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Diversity study of aphids and associated predatory fauna occurred in major *Kharif* and *Rabi* crop ecosystems of Akola, Maharashtra, India

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Abstract

The present investigation entitled "Aphid diversity and associated predatory fauna in different crop-ecosystems of Akola" was carried out during the year 2017-2018. During study period total 1810 specimens of aphids and 205 specimens of predatory fauna associated with aphids collected from various *Kharif* and *Rabi* crops agro-ecosystem. The collected data revealed that total seven species of aphids and sixteen species of predators were collected from different crop agro-ecosystem. In aphids seven species viz: *Aphis gossypii* (Glover), *Aphis craccivora* (Koch), *Rhopalosiphum maidis* (Fitch), *Aphis (Taxoptera) citricidus* (Kirkaldy), *Lipaphis erysimi* (Kaltenbach), *Hysteroneura setariae* (Thomas) and *Uroleucon compositae* (Theobald). Aphid's population varied in the *Kharif* and *Rabi* crop season in the various crop fields, maximum population of aphids was observed in the month of November-December. However, moderate to rich species biodiversity of aphids species was noticed as per Shannon Biodiversity Index ($H' = 1.545$) in Akola vicinity during kharif 2017-18. Simpson index value was 0.75. The Evenness index had a value of 0.79. Species wise data of aphids showed rich fauna of *U. compositae* with 37.24 per cent.

Keywords: Aphids, diversity, ecosystem, fauna, *Kharif*, predatory

Introduction

Aphids also known as plant lice are small sap-sucking insects and members of the super family Aphidoidea (Order: Hemiptera). Aphids are the most important insect pests of different crops all over the world, (Ibrahim, 1994) [15]. World over about 5000 species of aphid have been described and of these, some 450 species have colonized food and fibre crops (Emden et.al 2017) [13]. Of these, about 653 species belonging to 208 genera represent Indian Aphididae (Agarwala & Ghosh, 1984) [1]. About 1000 species are injurious to crops throughout the world (Singh, et al., 2015) [27].

An aphid is one of the highly prolific species of insects in the world. Aphid's reproduces mainly by parthenogenetically therefore they are highly prolific (Singh and Ghosh, 2002) [26]. Many species of aphids display complex life cycles with alternation of sexual and asexual generations and host plant alternation (Ghosh and Singh, 2000) [14].

An aphids mainly feed by sucking cell sap from the leaves of crops while feeding they excrete characteristic sugary substance, honeydew, which attracts wasps, butterflies, some moths and famously some species of ants. It mainly affects to plants by weakening and distortion of host plants, decreasing growth rates, secretion of large amounts of honeydew and by transferring of plant viruses to several crops that demand crop management strategies (Blackman, et.al.2000 [6]; Emden.et.al. 2007) [12]. Previous reports of (Singh, et al., 2000) [28] revealed that although aphids are the pest of crops; however, they are extremely important hosts for a number of parasitoids, predators and an essential meal for numerous other insects, as well as birds.

Aphids are a large group of insects. Most aphid species are host specific and known to feed on a restricted range of host plants (Eastop, 1986) [11]. Among the several species of aphids *Aphis craccivora* Koch is one of the species of aphids which was mainly feeds on several crops like cowpea, groundnut, pigeon pea, green gram, blackgram, soybean, broad bean and pea which affecting their growth and market value by sucking cell sap from various plants parts,

(Saxena, 1978) [25]. Worldwide, the *Aphis gossypii* Glover is a major threat to agriculture and horticulture in many tropical, sub-tropical and temperate countries which was found to attack a large number of plant species including crops (Cereals, Pulses and Oilseeds), vegetables, fruits, ornamental plants, weeds and wild Plants (Mifsud, *et al.*, 2011) [21]; (Butani and verma, 1976) [8] stated that it acts as a vector virus and transmits mosaic, leaf curl, etc. The *Lipaphis erysimi* (Kaltenbach) is the most important insect pest of rapeseed-mustard crop in India and due to severe infestation plant gets poor pod formation leaves get curled shrivel and plants become completely dried. (Arora, 1999) [4]. In India, wheat crop is attacked by more than 11 aphid species (Jarosik *et al.*, 2003) [16]. The aphids attack wheat crop from seedling stage onwards (Aheer *et al.*, 2008) [2].

Along with aphids species its associated natural enemy's biodiversity play a vital role in management of aphids. Coccinellids, are members of family Coccinellidae, and are amongst the most familiar beetles known variously as ladybirds or ladybugs. Numerous species of coccinellids are predators and major biological control agents of hemipteran pests such as aphids, mealybugs and scale insects, as well as thrips and mites in all parts of the world (Majerus, 1994) [19]; (Verma and Makhmoor, 1987) [31] have reported various species of syrphid preying upon *Brevicoryne brassicae* in mid-hill region of Himachal Pradesh. Syrphids are predators which play an important role in the suppression of population of many economically important aphid pests on cole crops, legumes, oilseeds, etc. (Chambers *et al.*, 1983) [9].

As the information regarding the biodiversity of aphids and its associated predatory fauna in vidharbha that too in agriculture sector is scanty. Therefore, the present investigations were carried out work out to evaluate diversity, species dominance and prey density dynamics of aphids and its associated predatory fauna in various kharif and Rabi crop agro-ecosystem in Akola vicinity. This information is valuable for IPM workers in planning IPM strategies involving biocontrol of this important pest.

Materials and methods

i. Study areas

The present study "Aphid diversity and associated predatory fauna in different crop-ecosystems of Akola" was carried out at Department of Entomology, Post Graduate Institute Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola during 2017-18.

ii. Collection of specimens

Aphids as well as its associated predatory fauna were collected periodically from kharif and Rabi crops of Akola, Maharashtra between July and December 2017. Aphid's collection done by cutting infested plant parts along with aphid colony in small plastic containers (12x7 cm) or polyethylene bags. Sometimes the aphids were collected directly from the plants using a camel hairbrush. Aspirators are among the most effective and easiest to use devices for collecting winged aphid. Different aphid predators such as lady bird beetle, green lacewing, syrphid fly of these adults were collected by using sweep net and grub and maggot of these predators were transfer into small plastic containers (12x7 cm). Predatory spiders were collected in small plastic containers (12x7 cm) containing 70% ethyl alcohol with the help of sweep net. Insect collecting net made up of wooden handle with collecting bag made up of ordinary mosquito net

cloth was used for collecting insects. The insect were collected by sweeping the net on the crop.

iii. Preservation of specimens

The aphids thus collected were preserved in 70% ethyl alcohol in small plastic vials (2.5 ml). Each vial was furnished with data on locality, host plant, date and collector's name on thin paper using a soft (2B) pencil. The label was inserted into each of the vials. Spiders specimens were preserve by using 70 % ethyl alcohol. Slides preparation for identification of aphids done as per the method suggested by (Eastop and van Emden 1972) [9]. Collected specimens were preserved, labeled, and characterization study was carried out in insect biosystematics laboratory ICAR-NPIB Project of Entomology Department, Post Graduation Institute, Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola during 2017-18.

iv. Observation recorded

A weekly survey of *kharif* and *rabi* crop ecosystems viz. cotton, bean, cowpea, okra, sorghum, mustard, safflower, sunflower, wheat, citrus was carried out in different crop research unit of Dr. P.D.K.V. Akola. Aphids and associated predatory fauna encounter during survey was recorded from each block. Wherever, aphids and adult stage of predators occurred were collected and preserved for identification in Taxonomy laboratory Department of Entomology.

v. Identification of specimens

The aphids and some predators were sent to NBAIR, Bengaluru for identification. Spiders specimens collected during the course of investigations have been identified upto generic level by Dr. M.V. Shirbhate, Asstt. Professor of Zoology, Shankarlal Khandelwal Arts, Science and Commerce College, Akola. By adjusting the magnifying Knob, zooms, characters were studied under microscope so as aphid's specimen were categorize up to species level with the help of taxonomic key as per (Blackman and Eastop 2006) [7]. Genus level identification of all predatory fauna which were collected during the present investigations was carried out in NPIB lab, Department of Agril. Entomology, Post Graduate Institute Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola.

vi. Data Analysis

The diversity of predaceous insect were analyzed by widely used indices viz., the Shannon-Wiener index, which is sensitive to changes in the abundance of rare species in a community, and the Simpson index, which is sensitive to changes in the most abundant species in a community (Solow, 1993) [29]. The simplest species richness index is based on the total number of species (S) and the total number of individuals of all species (N) in a habitat. Shannon diversity index and Simpson's index were calculated to support the study.

Diversity indexes

Shannon-Wiener index is defined as

$$H' = - \sum_{i=1}^S (P_i \ln P_i)$$

$P_i = n_i/N$, n_i = number of individuals of species "i", N = total number of individuals of all species

Pi = relative abundance of species "i", S = total number of species, H' = Shannon Diversity Index.

Simpson index is defined as

$$D = \sum ni (ni-1) / N (N-1)$$

Where D = the Simpson index; ni = the number of species of family i and N = total no. of species.

Evenness index: The Evenness index is measure of how evenly species are distributed in sample. When all species in a sample are equally abundant, an Evenness index will be at its maximum decreasing towards zero as the relative abundance of the species diverges away from evenness.

$$E = \ln(N1) / \ln(N0)$$

Where N1 = number of abundant species in the sample and N0 = number of all species in the sample.

Results

A. Agro ecosystem wise activity of Aphids and associated predatory fauna: During the study period total 1810 specimens of aphids and 205 specimens of predatory fauna associated with aphids collected from various *Kharif* and *Rabi* crops agro-ecosystem from Akola vicinity. The collected data revealed that total seven species of aphids and sixteen species of predators were collected from different crop agro-ecosystem from Akola vicinity.

a. *Kharif* crops agro-ecosystem

i. Cotton ecosystem: *Aphis gossypii* (Glover) and ten predator's species were recorded in cotton. Among predators lady bird beetles viz. *Cheilomenes sexmaculata* (Fabricius), *Coccinella transversalis* (Fabricius) and *Illeis* sp., syrphid fly [*Ischiodon scutellaris* (Fabricius)], mallada (*Mallada* sp.), green lace wing (*Chrysoperla* sp.) and spiders viz. *Neoscona* sp., *Eriovixia* sp., *Oxyopes pankajii* and *Clubiona* sp. were recorded.

ii. Cowpea ecosystem: *Aphis craccivora* (Fabricius) and five predator's species were recorded in cowpea. Among predators lady bird beetles viz. *Cheilomenes sexmaculata* (Fabricius) and *Coccinella transversalis* (Fabricius), syrphid fly [*Ischiodon scutellaris* (Fabricius)] and spiders viz. *Neoscona* sp. and *Leucauge decorata* were recorded (Table 1).

iii. Okra ecosystem: *Aphis gossypii* (Glover) and seven predators species were recorded in okra ecosystem. Among predators lady bird beetles viz. *Cheilomenes sexmaculata* (Fabricius) and *Illeis* sp., syrphid fly [*Ischiodon scutellaris* (Fabricius)], mallada (*Mallada* sp.) and spiders viz. *Neoscona* sp., *Eriovixia* sp. and *Thomisus* sp. were observed in okra ecosystem.

iv. Sorghum ecosystem: During *Kharif* season of 2017, one aphid species [*Rhopalosiphum maidis* (Fitch)] and ten predators species were recorded in sorghum. Among predators lady bird beetles viz. *Cheilomenes sexmaculata* (Fabricius) and *Coccinella transversalis* (Fabricius), syrphid fly [*Ischiodon scutellaris* (Fabricius)], mallada (*Mallada* sp.), green lace wing (*Chrysoperla* sp.) and spiders viz. *Neoscona* sp., *Eriovixia* sp., *Hyllus semicupreus*, *Tetragnatha* sp. and *Oxyopes pankajii* were recorded in sorghum.

v. Bean ecosystem: The observation recorded on aphids and associated predatory fauna in Bean ecosystem during *Kharif* 2017 at Akola are presented in (Table 1).

b. *Kharif* and *Rabi* crops agro-ecosystem

i. Citrus ecosystem: Two aphid species viz. [*Aphis (Taxoptera) citricidus* (Kirkaldy)] and *Aphis craccivora* (Fabricius) and ten predators species were recorded in citrus. Among predators lady bird beetles viz. *Cheilomenes sexmaculata* (Fabricius), *Coccinella transversalis* (Fabricius) and *Illeis* sp., syrphid fly [*Ischiodon scutellaris* (Fabricius)], mallada (*Mallada* sp.), green lace wing (*Chrysoperla* sp.) and spiders viz. *Neoscona* sp., *Eriovixia* sp., *Araneus* sp. and *Cyrtophora cicatrosa* were recorded in citrus (Table 1).

c. *Rabi* crops agro-ecosystem:

i. Sunflower ecosystem: During the observation recorded on aphids and associated predatory fauna in *rabi* 2017 on sunflower one aphid species [*Aphis gossypii* (Glover)] and Four predators species like lady bird beetle [*Cheilomenes sexmaculata* (Fabricius)] and spiders viz. *Neoscona* sp., *Eriovixia* sp. and *Clubionina* sp. were observed.

ii. Wheat ecosystem: During *rabi* season of 2017, one aphid species [*Hysteroneura setariae* (Thomas)] and three predators species were recorded in wheat (Table 8 and Plate 9). Among predator's lady bird beetle [*Cheilomenes sexmaculata* (Fabricius)] and spider's viz. *Neoscona* sp. and *Eriovixia* sp. were recorded in wheat.

iii. Mustard ecosystem: One aphid species [*Lipaphis erysimi* (Kaltenbach)] and five predator's species were recorded. Among the predators lady bird beetle *Cheilomenes sexmaculata* (Fabricius), syrphid fly [*Ischiodon scutellaris* (Fabricius)] and spiders viz. *Neoscona* sp., *Eriovixia* sp., *Thomisus* sp. were observed on mustard.

ix. Safflower ecosystem: One aphid species [*Uroleucon compositae* (Theobald)] and seven predators species were recorded in safflower (Table 10 and Plate 11). Among predators lady bird beetles viz. *Cheilomenes sexmaculata* (Fabricius) and *Illeis* sp., syrphid fly [*Ischiodon scutellaris* (Fabricius)], green lace wing (*Chrysoperla* sp.) and spiders viz. *Neoscona* sp., *Eriovixia* sp. and *Leucauge decorata* were recorded in safflower (Table 1).

b. Relative abundance of aphid fauna in *kharif* and *Rabi* crops agro-ecosystem

The dominant species was *Uroleucon compositae* comprises 674 specimens. Aphids of the category *Aphis craccivora* formed the next dominant aphids species in *Kharif* and *Rabi* crops agro-ecosystem comprising of 543 specimens of aphids. *Aphis (Taxoptera) citricidus* and *Aphis gossypii* contribute 209, 167 specimens, respectively. *Rhopalosiphum maidis* and *Hysteroneura setariae* have share of 54, 13 specimens, respectively. The diversity and evenness indices were calculated for the collected aphid's species in different crop ecosystems of Akola vicinity during *kharif* and *rabi* 2017. The Shannon- Wiener index value was 1.54 while Simpson index value was 0.75. The Evenness index has a value of 0.79. Aphid's species exhibited monthly variation in their occurrence in *kharif* and *rabi* crop agro-ecosystem (Table 2).

c. Relative abundance of predatory fauna associated with aphid population

The observation data revealed that maximum percent composition of coccinellid, *Cheilomenes sexmaculata* (53.17 %). This was followed by Syrphid fly, *Ischiodon scutellaris* (13.17 %), Spider, *Neoscona* sp. were recorded upto 6.82 %, and

Coccinella transversalis and *Mallada* sp. contributed 4.39 % each. This was followed by *Illeis* sp. and *Eriovixia* sp. (3.90 % each), Green lace wing, *Chrysoperla* sp. (2.93 %), Spiders, *Clubiona* sp. and *Leucauge decorata* (1.46 % each), *Oxyopes pankajii*, *Thomisus* sp. and *Tetragnatha* sp. (0.98 % each). The minimum composition of 0.49 percent was observed in *Hyllus semicupreus*, *Araneus* sp. and *Cyrtophora cicatrosa*. The Shannon-Wiener index value was 1.73 (Table 3).

d. Shannon biodiversity index of aphids and associated predatory fauna

1. Cotton ecosystem: Shannon diversity index was worked out based on the average of number of aphids and associated predators recorded during the survey in cotton ecosystem at Akola vicinity. The data revealed that cotton aphids, *Aphis gossypii* shared 73.96 per cent abundance. Among predators, *C. sexmaculata* shared 12.77 per cent abundance followed by *I. scutellaris* (3.15 per cent), *Chrysoperla* sp. (2.16 per cent), *C.transversalis* (1.99 per cent), *Mallada* sp. (1.33 per cent), *Neoscona* sp. (1.16 per cent), *Illeis* sp. (0.99 per cent), *Oxyopes pankajii* (0.99 per cent), *Clubiona* sp. (0.87 per cent) and *Eriovixia* sp. (0.67 per cent). A rich Shannon diversity index ($H' = 1.033$) was recorded in cotton ecosystem at Akola comprising aphids and associated predatory fauna (Table 4).

2. Cowpea ecosystem: The data depicted in Table 5 regarding aphids and associated predatory fauna recorded in cowpea ecosystems at Akola shared 84.56 per cent abundance of aphids (*A. craccivora*). Whereas, among predators *C. sexmaculata* shared 9.76 per cent abundance followed by *I. scutellaris* (3.02 per cent), *Neoscona* sp. (1.06 per cent), *C. transversalis* (0.89 per cent), and *Leucauge decorata* (0.8 per cent). Moreover, the data shared moderate Shannon diversity index ($H' = 0.601$) in cowpea ecosystem comprising aphids and associated predatory fauna (Table 5).

3. Okra ecosystem: The data revealed that aphids, *Aphis gossypii* shared 75.59 per cent abundance in okra agro-ecosystem. Among predators, *C. sexmaculata* shared 10.68 per cent abundance followed by *Illeis* sp. (4.58 per cent), *Mallada* sp. (2.29 per cent), *I. scutellaris* (2.03 per cent), *Neoscona* sp. (2.03 per cent), *Thomisus* sp. (1.78 per cent) and *Eriovixia* sp. (1.02 per cent). A moderate to rich Shannon diversity index ($H' = 0.954$) was recorded in okra ecosystem at Akola comprising aphids and associated predatory fauna (Table 6).

4. Sorghum ecosystem: The recorded data revealed that sorghum aphids, *Rhopalosiphum maidis* shared (62.14 per cent) abundance. Among predators, *C. sexmaculata* shared (20.44 per cent) abundance followed by *Mallada* sp. (4.18 per cent), *I. scutellaris* (3.02 per cent), *C.transversalis* (2.56 per cent), *Tetragnatha* sp. (2.56 per cent), *Neoscona* sp. (1.39 per cent), *Hyllus semicupreus* (1.16 per cent), *Chrysoperla* sp. (0.93 per cent), *Oxyopes pankajii* (0.93 per cent) and *Eriovixia* sp. (0.69 per cent). Predatory spiders had more species diversity. A rich Shannon diversity index ($H' = 1.28$) was recorded in sorghum agro-ecosystem (Table 7).

5. Bean ecosystem: The data depicted in Table 15 (Fig. 5) regarding aphids and associated predatory fauna recorded in bean ecosystems at Akola shared 84.74 per cent abundance of aphids (*A. craccivora*). Whereas, among predators *C. sexmaculata* shared 9.06 per cent abundance followed by *I. scutellaris* (3.32 per cent), *Neoscona* sp. (1.21 per cent), *C.*

transversalis (0.91 per cent), and *Leucauge decorata* (1.0 per cent). Moreover, the data shared moderate Shannon diversity index ($H' = 0.602$) in bean ecosystem comprising aphids and associated predatory fauna (Table 8).

6. Citrus ecosystem: Shannon diversity index was worked out based on the average of number of aphids and associated predators recorded during the survey in citrus ecosystem at Akola (Table 16 and Fig. 6). The data revealed that aphids, *Aphis (taxoptera) citricidus* shared 36.22 per cent abundance and *Aphis craccivora* 58.30 per cent abundance. Among predators, *C. sexmaculata* shared 2.43 per cent abundance followed by *I. scutellaris* (0.83 per cent), *C.transversalis* (0.52 per cent), *Chrysoperla* sp. (0.45 per cent), *Neoscona* sp. (0.35 per cent), *Illeis* sp.(0.24 per cent), *Mallada* sp. (0.21 per cent), *Cyrtophora cicatrosa* (0.21 per cent), *Araneus* sp. (0.17 per cent) and *Eriovixia* sp. (0.07 per cent). A moderate to rich Shannon diversity index ($H' = 0.933$) was recorded in citrus ecosystem at Akola comprising aphids and associated predatory fauna (Table 9).

7. Sunflower ecosystem: Shannon diversity index was worked out based on the average of number of aphids and associated predators recorded during the survey in sunflower ecosystem at Akola (Table 17 and Fig. 7). The data revealed that aphids, *Aphis gossypii* shared 51.58 per cent abundance. Among predators, *C. sexmaculata* shared (36.60 per cent) abundance followed by *Eriovixia* sp. (5.07 per cent), *Neoscona* sp. (3.94 per cent) and *Clubiona* sp. (2.81 per cent). A rich Shannon diversity index ($H' = 1.081$) (Table 10).

8. Wheat ecosystem: Shannon diversity index was worked out based on the average of number of aphids and associated predators recorded during the survey in wheat ecosystem at Akola (Table 18 and Fig. 8). The data revealed that aphids, *Hysteroneura setariae* shared 85.72 per cent abundance. Among predators, *C. sexmaculata* shared 6.49 per cent abundance followed by *Neoscona* sp. (5.19 per cent), *Eriovixia* sp. (2.60 per cent). A moderate Shannon diversity index ($H' = 0.559$) was recorded in wheat ecosystem at Akola comprising aphids and associated predatory fauna (Table 11).

9. Mustard ecosystem: Shannon diversity index was worked out based on the average of number of aphids and associated predators recorded during the survey in mustard ecosystem at Akola (Table 19 and Fig. 9). The data revealed that mustard aphids, *Lipaphis erysimi* shared 94.23 per cent abundance. Among predators, *C. sexmaculata* shared 2.89 per cent abundance followed by *I. scutellaris* (2.89 per cent), *Neoscona* sp. (0.50 per cent), *Clubiona* sp. (0.50 per cent) and *Thomisus* sp. (0.50 per cent). A low Shannon diversity index ($H' = 0.298$) was recorded in mustard ecosystem at Akola comprising aphids and associated predatory fauna (Table 12).

10. Safflower ecosystem: Shannon diversity index was worked out based on the average of number of aphids and associated predators recorded during the survey in safflower ecosystem at Akola (Table 20 and Fig. 2). The data revealed that aphids, *Uroleucon compositae* shared 96.50 per cent abundance. Among predators, *C. sexmaculata* shared 1.66 per cent abundance followed by *Illeis* sp.(0.77 per cent), *I. scutellaris* (0.52 per cent), *Eriovixia* sp. (0.17 per cent), *Neoscona* sp. (0.14 per cent), *Chrysoperla* sp. (0.12 per cent) and *Leucauge decorata* (0.12 per cent). A low Shannon diversity index ($H' = 0.202$) was recorded in safflower

ecosystem at Akola comprising aphids and associated predatory fauna (Table 13).

Discussion

Our results showed various types of aphid's species and its associated predatory fauna found in various kharif and Rabi crops agro-ecosystem. Total of seven species of aphids and sixteen species of associated predatory fauna was found during investigation at near Akola vicinity. Our results stated that abundant predatory fauna recorded in Akola vicinity this might be due to diversified agro-ecosystem.

Our results revealed that in kharif and Rabi agro-ecosystem various predatory species viz. Lady bird beetle, Syrphid fly, Mallada, Green lace wing, 11 Spiders species (*Neoscona* sp., *Eriovixia* sp., *Clubiona* sp., *Oxyopes pankajii*, *Leucauge decorate*, *Thomisus* sp., *Hyllus semicupreus*, *Tetragnatha* sp., *Araneus* sp., *Cyrtophora cicatrosa*, *Clubiniona* sp.) were recorded in Akola vicinity. During the present investigation spiders were active with diversified species and attempt was made for identification of this important predatory arthropods. Our results are in line with results of (Naikwadi *et al.* 2015) [23] which reported four species of spiders in kharif agro-ecosystem in Akola district viz.; *Neoscona* sp., *Oxyopes pankajii*, *Thomisus* sp., *Pseusetia* sp. Out of which *Neoscona* sp. and *Oxyopes pankajii* recorded during the present investigation endorsed the present findings.

Similar observation was recorded by (Menon and Thangavelu, 1979) [20] which reported various predators like coccinellids, mantid, syrphid fly and *Chrysoperla* sp. in cotton ecosystem. Similarly (Joshi *et al.* 1997) [17] reported that *A. craccivora* on cowpea with associated predatory fauna *C. sexmaculata*, *C. transversalis*, *C. septumpunctata*, *Hormonia octomaculata*, *Paragus serratus* and *I. scutellaris*. Out of which *C. sexmaculata*, *C. transversalis* and *I. scutellaris* recorded during the present investigation endorsed the present findings. Similar observation recorded by (Ramya and Thangjum 2016) [24], who recorded *C. sexmaculata* and *C. transversalis* along with other species in citrus ecosystems. The earlier worker (Basappa 2011) [5] reported three coccinellids predators and nine spiders in sunflower ecosystems whereas, (Naikwadi *et al.* 2015) [23] had also reported the coccinellids and spiders in sunflower ecosystem of Akola district support the present findings.

Diversity indices value of both species richness and evenness (Magurran A.E. 1988) [18] i. e. pinpointing both species richness and evenness Shannon-Wiener index (H) (1.54), which is responsive to changes in the abundance of rare species in a community, the Simpson index (D) (0.75) which

is sensitive to changes in the most abundant species in a community and the evenness index (0.79) measure of how evenly species are distributed in sample, have been calculated. The diversity indices indicated that wide diversity aphid's species in Kharif and Rabi crop agro-ecosystem in Akola vicinity may be due to the appropriate weather conditions like temperature, humidity, water and enough number of hosts available to these aphids species. In the present study, value of Wiener index (1.54) indicates presence of unusual species in the aphids community. The most common evenness index was maximum (0.79) indicating evenly species distribution in a sample.

During present investigation *Neoscona* was the most active genera in kharif agro-ecosystem which is in tune to the previous finding of (Naikwadi *et al.* 2015) [23] who in his studies had recorded maximum occurrence of *Neoscona* sp. in kharif agro-ecosystem at Akola. The present observations on coccinellids are in accordance with the (Ramya and Thangjum 2016) [24], who recorded *C. sexmaculata* and *C. transversalis* along with other species in citrus ecosystems. The earlier worker (Basappa 2011) [5] reported three coccinellids predators and nine spiders in sunflower ecosystems whereas, (Naikwadi *et al.* 2015) [23] had also reported the coccinellids and spiders in sunflower ecosystem of Akola district support the present findings.

Our results are in line with the results of (Nagrare *et al.* 2015) [22] who reported fifteen species of spiders from rainfed cotton agro ecosystem belonging to six families viz., Araneidae, Oxyopidae, Thomisidae, Salticidae, Tetragnathidae and Theridiidae mainly dominated by Araneidae, Oxyopidae and Thomisidae. Also reported frequent occurrence of *Neoscona theisi* followed by *Oxyopes pankaji* and *Thomisus spectabilis* in cotton agro-ecosystem. Our results of Shannon biodiversity index of aphids and associated predatory fauna was in line with the results of (Basappa 2011) [5] which stated that in 48 species of natural enemies and 7 parasitoids, 24 insect predators, 9 spiders and 8 predatory birds was recorded from sunflower ecosystem.

Biodiversity index in cowpea ecosystem indicated that presence of *cheilomenes sexmaculata* (Fabricius), found dominant predatory fauna followed by *Ischiodon scutellaris*. Similar observation was observed by (Ali *et al.* 2013) [3] recorded the population density of the cowpea aphid, *Aphis craccivora* Koch and its associated predators on faba bean and cowpea. The common predators observed in faba bean and cowpea fields were: *Coccinella undecimpunctata* L., *Chrysoperla carnea* Steph., *Paederus alfieri* (Koch.), *Orius* sp., *Syrphus* sp. *Scymnus* sp. and *Cydonia vicina* (Muls.).

Table 1: Agro ecosystem wise activity of Aphids and associated predatory fauna in kharif & Rabi crops in Akola district

S. No	Agro ecosystem	Name of Aphids species	Name of Predatory fauna found
Kharif crop			
1.	Cotton	<i>Aphis gossypii</i> (Glover)	Lady bird beetle, Syrphid fly, Mallada, Green lace wing, Spiders (<i>Neoscona</i> sp., <i>Eriovixia</i> sp., <i>Clubiona</i> sp., <i>Oxyopes pankajii</i>)
2.	Cowpea	<i>Aphis craccivora</i> (Fabricius)	Lady bird beetle, Syrphid fly, Spiders (<i>Neoscona</i> sp., <i>Leucauge decorate</i>)
3.	Okra	<i>Aphis gossypii</i> (Glover)	Lady bird beetle, Syrphid fly, Mallada, Spider (<i>Neoscona</i> sp., <i>Eriovixia</i> sp., <i>Thomisus</i> sp.)
4.	Sorghum	<i>Rhopalosiphum maidis</i> (Fitch)	Lady bird beetle, Syrphid fly, Mallada, Green lace wing, Spiders (<i>Neoscona</i> sp., <i>Hyllus semicupreus</i> , <i>Tetragnatha</i> sp., <i>Eriovixia</i> sp., <i>Oxyopes pankajii</i>)
5.	Bean	<i>Aphis craccivora</i> (Fabricius)	Lady bird beetle, Syrphid fly, Spiders (<i>Neoscona</i> sp., <i>Leucauge decorate</i>)
Kharif & Rabi crop			
6.	Citrus	<i>Aphis (Taxoptera) citricidus</i> Kirkaldy	Lady bird beetle, Syrphid fly, Green lace wing, Mallada, Spiders (<i>Neoscona</i> sp., <i>Eriovixia</i> sp., <i>Araneus</i> sp., <i>Cyrtophora cicatrosa</i>)
Rabi Crops			
7.	Sunflower	<i>Aphis gossypii</i> Glover	Lady bird beetle, Spiders (<i>Neoscona</i> sp., <i>Eriovixia</i> sp., <i>Clubiniona</i> sp.)
8.	Wheat	<i>Hysteroneura setariae</i>	Lady bird beetle, Spider (<i>Neoscona</i> sp., <i>Eriovixia</i> sp.)

		Thomas	
9.	Mustard	<i>Lipaphis erysimi</i> Kaltenbach	Lady bird beetle, Syrphid fly, Spiders (<i>Neoscona</i> sp., <i>Clubiona</i> sp., <i>Thomisus</i> sp.)
10.	Safflower	<i>Uroleucon compositae</i> Theobald	Lady bird beetle, Syrphid fly, Green lace wing, Spiders (<i>Neoscona</i> sp., <i>Eriovixia</i> sp., <i>Leucauge decorate</i>)

Table 2: Relative abundance of aphid fauna in kharif and Rabi crops agro-ecosystem diversity Akola vicinity

Species	No. of specimen recorded	Relative Abundance	pi ln pi	Month (Number of species found)						
				July (17)	Aug (496)	Sept (208)	Oct (28)	Nov (606)	Dec (1342)	Jan (498)
<i>Aphis gossypii</i>	167	0.09	-0.220	0	48	12	0	4	12	2
<i>Aphis craccivora</i>	543	0.30	-0.361	5	152	61	6	107	81	89
<i>Rhopalosiphum maidis</i>	54	0.03	-0.105	0	41	13	0	0	35	0
<i>Aphis (Taxoptera) citricidus</i>	209	0.12	-0.249	4	7	18	8	99	11	0
<i>Hysteroneura setariae</i>	13	0.01	-0.035	0	0	0	0	7	137	13
<i>Lipaphis erysimi</i>	150	0.08	-0.207	0	0	0	0	86	395	145
<i>Uroleucon compositae</i>	674	0.37	-0.368	8	248	104	14	303	671	249
Shannon-Wiener index (H) = 1.545										
Simpson index (1-D) = 0.75										
Evenness index (E) = 0.79										

Table 3: Species wise percent composition and Relative abundance of predatory fauna associated with aphid population in Akola vicinity

S. No.	Species	No. of specimen recorded	Percentage (%)	Relative abundance	pi ln pi
1.	<i>Cheilomenes sexmaculata</i>	109	53.17	0.53	-0.336
2.	<i>Coccinella transversalis</i>	09	4.39	0.04	-0.137
3.	<i>Illeis</i> sp.	08	3.90	0.04	-0.127
4.	<i>Ischiodon scutellaris</i>	27	13.17	0.13	-0.267
5.	<i>Chrysoperla</i> sp.	06	2.93	0.03	-0.103
6.	<i>Mallada</i> sp.	09	4.39	0.04	-0.137
7.	<i>Neoscona</i> sp.	14	6.82	0.07	-0.183
8.	<i>Eriovixia</i> sp.	8	3.90	0.04	-0.127
9.	<i>Clubiona</i> sp.	3	1.46	0.01	-0.063
10.	<i>Oxyopes pankajii</i>	2	0.98	0.01	-0.042
11.	<i>Leucauge decorata</i>	3	1.46	0.01	-0.063
12.	<i>Thomisus</i> sp.	2	0.98	0.01	-0.042
13.	<i>Tetragnatha</i> sp.	2	0.98	0.01	-0.042
14.	<i>Hyllus semicupreus</i>	1	0.49	0.00	-0.022
15.	<i>Araneus</i> sp.	1	0.49	0.00	-0.022
16.	<i>Cyrtophora cicatrosa</i>	1	0.49	0.00	-0.022
				H=	1.735

Table 4: Shannon biodiversity index of aphids and associated predatory fauna in cotton ecosystem

Name of Species	Avg. no. of insect recorded	Per cent abundance	Pi	ln Pi	Pi ln Pi
<i>Aphis gossypii</i> (Glover)	89.19	73.96	0.740	-0.301	-0.223
<i>Cheilomenes sexmaculata</i> (Fabricius)	15.4	12.77	0.128	-2.056	-0.263
<i>Coccinella transversalis</i> (Fabricius)	2.4	1.99	0.020	-3.912	-0.078
<i>Illeis</i> sp.	1.2	0.99	0.010	-4.605	-0.046
<i>Ischiodon scutellaris</i> (Fabricius)	3.8	3.15	0.032	-3.442	-0.110
<i>Mallada</i> sp.	1.6	1.33	0.013	-4.343	-0.056
<i>Chrysoperla</i> sp.	2.6	2.16	0.022	-3.817	-0.084
<i>Neoscona</i> sp.	1.4	1.16	0.012	-4.423	-0.053
<i>Eriovixia</i> sp.	0.8	0.67	0.007	-4.962	-0.035
<i>Clubiona</i> sp.	1.0	0.83	0.008	-4.828	-0.039
<i>Oxyopes pankajii</i>	1.2	0.99	0.012	-4.605	-0.046
Total	120.59			H' =	1.033

Table 5: Shannon biodiversity index of aphids and associated predatory fauna in cowpea ecosystem

Name of Species	Avg. no. of insect recorded	Per cent abundance	Pi	ln Pi	Pi ln Pi
<i>Aphis craccivora</i> (Fabricius)	95.32	84.56	0.846	-0.167	-0.141
<i>Cheilomenes sexmaculata</i> (Fabricius)	11.0	9.76	0.098	-2.323	-0.228
<i>Coccinella transversalis</i> (Fabricius)	1.0	0.89	0.009	-4.711	-0.042
<i>Ischiodon scutellaris</i> (Fabricius)	3.4	3.02	0.030	-3.507	-0.105
<i>Neoscona</i> sp.	1.2	1.06	0.011	-4.511	-0.050
<i>Leucauge decorata</i>	0.8	0.71	0.007	-4.962	-0.035
Total	112.72			H' =	0.601

Table 6: Shannon biodiversity index of aphids and associated predatory fauna in okra ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	ln Pi	Pi ln Pi
<i>Aphis gossypii</i> (Glover)	59.47	75.59	0.756	-0.280	-0.212
<i>Cheilomenes sexmaculata</i> (Fabricius)	8.4	10.68	0.107	-2.235	-0.239
<i>Illeis</i> sp.	3.6	4.58	0.046	-3.079	-0.141
<i>Ischiodon scutellaris</i> (Fabricius)	1.6	2.03	0.020	-3.912	-0.078
<i>Mallada</i> sp.	1.8	2.29	0.023	-3.772	-0.087
<i>Neoscona</i> sp.	1.6	2.03	0.020	-3.912	-0.078
<i>Eriovixia</i> sp.	0.8	1.02	0.010	-4.605	-0.046
<i>Thomisus</i> sp.	1.4	1.78	0.018	-4.017	-0.072
Total	78.67			H' =	0.954

Table 7: Shannon biodiversity index of aphids and associated predatory fauna in sorghum ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	lnPi	Pi ln Pi
<i>Rhopalosiphum maidis</i> (Fitch)	53.5	62.14	0.621	-0.476	-0.296
<i>Cheilomenes sexmaculata</i> (Fabricius)	17.6	20.44	0.204	-1.590	-0.324
<i>Coccinella transversalis</i> (Fabricius)	2.2	2.56	0.026	-3.650	-0.095
<i>Ischiodon scutellaris</i> (Fabricius)	2.6	3.02	0.030	-3.507	-0.105
<i>Mallada</i> sp.	3.6	4.18	0.042	-3.170	-0.133
<i>Chrysoperla</i> sp.	0.8	0.93	0.009	-4.711	-0.042
<i>Neoscona</i> sp.	1.2	1.39	0.014	-4.269	-0.060
<i>Hyllus semicupreus</i>	1.0	1.16	0.012	-4.423	-0.053
<i>Tetragnatha</i> sp.	2.2	2.56	0.026	-3.650	-0.095
<i>Eriovixia</i> sp.	0.6	0.69	0.007	-4.962	-0.035
<i>Oxyopes pankajii</i>	0.8	0.93	0.009	-4.711	-0.042
Total	86.1			H' =	1.28

Table 8: Shannon biodiversity index of aphids and associated predatory fauna in bean ecosystem

Name of Species	Avg. no. of insect recorded	Per cent abundance	Pi	ln Pi	Pi ln Pi
<i>Aphis craccivora</i> (Fabricius)	112.2	84.74	0.847	-0.166	-0.141
<i>Cheilomenes sexmaculata</i> (Fabricius)	12.0	9.06	0.091	-2.397	-0.218
<i>Coccinella transversalis</i> (Fabricius)	1.2	0.91	0.009	-4.711	-0.042
<i>Ischiodon scutellaris</i> (Fabricius)	4.4	3.32	0.033	-3.411	-0.113
<i>Neoscona</i> sp.	1.6	1.21	0.012	-4.423	-0.053
<i>Leucauge decorata</i>	1.0	0.76	0.008	-4.428	-0.035
Total	132.4			H' =	0.602

Table 9: Shannon biodiversity index of aphids and associated predatory fauna in citrus ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	ln Pi	Pi ln Pi
<i>Aphis (Taxoptera) citricidus</i> Kirkaldy	208.53	36.22	0.362	-1.016	-0.368
<i>Aphis craccivora</i> Koch	335.68	58.30	0.583	-0.540	-0.315
<i>Cheilomenes sexmaculata</i> (Fabricius)	14.0	2.43	0.024	-3.730	-0.090
<i>Coccinella transversalis</i> (Fabricius)	3.0	0.52	0.005	-5.299	-0.026
<i>Illeis</i> sp.	1.4	0.24	0.002	-6.215	-0.012
<i>Ischiodon scutellaris</i> (Fabricius)	4.8	0.83	0.008	-4.829	-0.039
<i>Chrysoperla</i> sp.	2.6	0.45	0.005	-5.298	-0.026
<i>Mallada</i> sp.	1.2	0.21	0.002	-6.215	-0.012
<i>Neoscona</i> sp.	2.0	0.35	0.003	-5.809	-0.017
<i>Eriovixia</i> sp.	0.4	0.07	0.0006	-7.419	-0.004
<i>Araneus</i> sp.	1.0	0.17	0.002	-6.215	-0.012
<i>Cyrtophora cicatrosa</i>	1.2	0.21	0.002	-6.215	-0.012
Total	575.81			H' =	0.933

Table 10: Shannon biodiversity index of aphids and associated predatory fauna in sunflower ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	ln Pi	Pi ln Pi
<i>Aphis gossypii</i> Glover	18.32	51.58	0.516	-0.662	-0.342
<i>Cheilomenes sexmaculata</i> Fabricius	13	36.60	0.366	-1.005	-0.368
<i>Neoscona</i> sp.	1.4	3.94	0.039	-3.244	-0.127
<i>Eriovixia</i> sp.	1.8	5.07	0.051	-2.976	-0.152
<i>Clubiniona</i> sp.	1.0	2.81	0.028	-3.689	-0.092
Total	35.52			H' =	1.081

Table 11: Shannon biodiversity index of aphids and associated predatory fauna in wheat ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	ln Pi	Pi ln Pi
<i>Hysteroneura setariae</i> Thomas	13.2	85.72	0.857	-0.154	-0.132
<i>Cheilomenes sexmaculata</i> Fabricius	1.0	6.49	0.065	-2.733	-0.178
<i>Neoscona</i> sp.	0.8	5.19	0.052	-2.957	-0.154
<i>Eriovixia</i> sp.	0.4	2.60	0.026	-3.650	-0.095
Total	15.4			H [*] =	0.559

Table 12: Shannon biodiversity index of aphids and associated predatory fauna in mustard ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	ln Pi	Pi ln Pi
<i>Lipaphis erysimi</i> Kaltenbach	150.33	94.23	0.942	-0.060	-0.057
<i>Cheilomenes sexmaculata</i> Fabricius	4.6	2.89	0.029	-3.540	-0.103
<i>Ischiodon scutellaris</i> Fabricius	2.2	1.38	0.014	-4.269	-0.060
<i>Neoscona</i> sp.	0.8	0.50	0.005	-5.298	-0.026
<i>Clubiona</i> sp.	0.8	0.50	0.005	-5.298	-0.026
<i>Thomisus</i> sp.	0.8	0.50	0.005	-5.298	-0.026
Total	159.53			H [*] =	0.298

Table 13: Shannon biodiversity index of aphids and associated predatory fauna in safflower ecosystem

Name of species	Avg. No. of insect recorded	Percent abundance	Pi	ln Pi	Pi ln Pi
<i>Uroleucon compositae</i> Theobald	673.6	96.50	0.965	-0.036	-0.035
<i>Cheilomenes sexmaculata</i> Fabricius	11.6	1.66	0.017	-4.075	-0.069
<i>Illeis</i> sp.	5.4	0.77	0.008	-4.828	-0.039
<i>Ischiodon scutellaris</i> Fabricius	3.6	0.52	0.005	-5.298	-0.026
<i>Chrysoperla</i> sp.	0.8	0.12	0.001	-6.908	-0.007
<i>Neoscona</i> sp.	1.0	0.14	0.001	-6.908	-0.007
<i>Eriovixia</i> sp.	1.2	0.17	0.002	-6.215	-0.012
<i>Leucauge decorata</i>	0.8	0.12	0.001	-6.908	-0.007
Total	698			H [*] =	0.202

Conclusion

During the course of investigation seven species of aphids and sixteen species of predators were recorded. In aphids seven species were observed from different crop-ecosystems viz; *Aphis gossypii* (Glover), *Aphis craccivora* (Koch), *Rhopalosiphum maidis* (Fitch), *Aphis (Taxoptera) citricidus* (Kirkaldy), *Lipaphis erysimi* (Kaltenbach), *Hysteroneura setariae* (Thomas) and *Uroleucon compositae* (Theobald). Species wise data of aphids showed rich fauna of *U. compositae* with 37.24 per cent. This was followed by *A. craccivora*, *A. (Taxoptera) citricidus*, *A. gossypii*, *L. erysimi*, *R. maidis*. The aphid species *H. setariae* (0.72 per cent) was observed with minimum fauna in akola vicinity. In predators sixteen species were observed among them predators rich fauna of *C. sexmaculata* was observed with contribution of 53.17 per cent, followed by *Neoscona* sp., *C. transversalis*, *Mallada* sp., *Illeis* sp., *Eriovixia* sp., *Oxyopes pankajii*, *Chrysoperla* sp., *Thomisus* sp., *Tetragnatha* sp. Whereas, minimum species composition of spiders *Hyllus semicupreus*, *Araneus* sp. and *Cyrtophora cicatrosa* (0.49 per cent) was recorded during the course of investigation. Shannon diversity index of aphid species revealed that *U. compositae* showed abundance in population (-0.368), followed by *A. craccivora*. Whereas, *A. (Taxoptera) citricidus*, *A. gossypii* and *L. erysimi* showed moderate abundance in population. Whereas, *R. maidis* and *H. setariae* showed lower abundance in population of aphid fauna. However, rich shannon biodiversity index of aphid population (H^{*}=1.545) was noticed in Akola vicinity. Among predators shannon diversity index revealed that *C. sexmaculata* showed abundance in population (-0.336) followed by *I. scutellaris*.

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