, November, December and January respectively while *C. circumdatus* and *C. munda* showed least monthly variations (0.03%) throughout whole year. Overall the rainy months were richer than the drier months.

Association between various predatory Coccinellids species and environmental factors revealed 84.6% variations in the distribution of Coccinellid species throughout the year. *A. labiculata*, *H. variegate, O. sauzeti, M. allardi* and *H. variegate* were found positively associated with temperature whereas *E. indica, H. convergens, H. axyridis* were associated negatively. *B. suturalis*, *C. circumdatus, C. transversalis, S. nubilus* and *S. posticalis* were positively associated with rainfall while *C. septempunctata, C. munda, C. novemnotata* and *S. posticalis* seemed to show least association with rainfall.

DISCUSSION

Conservation of natural enemies and their use in the agro-ecosystems is one of the important aspects of Integrated Pest Management (Ragsdale *et al.,* 2011; Rutledge *et al.,* 2004; Tscharntke *et al.,* 2007). The natural biocontrol of pests requires the presence of natural enemies in the system, the effectiveness of which can only be approximated by measuring enemy community composition and their interactions at all relevant spatial and temporal scales (Martin *et al.,* 2013). Ladybird beetles (Hoffmann *et al.,* 2005) and lady bugs (William, 2002) are the most notable predators for aphids are that has been intensively studied for their services to agriculture (Honek *et al.,* 2017). The faunal diversity of

Coccinellid predators and their interactions with biotic and abiotic factors are little known. Therefore, this research was aimed to explore the services of biological control provided by Coleopteran predators in relation to their diversity and distribution with respect to abiotic factors in cereal crops of district Faisalabad.

Coccinellid communities consisted of a few dominant and several less common and even rare species in this study. Results of field surveys in three cereal crops represented eighteen species of Coccinellid predators in wheat, maize and rice crops for which wheat harbored fourteen species of Coccinelids, while maize was bearing eleven species. Rice crop was found species poor as well as less abundant and only six Coccinellid species were captured in this habitat. The reason might be that rice fields in many areas were found heavily flooded with water.

All these species were from four sub families Chilocorinae, Coccinellinae, Scymninae and Epilachninae. Coccinellid species *C. circumdatus, H. convergens P. vigintiduo, S. punctata, S. nubiles,* and *S. gylvifrons* were prevalent only in wheat while *C. munda, O. sauzeti* and *E. indica* in maize. *A. labuculata* was the only species found in rice cropland. Predacious Coccinellid species especially of the sub family Coccinellinae were more abundant than others as members of this sub-family are generalist predators having broad feeding niche and inhabit in broad range of habitats. Results of Abbas *et al.* (2013) and Joshi and Sharma (2008) are also in conformity with this research.

Rahatullah *et al.* (2011) in district Dir and Inayatullah *et al.* (2005) in district Poonch of Azad Jammu Kashmir after an extensive survey reported almost same species and families that were captured in the present study. Coccinellid fauna was found distributed throughout district Faisalabad but some areas were richer than others.

The most abundant Coccinellid encountered was *C. septempunctata*, a well-known generalist predator species that occurs worldwide, was also common in all three cereal crops but particularly prevalent in wheat cropland of district Faisalabad. *C. septempunctata* is a multicultural species having extensive dispersal power (Ali and Rizvi, 2009). This species was previously reported by Irshad (2001) and Ahmad *et al.* (1999). Inayat *et al.* (2011) and Abbas *et al.* (2013) during survey of different croplands of district Faisalabad reported this species.

The second most abundant predator species encountered was *C. sexmaculata* followed by *C. transversalis* as third and *H. variegata*as fourth most abundant species sampled from cereal crops. *C. sexmaculata* was found dominant in maize crop while *B. suturalis* in rice crop. Shah (1985) and Irshad (2001) reported *C. transversalis.* Galany (1976) explored predaceous Coccinellid fauna of district Faisalabad for the first time. Rafi *et al.* (2005) enlisted seventy five Coccinellid species in Pakistan. Comparative analyses of diversity and evenness revealed two diverse structural patterns among

crops characterized by high (maize) or low (rice) diversity and evenness, respectively.

Highest diversity index H' 1.6760 was calculated for maize and lowest 1.0585 for wheat. Predator densities in cereal crops were variable among locations averaging 4.821 Coccinellid individuals per quadrat during the growing season. Per quadrat number for all Coccinellid species revealed variations in their abundance for three cereal crops during the whole sampling period. Per quadrat occurrence of *C. septempunctata* remained highest in these crops that shows its potential as biological control agent. High level density of natural enemies and species richness is the basis for biological pest control (Liu *et al.,* 2016).

Temporal study of order coleoptera: Environmental change influence Coccinellid species in several ways and climate warming has important effects that brings local changes in the ladybird composition of communities and abundance of particular species occurrence as well (Honek *et al.,* 2017). Seasonal segregation of predators' diversity and abundance in cereal crops was observed in the present study. Predatory Coccinellid richness showed significant variations among months in this study. Mean period of maximal diversity and abundance for Coccinellidae was early spring as maximum abundance 52.04% was recorded in February and March 2016 only. *C. septempunctata* richness was higher with peaks of activity in February and March. The data of these months together yielded 37.12% of Coccinellid abundance compared with rest of months whereas *C. circumdatus* and *C. munda* showed least monthly variations (0.03%) throughout the year. Overall rainy months were richer than the dried. The results of Abbas *et al.* (2013) were in conformity with ours who found that abundance of family Coccinellidae varied throughout the sampling period. March and April proved more suitable as maximum number of specimens pertaining to three sub-families of Coccinellidae in March and four sub-families in April were captured during those months. Moreover, relative abundance *C. septempunctata* and *C. sexmaculata* was recorded highest in the months of March and April.

The species abundance decreased with higher rainfall, warmer temperature while increased with higher air moisture. Hence, the sampling periods characterized by hot days, but high enough humidity to avoid desiccation represent favorable abiotic conditions for beetle abundance. Results of this study suggested that climate affect more on beetle communities than spatial differences. The spatial and temporal organization patterns of Coccinellidae revealed in this study highlighted Coccinellids as research tools for biocontrol program in natural ecosystems. It is possible that Coccinellid predators can provide effective biological control services if their densities are enhanced early in the season at least for short-term suppression of pest population that may affect the long-term temporal dynamics of their prey (Symondson, 2002).

Conclusion: The data gathered and observations on the natural abundance of the Coccinellid predators gives the direction that helps in understanding the predatory fauna, which might be beneficial in developing the strategy in the natural biological control of the pest using Coccinellid predators in the ecosystem context for understanding the proper regulation of agro-ecosystem of cereal crops without any input outside. However, their commercial viability of using augmentative releases needs to be tested for most pest species in agricultural crops.

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