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Biodiversity of Foliage Arthropods in the Mixed Crop Zone and Cotton-Wheat Zone in Punjab Province, Pakistan

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ABSTRACT

Arthropods are the most integral part of an agro-ecosystem, but the crop intensification practices are badly affecting these key components. Studies pertaining to biodiversity of arthropods in the cropland of two zones i.e., mixed crop zone (Faisalabad) and Cotton-Wheat zone (Multan) Punjab, Pakistan were conducted for a period of one year. The main focus was to collect, identify and compare the species richness and evenness. Sugarcane, Fodder, Wheat and Brassica were sampled round the year showed variations in species composition of their fauna in the two districts representing the two zones. Mixed-crop zone was highly diversified with respect to species and abundance of individuals per species. On the whole order Orthoptera was dominant followed by Araneae, Hemiptera, Coleoptera, Lepidoptera, Hymenoptera, Odonata, Diptera and Thysanoptera, Neuroptera, Prostigmata each represented by single species except Mantodea with two species. This data base will be helpful in future ecological pest management strategies. The mixed-crop zone was found better than cotton-wheat zone with respect to faunal diversity that may be functional in keeping the sustainability of agro-ecosystem intact.

Key Words: Foliage fauna; Arthropods; Croplands; Sustainable agro-ecosystem

INTRODUCTION

The increasing world population and changes in consumption patterns increased significance of agricultural intensification during the last few decades. Unless crop yield is improved and release of fertilizers and pesticides in the croplands is reduced, such intensification would augment contamination and perturbation of managed and natural ecosystems, ultimately damaging biodiversity and public health (Hughes, 2002).

In more intensive agriculture, arthropod populations are lowest. This intensification highlights many contributory factors, which can be addressed individually. These include cropping pattern, frequency of tillage, amount and nature of fertilizers used, amount and nature of pesticides used etc. However, it should be noted that all these factors, which are interrelated to a greater or lesser degree, often cause negative synergies to the agriculture (Cherry, 2003). The crop systems, biodiversity performs a variety of ecological functions beyond the production of food, including recycling of nutrients, help regulation of microclimate and local hydrological cycles, suppression of undesirable organisms and detoxification of chemicals especially the agro-chemicals. Biodiversity mediated renewal processes and ecological functions are largely biological and their persistence depends upon the maintenance of species integrity and diversity in agro-ecosystem (Alteiri, 1999).

Diversification of cropping system often leads to reduce herbivore populations. Studies suggest that more diverse the agro-ecosystem and the longer this diversity remains undisturbed, the more internal links develop to promote greater insect stability. It is clear, however, that the stability of insect community depends not only its trophic diversity, but also on the actual density dependence nature of the trophic levels (Southwood & Way, 1997). Olfert *et al.* (2002) highlighted the importance of arthropods. According to them, arthropods fauna is integral during evaluation of ongoing cropping practice and helps in redesigning of farming systems in order to make it economically viable and environment sustainable. It is now an established that arthropod predators suppress pest populations (Chang & Kareiva, 1999; Gurr & Wratten, 2000; Symondson *et al*., 2002). There are evidences that species-rich ecosystems are more stable than species-poor ecosystems. If the relationship between biodiversity and stability holds, then it is in the interest of the long-term viability of a region to encourage diverse human and natural ecosystems (Minor, 2005).

Based on different cropping patterns and agro climatic conditions, cultivations in Punjab are classified into different zones. Two of them are (1) mixed-crop zone and (2) cotton-wheat zone. Mixed crop zone (2.6 million hectares) constitutes vast area of central Punjab. The Rabi crops like sugarcane and fodder and Kharif crops e.g., wheat

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and brassica are sown in the fields and fellow lands. Due to small land ownership, heterogeneity of crops and their importance as food crops the use of pesticides and synthetic fertilizers are relatively less intensive in this zone. Cotton-wheat zone (1.36 million hectares) constitutes vast area of southern Punjab. Cash crops of the zone are wheat, cotton and brassica and are sown extensively, while sugarcane and fodder cultivations are sparse. There is a trend of mono-cropping in this zone and use of pesticides, herbicides and synthetic fertilizers is extensive. The arthropod fauna of the two different cropping systems is suspected to vary due to the differential chemical off-farm inputs. The objectives of the present study aim at (i) identification of the major arthropods in the crop fields of two zones, (ii) effect of important environmental factors on faunal populations (iii) crop preference of different faunal species in the two cropping systems.

MATERIALS AND METHODS

A preliminary survey was made to select the crop fields of sugarcane, fodder, wheat and brassica in two zones i.e. mixed crop zone and cotton-wheat zone. For extensive information on current and past management practices in these habitats a questionnaire was made for interviewing the land owners/farmers, with specific reference to the use of chemicals and mechanical operations at farms. At each locality two blocks, each of more than five acres of different cropland were taken. Then at each block, two acres were selected randomly for collection of fauna. Sampling was initiated as per schedule (two days in a month in each zone). Sweep net was used to sweep all types of adult and large arthropod present above the canopy of the crop. Heavy duty muslin nets (38 cm dimension) were used to sweep through vegetation forming a figure of eight. Direct hand picking and automated sifters were also employed to collect the foliage fauna. All the arthropod specimens were preserved in laboratory grade Alcohol with few drops of Glycerine.

The identification up to species level was done with the help of available, related taxonomic information in the "Fauna of British India" and online electronic keys available on different websites. Museum of the Department of Agri. Entomology, University of Agriculture, Faisalabad and Entomological Research Institute Jhang road Faisalabad was also consulted for this purpose. The trophic level of each species (phytophagous, zoophagous & saprophagous) was confirmed from recent available literature. Shannon's diversity index and Multiple Linear Regression (Magurran, 1988; Ludwig & James, 1989) using GW Basic vesion 6, while Cluster analysis using Statistica version 9 were employed to get various inferences.

RESULTS AND DISCUSSION

Out of 218 species of arthropods reported from two zones, 212 were captured from Faisalabad representing mixed crop zone hereafter called MCZ fields, whereas 182 from Multan representing cotton-wheat zone hereafter CWZ. Twelve orders were identified and grouped as more abundant (Orthoptera, Hemiptera, Coleoptera, Lepidoptera & Araneae) less abundant (Hymenoptera, Odonata & Diptera) and rare (Thysanoptera, Mantodea, Neuroptera & Prostigmata). Order Orthoptera had highest diversity followed by Hemiptera, Coleoptera, Araneae, Lepidoptera, Hymenoptera, Odonata and Diptera in MCZ whereas in CWZ Orthoptera was followed by Araneae, Hemiptera, Coleoptera, Lepidoptera, Diptera, Hymenoptera and Odonata. Thysanoptera, Mantodea, Neuroptera and Prostigmata showed no difference in species diversity in two zones studied. The reduction in number of species was consistent for all the orders in CWZ fields except Araneae. Table I showed highly significant differences between MCZ and CWZ fields. Changed farming practices of these two areas were probably the reason for this trend. Intensification of agriculture by use of high-yielding crop varieties, fertilization, irrigation and pesticides has altered the biotic interactions and reduced the in-farm resources for sustainability of the system and have serious local, regional and global environmental consequences (Matson *et al.*, 2007). Similar findings for MCZ and CWZ were also given by Siddiqui (2005) in the wheat agro-ecosystem, while comparing four major zones in Punjab. T-tests confirmed the difference in diversity of species in different orders (Table I).

Majority of Orthopterans and Lepidopterans are known crop pests whereas most of the Coleopteran, Hymenopteran and Araneae species are natural enemies of crop pests. In MCZ more habitats in the form of phytomorphic heterogeneity were available to faunal species as compared to CWZ, which agreed with that of Bos *et al.* (2007) who also found most of the pest and predator species residing in the agro forestry systems with a diversity of shade trees in tropical areas in addition to pristine forest reserves. Fig. 1 shows the comparison of specie diversity of various orders in four crops of two zones. Accordingly, almost all orders were highly diversified with respect to species richness including pest and predator species except Araneae which had significantly high diversity in all crops of CWZ. Similarly, Coleoptera which included major part of coccinellid predators had higher species diversity in all four crops of MCZ.

Furthermore, the faunal species from eight sampling units (four crops in each zone) were transformed into three principal components. Multiple linear regression was applied on these dependent variables to check the effect of four environmental factors (independent variables). Environmental factors were, Temperature, Relative humidity, Rainfall and Wind velocity. The MLR was statistically significant in Order Hemiptera, Coleoptera, Lepidoptera, Hymenoptera and Araneae at F-ratio 10.019, 9.725, 9.264, 10.091 and 9.364, respectively at df 3,4 for PCA component-I as shown in (Table II). The correlation of

Table I: Shannon Diversity Index among mixed crop zone and cotton-wheat zone

Order	MCZ					CWZ					t-test	df	p-value
	N0	H'	N1	N2	E5	N0	H'	N1	N2	E5			
Odonata	11	2.09	8.19	6.81	0.81	7	1.83	6.28	6.12	0.96	1.854	83	0.067*
Orthoptera	61	2.85	47.34	37.52	0.78	52	2.67	39.57	28.96	0.72	17.4	>120	000***
Hemiptera	33	2.7	15.02	8.4	0.52	27	2.58	13.29	7.85	0.55	0.483	>120	0.639
Coleoptera	32	2.69	14.77	9.05	0.58	26	2.17	15.06	10.82	0.69	3.742	>120	000***
Lepidoptera	21	2.56	12.98	9.69	0.72	17	2.47	11.91	10.56	0.87	3.742	>120	000***
Diptera	10	1.83	6.24	4.61	0.69	8	1.73	5.68	4.8	0.81	11.71	101	0.008**
Hymenoptera	12	2.24	9.44	7.68	0.79	8	1.93	6.92	6.53	0.93	17.4	>120	000***
Araneae	27	2.17	23.82	20.74	0.86	34	2.38	29.55	28.3	0.95	3.782	>120	000***
Others	5	1.2	3.32	2.92	0.82	5	1.29	3.64	2.84	0.69	2.462	>120	0.014*

MCZ= Mixed crop zone; CWZ= Cotton-Wheat zone; No= Number of species;
H'= Diversity; E5= Eveness
P-value for the factor are given (ns: p>0.05, *: p<0.05, * *: p<0.01, * * *: p<0.001)

rainfall with a value of 90.9 in Hemiptera, 90.2 for Coleoptera, 35.8 for Lepidoptera, 39 for Hymenoptera and relative humidity 55 in Araneae were more pronounced than those of other environmental factors. According to Trewavas (2001) the rain water and humid environment is always suitable for beetle (larvae, pupae) and spiderlings to achieve growth and development. Moreover, the prey populations they consume also flourish in such environmental conditions of much vegetational growth. In the present situation although the R-value was not statistically significant for remaining orders even though the relative contribution of rainfall with a value of 42 in Odonata, 78.3 for Diptera, relative humidity 53.4 for Orthoptera and wind velocity 65.4 for others were more important correlates.

Cluster analysis was performed to evaluate the habitat preferences of different species in the cropland. It was speculated that similar crop would support same faunal diversity irrespective of the locality. Interestingly many different clustering patterns were observed (Fig. 2). Among them the wheat and brassica crop in CWZ were preferred by many species of Odonata, Hemiptera, Coleoptera, Diptera and Araneae. Second combination was of fodder and wheat in MCZ supporting a number of Odonata, Coleoptera and Diptera, The wheat crop, wherever present, supported similar diversity of Orthopteran and Lepidopteran species. Landscape structure influences local diversity by different movement pattern between natural habitats and as well as crop and non-crop interfaces. In such conditions generalist predators prefer the habitats, where more food is available; in case one prey is absent its alternate is available in plenty (Tscharntke *et al.*, 2005). As majority of dragons, beetles and spiders were generalist predators therefore they were present in the crops, where aphids, grubs and larvae were present.

Identified specimens were categorized on the basis of their feeding habits. Six major categories defined were Phytophagous (Plant eater), Zoophagous (capture preys), Phytozoophagous (feed on both plant & animals fluids), phytosaprophagous (feed on dead remains of plants), phytozoophagous (feed on dead remain of animlas etc.) and omnivores (feed on whatever is available) organisms. Among the predators order Araneae was most dominant

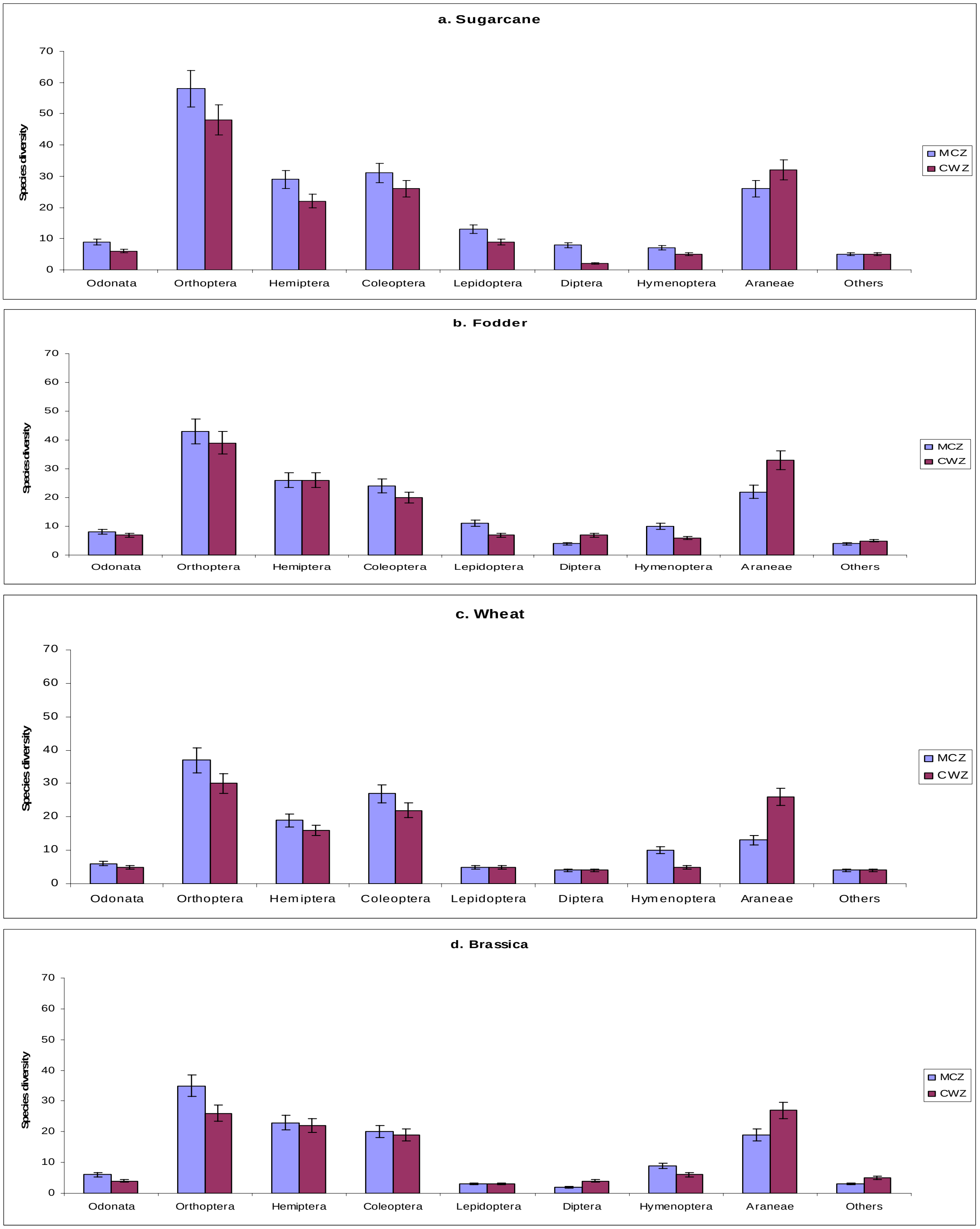
Table II: Multiple linear regression showing impact of environmental factors on different orders

Order	Principle Component	T	RH	RF	WV	R-value	F-ratio
Odonata	I	26.9	29.9	**42**	1.2	0.663	9.661
	II	25.6	35.9	36.7	1.8	0.332	3.421
	III	8.5	40.4	46.2	5	0.466	0.655
Orthoptera	I	5.9	**53.4**	36.1	4.6	0.502	11.789
	II	8.9	74.2	11.8	5.2	0.309	7.355
	III	17.4	55.1	26.9	0.6	0.455	2.314
Hemiptera	I	3.9	5	**90.9**	0.2	**0.968**	10.019
	II	0.1	83	11.9	4.9	0.243	3.919
	III	35.8	29.3	21.9	13.1	0.729	0.903
Coleoptera	I	6.9	2.5	**90.2**	0.4	**0.901**	9.725
	II	53.5	10.6	35.5	0.5	0.74	2.383
	III	64.7	2.2	29	4.1	0.616	1.978
Lepidoptera	I	23.3	26.9	**35.8**	14	**0.988**	9.264
	II	4.3	10.9	83.8	1	0.881	5.528
	III	5.2	32.6	62.1	0.1	0.859	4.571
Diptera	I	8.1	11.4	**78.3**	2.2	0.435	0.577
	II	10.9	33.33	50	5.8	0.314	0.343
	III	6.8	39	49.1	5.2	0.648	1.383
Hymenoptera	I	17.8	7.8	**39**	35.4	**0.976**	10.091
	II	9.6	20.3	16	34	0.551	0.919
	III	3.7	30	38	8.3	0.546	0.903
Araneae	I	16.1	**55**	28.5	0.4	**0.897**	9.364
	II	16.1	55	28.5	0.4	0.327	9.364
	III	16.3	36.7	33.3	13.7	0.74	2.131
Others	I	1.7	25.5	7.2	**65.6**	0.537	0.522
	II	9.9	9.4	41.2	39.6	0.355	0.358
	III	0.7	15.9	39.9	43.5	0.335	1.383

T= Temperature; RH= Relative Humidity; RF= Rainfall; WV= Wind velocity
R-value 0.900***

with respect to diversity and abundance. Next was the order Coleoptera though less diverse but highly abundant with respect to family Coccinellidae having a pioneering role in control of different insect pests. They play their effective role as biocontrol agents for those crops that are especially susceptible to aphid attack, namely maize, alfalfa, canola, wheat, flax, the forage crops canary seed (or canary grass), peas, apples and potatoes (Khan & Suhail, 2001; Zahoor *et al.,* 2003). Odonates were represented by 11 species of dragon and damsel flies. Odonata naiads or nymphs are aquatic and powerful predators of protozoa, fry, small tadpols, oligochaetes, larvae of flies, chiromonids, mosquitoes and bugs (Hussain & Ahmed, 2003).

Fig. 1: Diversity of arthropod species in four crops of Faisalabad (MCZ) and Multan (CWZ)
(a) Sugarcane, (b) Fodder, (c) Wheat and (d) Brassica

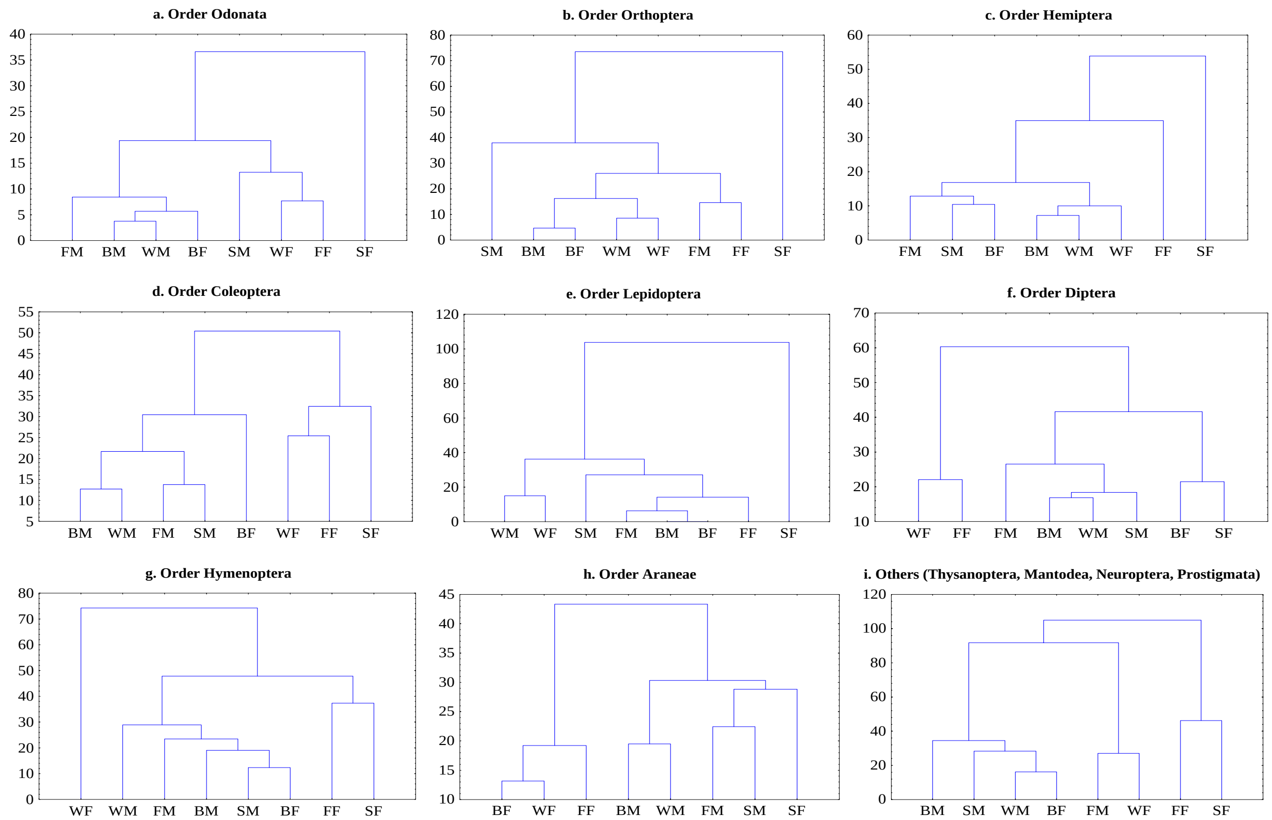


Outstanding diversity and abundance of predators could be due to the lesser sensitivity of Arachnid and Coccinellid predators to chemicals, which shared fairly in the samples. Their existence could be interpreted in the light of findings of Feber *et al.* (1998) who concluded that the abundance and diversity of spiders was directly affected by the increased levels of understory vegetation in the organic fields. Wisniewska and Prokopy (1997) reported that if pesticides were only used early in the growing season spider populations increased. Spatial limitations of pesticides also

Fig. 2: Cluster analysis based on Euclidean distances showing habitat preferences by faunal orders in different crop combinations in Faisalabad (MCZ) and Multan (CWZ) X-axis= Crop combinations; Y-axis= Species abundance

SF = sugarcane Fsd, FF = fodder Fsd, WF = wheat Fsd, BF = brassica Fsd

SM = sugarcane Mnt, FF = fodder Mnt, WM = wheat Mnt, BM = brassica Mnt



resulted in higher spider numbers since they could move out of the treated area and returned when the chemical dissipated (Balanca & De Visscher, 1997).

CONCLUSION

Orders Orthoptera, Hemiptera, Coleoptera and Araneae were dominating in both zones with significantly greater diversity of the former three orders in MCZ and the later one in CWZ. A significantly greater diversity of Araneae could be related to relative humidity, which was lower in relatively arid climate of CWZ. By and large, mixed cropping system with reduced chemical applications was relatively better with respect to the conservation of cropland biodiversity.

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