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BIODIVERSITY OF APHIDOPHAGOUS COCCINELLIDS AND THEIR ROLE AS BIOINDICATORS IN AGRO-FOREST-ECOSYSTEM

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ABSTRACT

The pioneering role in the development of biological pest control has rendered the coccinellids of great practical and scientific interest. The species found in the agro-ecosystem in terms of biodiversity can be recruited as bioindicators owing to their climatic and trophic characteristics. Two types of habitats were selected for the biodiversity study *i.e.,* crop and forest ecosystem. The data obtained by trapping, hand picking and netting during March – September 2009 and 2010 showed the diversity, richness and evenness of aphidophagous coccinellids and their role as bioindicators in these area. A total of 4119 specimens of coccinellids insects were captured out of which 3612 were aphidophagous predator representing 35 species. In forest ecosystem a total of 1756 specimens were collected in which 1372 were the aphidophagous coccinellids. Similarly 2290 aphidophagous specimens were collected out of a total 2363 coccinellids in the crop ecosystem. When diversity of both the areas was compared, it was concluded that the aphidophagous coccinellids was most diverse in the crop area than forest ecosystem.

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INTRODUCTION

The word "biodiversity" is a contraction of biological diversity. Biodiversity of insects in forestry parlance can be summarized with two of its components species richness and evenness. The "richness" indicates the number of species present in a designated area whereas "evenness" stands for the relative abundance of each species (Vanclay, 1992).

Crop agro-ecosystems are diversified with different groups of insect predators. Among the predatory insects, the ladybirds (Coccinellidae: Coleoptera) have been respected through the centuries with extremely diverse in their habits. The majority of coccinellid species are beneficial because of their predaceous nature. In spite of their polyphagy, adults tend to prefer certain types of food, which are eaten voraciously. Both the larvae and adults of the coccinellids feed on soft body insects like scale insects, aphids and other small soft bodied creatures or their eggs. Coccinellids are also regarded as bioindicators (Iperti and Paoletti, 1999) and provide more general information about the ecosystem in which they occur (Andersen, 1999). They play their important role as biocontrol for those crops that are especially susceptible to aphid attack, namely maize, pigeon pea (Shantibala *et al.,* 1997). Pesticides used in the crop fields where aphids and other preys are likely to be found cause damage to the predatory coccinellids which ultimately results in the reduction of biodiversity.

Agro-forests are defined as complex agro-forestry systems that look like and function as natural forest ecosystems, but are integrated into agricultural management systems (Ishizuka *et al.,* 1995). Typically, the agro-forest area consists of densely cropped and planted sites which increasing naturalness and surrounded by decreasing intensity of developmental areas. Through consistent monitoring efforts, these areas can be treated as field experiments for addressing basic ecological questions and issues related to the impact of humans on their environment (McDonnell and Pickett, 1990; Niemela, 1999) and for the assessment of biodiversity.

The objectives of the present study were to explore the predatory ladybeetle fauna of Papum-Pare district of Arunachal Pradesh, to estimate the diversity, species richness and species evenness of aphidophagous coccinellids in agro-forest ecosystem and to know about the role of aphidophagy as bioindicators in an agro-forest habitat.

MATERIALS AND METHODS

Papum-Pare lies from 26°55' – 28°40'N latitude and 92°40' – 94°21' E longitude, at an altitude of 459-1250 msl, it is a land of lush green forests, deep river valleys and beautiful plateau, mostly mountainous with Himalayan ranges. The agro-forest area of Balijan, situated in the northern part and 78 km away from the district headquarter, Yupia, was selected for the present study. It consists of 123.00 acre of land under forest ecosystem that is integrated into agricultural management systems. This agro-forest area was classified into two parts *i.e.,* crop area and forest area.

Collection was made randomly by netting, hand picking and light trapping (one light traps per part of both areas) during March – September 2009 and 2010. Sampling was done for 2 consecutive days in each week and total population per month was counted. All specimens were manually stored and identified to species level. Mostly the adults of this family were collected in our samples. Some coccinellid larvae also found in the sampled areas. To minimize counting a species twice, all larvae were carefully examined and if they might have been the same species as an adult we counted them as a single species. The meteorological data were recorded to know environmental impact on the dispersal and diversity of coccinellid beetles. Temperature, relative humidity data were taken for each census day and were averaged for each month.

The data collected was analysed statistically to calculate the diversity, species richness and evenness in both areas separately. The Shannon diversity index was used which is as follows:

$$\bar{H} = \Sigma \text{ pi } \log_2 \text{pi}$$

$$H_{max} = \log_2 S$$

$$J = \frac{\bar{H}}{H_{max}} \text{ (Evenness)}$$

$$D = 1 - J \text{ (Dominance)}$$

For Diversity Comparison

$$t \text{ cal} = \frac{\bar{H}_1 - \bar{H}_2}{S^2 \bar{H}_1 - \bar{H}_2}$$

The diversity indices calculated from both of two areas was compared by *t-test* (Hutcheson, 1970). $\bar{H}_1$ is the diversity index from crop area and $\bar{H}_2$ is the diversity index from forest area. $S^2\bar{H}_1 - \bar{H}_2$ is the standard error of the difference between two diversity indices.

Estimation of species: Estimation of coccinellid species in the entire area was made as described by MacArthur and Wilson (1967).

RESULTS AND DISCUSSION

The entire district is mountainous forming part of Eastern Himalayans biodiversity hot spot. The Agriculture practice though of traditional type, is the important means of sustaining livelihood of the tribal communities of the district. Shifting cultivation (Jhuming) in the hill slope and wet field cultivation in the foot hills are the two main agricultural practices. Major agricultural crops are paddy, maize, millets, pulses, oilseed, sugarcane and tuber crops. Jhuming is deeply rooted with the socio-economic conditions of the hills farmers.

The research study was conducted from March – September in 2009 and 2010. A total of 4119 specimens of coccinellid insects were captured out of which 3662 were the aphidophagy representing 35 different species. In crop area, a total 2363 individuals were collected, in which 2290 belonged to the aphidophagy, similarly 1372 aphidophagous species were collected in total of 1756 individuals in the forest area. *Cheilomenes sexmaculata* (Fabricius) had more dominated population with mean value of 66.50, following *Micraspis discolor* (Fabricius), *Coelophora saucia* (Mulsant) and *Coccinella septempunctata* Linn. with the mean dominancy values of 54.50, 40.50 and 40.00 respectively in the whole agro-forest area (Table 1).

Diversity, species richness and evenness (Table 2) were calculated by Shannon diversity index. This index considers both the number of species and the distribution of individuals among species. For a given number of species, the largest value *H* results when every individual belongs to different species, and *J* is the relative measure of diversity (Kikkawa, 1996).

In crop area, there were 35 species of aphidophagous coccinellids with highest population of *C. sexmaculata*. The evenness value showed that the whole of the crop area was evenly distributed with only the dominance of a few species namely *C. sexmaculata, C. septempunctata, M. discolor, C. saucia* and *Pseudaspidimerus flaviceps* (Wajker) with more population as compared to others. The dominance value in crop agro-system is 0.08 (Table 2) indicated that 8 % of the 35 species dominating the crop area.

In forest-ecosystem, the distribution of 25 species of aphidophagous coccinellids was heterogeneous. *H* value showed that these aphidophagy species were less diverse than crop area. *J* value showed that in forest area relative abundance or evenness within 25 species was lesser than crop area (0.903) with dominance of 9 % (Table 2).

Diversity comparison

$t_{cal} > t_{tab}$

Since t_{cal} lies in the rejection region, therefore, *H* was rejected. It was concluded that the diversity indices are not same for the two areas.

The meteorological data were recorded to know environmental impact on the dispersal and diversity of aphidophagous coccinellid species. Temperature and humidity data were taken for each census day and were averaged for each month (Table 3). A slight fluctuation in monthly collected population was attributed to the ecological conditions(Fig. 1). The ecological conditions *i.e.,* the monsoon season and the rapid growth of plants (Coley and Aide, 1991), habitat quality (Rice and Riley, 2000) and climatic factors (Didham *et al.,* 1998; Vulinec, 2000) caused the dispersal of insects within this agro-forest area. The random collection methods also considered for this fluctuation (Kikkawa, 1996) but estimation of the coccinellids over the entire area overcomes this factor (McArthur and Wilson, 1967).

Estimation of coccinellid species

The collected species were 35 (Table 1) and the estimated number of coccinellid species in the entire area was 116, as described by MacArthur and Wilson (1967). The number of species of a particular group of

Table 1: Aphidophagous Coccinellids species captured across agro and forest ecosystem of Papumpare district of Arunachal Pradesh

S. No.	Coccinellids	Crop area	Forest area	Mean
1	*Anisolemnia dilatata* (Fabricius)	+	+	7.00
2	*Brumoides suturalis* (Fabricius)	+	+	5.50
3	*Bucolus posticalis* Blackburn	+	-	5.00
4	*Cheilomenes sexmaculata* (Fabricius)	+	+	66.50
5	*Chilocorus circumdatus* Gyllenhal	-	+	11.00
6	*Coccinella septempunctata* Linn.	+	+	40.00
7	*C. transversalis* Fabricius	+	+	20.00
8	*Coelophora bisselata* Mulsant	+	+	9.00
9	*C. saucia* (Mulsant)	+	+	40.50
10	*Cryptogonus kapuri* Ghorpade	+	+	9.00
11	*C. postmedialis* Kapur	+	-	16.00
12	*Cryptogonus quadriguttatus* (Weise)	+	-	13.00
13	*Cryptolaemus montrouzieri* Mulsant	+	+	19.00
14	*Harmonia dimidiata* (Fabricius)	+	+	27.50
15	*H. eucharis* (Mulsant)	+	-	21.00
16	*H. octomaculata* (Fabricius)	+	+	14.50
17	*Illeis indica* Timberlake	+	-	23.00
18	*Jauravia quadrinotata* Kapur	+	+	16.50
19	*Micraspis discolor* (Fabricius)	+	+	54.50
20	*Nephus bipunctatus* Kug	+	+	9.50
21	*Nephus regularis* Sicard	+	+	15.50
22	*Oenopia kirbyi* Mulsant	+	-	29.00
23	*Oenopia sexareata* (Mulsant)	+	+	22.50
24	*Propylea dissecta* (Mulsant)	+	+	26.00
25	*Propylea japonica* (Thunberg)	+	+	21.00
26	*Propylea luteopustulata* (Mulsant)	+	-	25.00
27	*Pseudaspidimerus flaviceps* (Walker)	+	+	24.00
28	*Rodolia breviuscula* Weise	+	+	11.00
29	*Sasajiscymnus dwipakalpa* (Ghorpade)	+	+	6.00
30	*Scymnus (Pullus) castaneus* Sicard	+	-	4.00
31	*Scymnus (Scymnus) nubilus* Mulsant	+	-	21.00
32	*Scymnus caudalis* LeConte	+	+	8.50
33	*Scymnus coniferarum* Crotch	+	-	31.00
34	*Scymnus ferrugatus (Moll.)*	+	+	15.00
35	*Synonycha grandis* (Thunberg)	+	+	22.00
Total No. of coccinellids		2363	1756	
Total No. of aphidophagous coccinellids		2290	1372	
Total No. of aphidophagous coccinellids species		35	25	

+ = Presence of predators; - = Absence of predators

Table 2: Result of Shannon Weiner Diversity Index for aphidophagous coccinellids

Diversity components		Agro-ecosystem	Forest ecosystem
Diversity	(H)	3.279	2.905
Max. Diversity	(H max)	3.555	3.219
Evenness	(J)	0.923	0.903
Dominance	(D)	0.08	0.09

H = Shannon Weiner diversity index, where absolute diversity = 1.00; J = Evenness or relative diversity, where absolute evenness = 1.00; D (1 – J) = Dominance or heterogeneity, where absolute dominance = 0.00

Table 3: Seasonal fluctuation of environmental factors for different month

Months	Temperature (ºC)		Relative humidity (%)	
	Maximum	Minimum	Morning	Evening
March	29.45	11.34	69.85	56.75
April	32.63	11.62	79.55	65.86
May	36.56	14.34	65.38	60.65
June	38.35	15.91	68.65	63.67
July	37.85	15.68	86.56	85.32
August	36.36	14.54	87.78	80.92
September	33.50	14.32	88.57	80.90

organism increases approximately as the fourth root of the area. In other words, the number of species can be predicted as

Estimated number of species = Constant X $(Area)^{0.25}$

The predaceous and bioindicators role of ladybird beetles benefit from the maintenance of field diversity, which supports the population of prey such as aphids, thrips and mites (Iperti and Paoletti, 1999). It was also noted that the erosion of predatory potential occurred due to use of pesticides. The ladybird beetles migrated between various crop fields throughout the season depending upon the availability of prey and habitat disturbance (Maredia *et al.,* 1992). Gray's (1989) postulated that in habitats affected by increased disturbance, diversity should decrease; opportunist species should gain dominance and mean size of the dominant species decrease. Our results corroborate this hypothesis to some extent. The actual reason, if not, could be the disturbance in forest area in the form of Jhuming cultivation practices and the deforestation/soil erosion due to natural calamity causes a decrease in the diversity (Perfecto and Snelling, 1995; Favila and Halffter, 1997; Niemela *et al.,* 2000; Parkash, 2002). Seasonal changes influence the occurrence of aphid outbreaks, the type of plant infested and thus the behaviour of the aphidophagous coccinellids. In the context of biological control, the aphidophagous coccinellids represent an important cause of mortality of coccids, aphids and mites (Iperti and Paoletti, 1999).

CONCLUSIONS

The main objective of this study was the assessment of biodiversity of aphidophagous coccinellids in this area but their behavior with the changes in environment and with the increase in prey population was also studied. From the species richness and diversity comparison through *t-test*, it was concluded that the crop area was relatively more diverse than forest area. The distribution of 35 species of coccinellids was heterogeneous in the entire agro forest area. The females deposited its eggs near prey often in small clusters in protected sites on leaves and stems. The adults live for weeks or months depending on their geographic location and the availability of the prey. These predatory insects are active searchers for food and have been known to arrive at heavily aphid-infested fields. These beetles are density dependent predators, their numbers rise as the prey numbers increase. The prey population, thus thereby determines the ladybird beetle population. The results of present study agreed to the observations of Dufrene and Legendre (1997) and McGeoch (1998) also indicated that the aphidophagous coccinellids can be considered as useful ecological indicators.

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