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Diversity and Dynamics of Macro-Invertebrates in Sugarcane Agro-Ecosystem of Punjab (Pakistan)

[1]Saima Kausar, [2]Muhammad Nadeem Abbas, [2]Muhammad Mahmood-ul-Hassan, [2]Shahnaz Akhtar Rana, [2]Naureen Rana, [3]Iram Maqsood and [2]Isma Gul

[1]College of Life Sciences, Anhui Agricultural University, Hefei, 230036, China
[2]Department of Zoology and Fisheries, University of Agriculture, Faisalabad, Pakistan
[3]Preventive Veterinary medicine Department, Veterinary Medicine College,
Northeast Agricultural University, Mucai Street 59, Harbin 150030, People's Republic of China

Abstract: Macro-invertebrate diversity in a sugarcane agro-ecosystem in Faisalabad district (30° 31.5 N and 73° 74 E) Punjab was quantified. Cane plants and weeds growing at the edges and center of the field were sampled for macro-invertebrates. Foliage fauna thus collected was identified up to species level. Arthropodes (96.35%) and mollusks (3.65%) constituting 232 species were recorded. Hemiptera (30.01%), Coleoptera(18.01%), Diptera (16.79%), Orthoptera (10.29%) and Araneae (7.31%) were dominant. Of the arthropods groups, Hymenoptera, Isopoda, Mantodea, Lepidoptera, Blattaria, Neuroptera, Thysanura, Odonata and Dermaptera collectively constituted 14% of the total macro-invertebrates. Mollusks comprising only of pulmonates constituted (3.65%). Weeds had a significantly greater diversity (H′ = 4.075) of macro-invertebrates than cane (H′ = 3.673) (p = <0.001). Similarly field edges had greater macro-invertebrate diversity (H′=4.292) than center (H′= 3.872). Findings indicated that weeds growing at the edges of a cane field help to maintain macro-invertebrate diversity.

Key words: Sugarcane fields · Arthropods · Pulmonates · Weeds · Species richness

INTRODUCTION

Sugarcane besides being used as a livestock forage is utilized c commercially for manufacture of white sugar and *gur* (non-centrifugal sugar).It is cultivated on an area of 988 thousand hectare and yields 55981 Kgs/Hec. Its estimated production during 2011 was 55.3 million tons and was used as raw material in 84 mills for the manufacture of sugar. It's by products are used within the country for the manufacture of alcohols, paper and chipboard which contribute 3.6% in value added agriculture and 0.8% to the GDP. The crop contributes a major share to annual income of, landowners, farmers and daily paid laborers [1].

Pakistan ranks 5th in world's sugarcane acreage and 15th in sugarcane production [2]. A substantial role in the decline of sugarcane production is played by such insect pests as top borer (*Scirpophaga nivella* F.), stem borer (*Chilo infuscatellus* Snell), root borer (*Emmalocera depressella* Swin.) and Gurdaspur borer (*Acigona steniellus* Hampson) that inflict heavy damage to the crop annually [3]. Farmers, in order to avoid these losses, rely on pesticides. They also use weedicides to minimize competition among sugarcane and weeds. They have never valued biological control which is self-perpetuating once established and usually does not harm non-target organisms. In addition, it is neither disruptive to environment nor does it leave residues on food [4, 5].

Weeds in crops enhance floral diversity, which in turn supports diversity of phytophagus species and their natural enemies in the agro-ecosystems. It provides nectar, food, pollen, shelter and a suitable habitat for both the pests and their natural predators in a field [6]. Weeds ensure alternative food sources to pests and provision of suitable habitat to their natural enemies [7] thereby reducing pest damage on the cultivated crop [8].

Corresponding Author: Muhammad Nadeem Abbas, Department of Zoology and Fisheries, University of Agriculture, Faisalabad, Pakistan.

Previous work on the abundance and diversity of macro-invertebrates in sugarcane is fragmentary [9, 10, 11] and as such little attention has been paid towards the documentation of whole macro invertebrate diversity in the field. There is an extreme dearth of literature on this issue in Pakistan and no worthwhile literature is available except [12, 13, 14, 5]. The present study is designed to fill this gap and particularly focuses on documentation of biodiversity of macro-invertebrates in a sugarcane-weed agro-ecosystem of Faisalabad district.

MATERIALS AND METHODS

Study Area: This study was conducted in Faisalabad (30° 31.5 N and 73° 74 E with an elevation of 184.4m asl) that lies in northeast of Punjab (Pakistan). Faisalabad is the third most populous city with Chenab river flow about 30 km (19 mi) to the northwest, while the River Ravi roams about 40 km (25 mi) south east of the city. The lower Chenab canal is the key source of irrigation water, which meets the requirements of 80% of cultivated land. The soil of Faisalabad comprises alluvial deposits mixed with loess having calcareous characteristics, making the soil very fertile [15]. May, June and July are the hottest months of the year, with mean maximum temperature reaching 39°C and maximum daily temperatures up to 49°C. The monsoon rains mostly fall in July and August, which are the wettest months. December and January are the coldest months with a mean minimum temperature of 6°C and occasionally passing below freezing [16].

This study was conducted for two consecutive years during 2014 and 2015. The total annual rainfall in 2015 was 625.9 mm, while it was 285.6 mm in 2014. But the mean annual maximum and minimum temperatures in both the sampling years were almost similar. The mean annual maximum and minimum temperature in 2009 were 31.23°C, 18.07°C respectively while they were 31.15°C, 18.50°C in 2010 (Fig. 1).

Sampling Technique: For the collection of macro-invertebrates, One block sugarcane (area = 4.05 ha) was selected on 24 randomly selected sites. Three plots (total area = 0.405 ha) from each of these randomly selected blocks of sugarcane was again randomly selected and two quadrates (area = $1m^2$ each) of foliage macro-invertebrates were sampled by using sweep net and hand picking from each of these three plots in such a way that one of these quadrate was sampled from edge and other from the center of the field. All the quadrates were randomly selected by the surveyor in a transect, one from the edge (0 m distant from the field periphery) and the center (5 m inside the field), both quadrates were differ with regard to crop plant density as well as weeds diversity and density [17]. Sampling was done fortnightly and each sampling session comprised of three hours in the afternoon from 2:30 pm to 5:30 pm in winter months and 4:00 pm to 7:00 pm in summer months. Sampling was done for two consecutive cropping seasons of sugarcane. The sampling was done through November to April during both study years. Sweep nets were used to capture

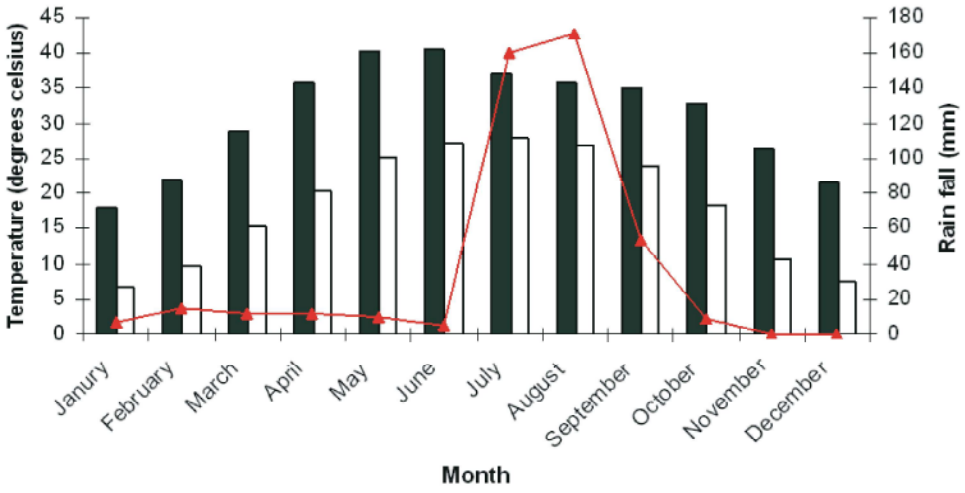

Fig. 1: Mean monthly maximum (black bars) and minimum (white bars) temperatures and rainfall (Red line), from 2013 to 2015, recorded at the Agricultural Meteorology Cell in university of Agriculture Faisalabad

flying insects present above the canopy of the weed and crop plants. All the collected macro-invertebrates were preserved in glass vials containing 70% ethanol.

The collected macro-invertebrate taxa were identified upto species level by using taxanomic keys and descriptions e.g. Pocock (1900a) for arachnids and [18, 19] for insects. The identification of arthropods was also done with the help of the reference collections lodged in the Insect Biodiversity and Biosystematics Research Laboratory in the Department of Agriculture Entomology, University of Agriculture, Faisalabad, Pakistan and the Entomology Museum, Department of Agriculture Entomology, University of Agriculture, Faisalabad.

Statistical Analysis: Shannon's diversity index [20] was applied to draw inferences.

RESULTS

Species Composition and Diversity of Macro-invertebrates: Macro-invertebrates belonging to two phyla and fifteen orders were recorded from sugarcane plants and associated weeds (Table 1). Arthropods were the most abundant group of macro-invertebrates collected from sugarcane (94.26%) and its associated weeds (98.22%). Among the arthropods, Hemiptera (30.01%), Coleoptera (18.01%), Diptera (16.78%), Orthoptera (10.295) and Araneae (7.31%) constituted 82% of the macro-invertebrates. Hemiptera (37.37%), Coleoptera (28.45%), Isopoda (8.36%) and Araneae (6.92%) were the dominant on sugarcane plants, whereas Diptera (28.39 %), Hemiptera (23.29%), Orthoptera (19.34%) and Coleoptera (8.47%) were dominant on its associated weeds.

Foliage macro-fauna of sugarcane and associated weeds represented two animal phyla, Arthropoda and Mollusca. Among arthropods, twelve Orders of Class Insecta (84.95%) and one of Class Arachnida (7.31%) and Malacostraca (4.12%) were recorded. Molluscs (3.6%) formed only a fraction of macro-invertebrates and all of them were pulmonates. In total, 178 species of insects belonging to 79 Families and 12 Orders, 35 species of arachnids belonging to 13 families and one Order and three species of isopods belonging to two families and one Order were recorded while pulmonates (16 species) belonged to 10 families and one Order. Thus, a total of 232 species of macro-invertebrates (n = 5665) were recorded both from sugarcane and associated weeds (Table 2). Of these, 118 were common to both sugarcane and its weeds, 53 were recorded only from sugarcane while the remaining (63 spp) were recorded exclusively from weeds present in the cane fields.

Coleoptera was the most spacious Order, constituted highest number of species (42 spp), in which Coccinellidae was the most dominant Family with nine species. Araneae comprising of 35 species was second in decreasing order of species richness. Clubionidae with eight species was the most dominant Family among arachnids. Diptera (34 spp), Hemiptera (32 spp), Hymenoptera (25 spp), Orthoptera (20 spp), Lepidoptera and Pulmonata (16 spp each) were the other species rich assemblages in Family Chloropidae, Lygaeidae, Formicidae, Acrididae, Noctuidae and Hygromiidae, respectively. Order Isopoda, Odonata, Dermaptera and Neuroptera (2 spp each), Thysanura, Mantodea and Blattaria (1 spp each) formed only a fraction of the total macro-invertebrates recorded collectively from the cane and weed leaves. See % relative abundance of species recorded in each taxa (Fig. 2).

The order of species richness on both cane and its associated weeds were differed significantly, hence studied separately. On cane plants Coleoptera (n= 38) and Araneae (n= 29) were recorded more species rich, whereas Isopoda (n= 3), Dermaptera and Odonata (n= 2), Mantodea, Neuroptera and Blattaria (n= 1) were least in species richness. On cane weeds Diptera (n= 31), Hemiptera (n= 30) were recorded most species rich, while Isopoda (n= 3) Neuroptera (n= 2), Thysanura, Mantodea and Blattaria (n= 1 each) formed fraction of total macro-invertebrates.

Overall in sugarcane-weeds agro-ecosystem, *Coccinella septempunctata, Cuora trifasciata*, *Stenolophus* sp., *Enoclerus rosmarus* and *Pycnocoma littoralis* collectively formed 70% of coleopterans. *Dolichopus plumipes*, *Culex pipiens*, *Anatrichus erinaceus*, *Chironomus grande* and *Aedes dorsalis* constituted = 60% of the dipterans fauna. *Pyrilla. perpusilla*, *Perkinsiella saccharicida*, *Cavelerius saccharivorus*, *Xysticus californicus* and *Aphis nerii* were 80% of the hemipteran fauna. *Solenopsis invicta*, *Camponotus pennsylvanicus*, *Polyrachis* sp., *Craterellus fallax*, *Apis mellifera* and *Solenopsis xyloni*, constituted a little over 60% of the hymenopterans macroinvertebrates. *Phyllopalpus pulchellus*, *Acheta domesticus*, *Melanoplus bivittatus* contributed almost 80% of the orthopterans. While *Sepsid* spp., *Hlicoverpa armigera*, *Agrotis ipsilon* larvae, *Palpita flegia* and Pyralidae caterpillar collectively constituted a little over 70% of lepidoterans on cane and weeds.

Table 1: Relative abundance (%) of macro-invertebrates recorded from sugarcane and its associated weeds in Punjab (Pakistan). (n is the number of individuals of each order)

	% Relative abundance (n)		
Phylum/Order	Crop	Weeds	Total
Arthropoda	94.27 (2548)	98.22 (2910)	96.35 (5458)
Thysanura	-	0.07 (2)	0.04 (02)
Odonata	0.07 (02)	-	0.04 (02)
Orthoptera	0.48 (13)	19.24 (570)	10.29 (583)
Dernaptera	0.07 (02)	-	0.04 (02)
Mantodea	0.15 (04)	4.66 (138)	2.51 (142)
Blattaria	1.11 (30)	0.41 (12)	0.74 (42)
Hemiptera	37.37 (1010)	23.29 (690)	30.01 (1700)
Coleoptera	28.45 (769)	8.47 (251)	18.01 (1020)
Neuroptera	0.11 (3)	0.07 (02)	0.09 (05)
Hymenoptera	5.88 (159)	3.47 (103)	4.63 (262)
Lepidoptera	1.22 (33)	2.26 (67)	1.76 (100)
Diptera	4.07 (110)	28.39 (841)	16.79 (951)
Araneae	6.92 (187)	7.66 (227)	7.31 (414)
Isopoda	8.36 (226)	0.24 (07)	4.12 (233)
Pulmonata	5.73 (155)	1.77 (52)	3.65 (207)
Total	2703	2962	5665

Table 2: Relative abundance (%) of macro-invertebrates recorded from edge and center of sugarcane and associated weeds in Punjab (Pakistan). (n is the number of individuals of each order)

	Sugarcane crop		Sugarcane weeds	
Phylum/Order	Edge	Center	Edge	Center
Arthropoda	93.533% (1403)	95.17% (1144)	98.600 %(2113)	97.314% (797)
Thysanura	-	-	0.05 (01)	0.12 (01)
Odonata	0.13 (02)	-	-	-
Orthoptera	0.67 (10)	0.25 (03)	22.45 (481)	25.15 (206)
Dernaptera	-	0.17 (02)	-	-
Mantodea	-	0.33 (04)	0.89 (19)	0.24 (02)
Blattaria	1.67 (25)	0.42 (05)	0.52 (11)	0.12 (01)
Hemiptera	31.47 (472)	44.76 (538)	24.41 (523)	20.39 (167)
Coleoptera	30.13 (453)	26.29 (316)	8.87 (190)	7.45 (61)
Neuroptera	0.13 (02)	0.08 (01)	0.09 (2)	-
Hymenoptera	6.80 (102)	4.74 (57)	3.97 (85)	2.19 (18)
Lepidoptera	1.40 (21)	0.99 (12)	2.75 (59)	0.98 (8)
Diptera	5.00 (75)	2.92 (35)	26.93 (577)	32.23 (264)
Araneae	7.87 (118)	5.74 (69)	7.37 (158)	8.43 (69)
Isopoda	8.27 (124)	8.49 (102)	0.33 (7)	-
Pulmonata	6.47 (97)	4.83 (58)	1.40 (30)	2.69 (22)
	1501	1202	2143	819

Among the pulmonates (16 species), eight were recorded both from cane and weed leaves, six from crop and two from weed. *Candidula gigaxii*, *Bradybaena similaris*, *Cepaea nemoralis*, *Hellicela itala*, *Oxychilus cellarius* and *Candidula unifasciata* collectively constituted almost 80%. They contributed almost 3:2 on weeds and cane respectively. *Hellicela itala* was recorded only on cane.

More arachnids (11 species) were recorded from crop than from weeds (n = 6) whereas the combined number of arachnid species recorded both from cane and weeds foliage was 18. *Oxyopes sertatus*, *Oxyopes javanus*, *Clubiona phargmitis* and *Clubiona lutescens*, collectively constituted 60 % of the arachnid fauna (Annexure 1a, b, c).

Over all the richness of macro-invertebrates in sugarcane-weed agro-ecosystem was (S= 232), diversity (H′= 4.25) and evenness (E= 0.30). However, the richness (S= 169), diversity (H′=3.67) and evenness (E= 0.71) on cane while the richness (S= 162), diversity (H′= 4.06) and evenness (E= 0.80) on weeds in sugarcane-weed agro-ecosystem (Table 3).

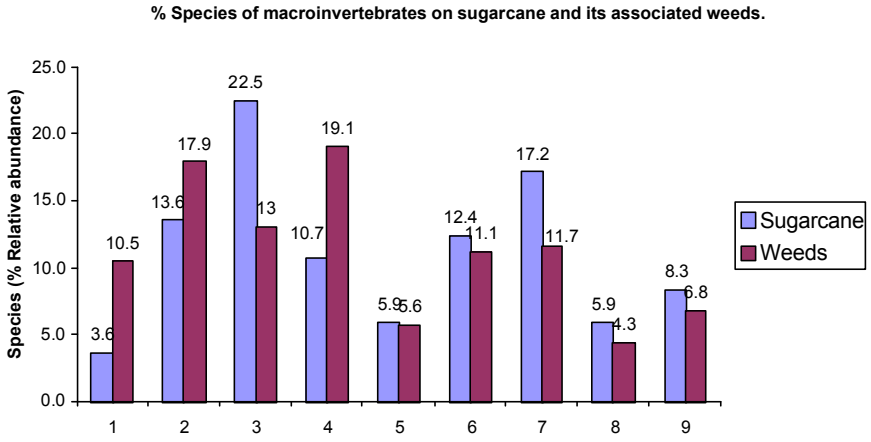

Fig. 2: 1. Orthoptera, 2. Hemiptera, 3. Coleoptera, 4. Diptera 5. Lepidoptera, 6. Hymenoptera, 7. Araneae, 8. others, 9. Pulmonata

Table 3: Variations in richness, diversity and evenness values for macro-invertebrates recorded from edge and center of sugarcane fields in Faisalabad district

Sugarcane field	S	H´	E	S	H´	E	*df*	t-value	*p*-value
Sugarcane edge/ Sugarcane center	140	3.695	0.747	112	3.363	0.712	>120	5.745	<0.001***
Sugarcane edge/ Sugarcane weeds edge	140	3.695	0.747	149	4.054	0.810	>120	7.815	<0.001***
Sugarcane edge/ Sugarcane weeds center	140	3.695	0.747	79	3.560	0.814	>120	2.494	0.012**
Sugarcane center/ Sugarcane weeds edge	112	3.363	0.712	149	4.054	0.810	>120	13.373	<0.001***
Sugarcane center/ Sugarcane weeds center	112	3.363	0.712	79	3.560	0.814	>120	3.335	<0.001***
Sugarcane weeds edge/ Sugarcane weeds center	149	4.054	0.810	79	3.560	0.814	>120	10.391	<0.001***
Sugarcane crop/ Sugarcane weeds	169	3.673	0.716	162	4.075	0.801	5150	10.861	<0.001***

Annexure Table 1a: Relative abundance (%) of macro-invertebrates belonging to order (a) Hemiptera, (b) Coleoptera, (c) Diptera, (d) Orthoptera and (e) Araneae in sugarcane and its associated weeds

Order/Family/ Species	Sugarcane	Weeds	Total
(a) Hemiptera	37.37(1010)	23.30(690)	30.01(1700)
Miridae	0.15(04)	1.28(38)	0.74(42)
Miridae nymph	0.11(03)	1.25(37)	0.71(40)
Taylorilygus apicalis	0.04(01)	0.03(01)	0.04(02)
Lygaeidae	16.91(457)	3.58(106)	9.94(563)
Xyonysius californicus	7.44(201)	0.57(17)	3.85(218)
Lygaeus kalmia	0.11(03)	0.37(11)	0.25(14)
Cavelerius saccharivorus	9.14(247)	0.07(02)	4.40(249)
Oxycarenus spp.	0.11(03)	1.55(46)	0.86(49)
Lygaeidae nymph	0.11(03)	0.68(20)	0.41(23)
Lygaeus kalmii nymph	-	0.34(10)	0.18(10)
Blissidae	-	0.03(01)	0.02(01)
Blissidae nymph	-	0.03(01)	0.02(01)
Berytidae	-	0.03(01)	0.02(01)
Neides tipularius	-	0.03(01)	0.02(01)
Largidae	-	0.03(01)	0.11(06)
Largus davisi	-	0.20(06)	0.11(06)
Pyrrhocoridae	0.41(11)	0.07(02)	0.23(13)
Dysdercus cingulatus	0.37(10)	0.03(01)	0.19(11)
Dysdercus koenigii	0.00	0.03(01)	0.02(01)
Dysdercus mimulus	0.04(01)		0.02(01)
Coreidae	0.15(04)	0.24(07)	0.19(11)
Coreidae nymph	-	0.10(03)	0.05(03)
Acanthocephala declivis	0.15(04)	0.14(04)	0.14(08)

Annexure Table 1a: Continued

Pentatomidae	0.48(13)	0.95(28)	0.72(41)
Euschistus servus	0.48(13)	0.95(28)	0.72(41)
Geocoridae	0.55(15)	0.41(12)	0.48(27)
Geocoridae nymph	0.33(09)	0.30(09)	0.32(18)
Geocoris uliginosus	0.22(06)	0.10(03)	0.16(09)
Pseudococcidae	1.15(31)	0.00()	0.55(31)
Saccharicoccus sacchari	1.15(31)	0.00	0.55(31)
Lophopidae	12.84(347)	3.81(113)	8.12(460)
Pyrilla perpusilla	12.84(347)	3.81(113)	8.12(460)
Acanaloniidae	-	0.30(09)	0.16(09)
Acanalonia spp.	-	0.30(09)	0.16(09)
Cicadellidae	0.37(10)	1.76(52)	1.09(62)
Cicadellidae nymph	0.07(02)	0.07(02)	0.07(04)
Agalliopsis sp.	0.22(06)	1.18(35)	0.72(41)
Austroagallia torrida	0.04(01)	0.51(15)	0.28(16)
Orosius orientalis	0.04(01)	0.00	0.02(01)
Delphacidae	4.14(112)	5.47(162)	4.84(274)
Perkinsiella saccharicida	4.14(112)	5.47(162)	4.84(274)
Membracidae	-	0.27(08)	0.14(08)
Entylia carinata	-	0.27(08)	0.14(08)
Aphididae	0.07(02)	4.66(138)	2.47(140)
Aphis nerii	0.04(01)	4.09(121)	2.15(122)
Aphis glycines	0.00	0.44(13)	0.23(13)
Melanaphis spp.	0.04(01)	0.14(04)	0.09(05)
Coccidae	0.15(04)	0.24(07)	0.19(11)
Ceroplastes ceriferus	0.15(04)	0.24(07)	0.19(11)
(b) Coleoptera	28.45(769)	8.47(251)	18.01(1020)
Carabidae	2.29(62)	0.00	1.09(62)
Stenolophus sp.	1.89(51)	-	0.90(51)
Calosoma semilaeve	0.26(07)	-	0.12(07)
Nebria brevicollis	0.11(03)	-	0.05(03)
Tanystoma maculicolle	0.04(01)	-	0.02(01)
Staphylinidae	1.48(40)	1.22(36)	1.34(76)
Paederus littoralis	0.81(22)	0.74(22)	0.78(44)
Staphylinus olens larvae	0.59(16)	0.47(14)	0.53(30)
Ocypus olens	0.07(02)	-	0.04(02)
Cleridae	0.85(23)	0.78(23)	0.81(46)
Enoclerus rosmarus	0.85(23)	0.78(23)	0.81(46)
Elateridae	0.11(03)	0.03(01)	0.07(04)
Dalopius marginatus	0.11(03)	0.03(01)	0.07(04)
Coccinellidae	20.68(559)	5.20(154)	12.59(713)
Coccinella septempunctata	6.99(189)	1.38(41)	4.06(230)
Coccinella novemnotata	0.18(5)	0.03(01)	0.11(06)
Brumoides suturalis	1.00(27)	1.25(37)	1.13(64)
Coccinella trifasciata	4.74(128)	0.71(21)	2.63(149)
Hippodamia convergens	0.07(02)	0.20(06)	0.14(08)
Cheliomenes sexmaculata	0.59(16)	0.10(03)	0.34(19)
Coccinella septempunctata pupae	0.18(05)	-	0.09(05)
Coccinella septempunctata larvae	6.88(186)	0.78(23)	3.69(209)
Coccinella transversalis	-	0.20(06)	0.11(06)
Micaspis allardi	-	0.54(16)	0.28(16)
Harmonia axyridis	0.04(01)	-	0.02(01)

Annexure Table 1a: Continued

Chrysomellidae	0.70(19)	0.44(13)	0.56(32)
Aphthona spp.	-	0.34(10)	0.18(10)
Aulacophora femoralis	0.15(04)	0.07(02)	0.11(06)
Podagrica fuscicornis	-	0.03(01)	0.02(01)
Chrysochus cobaltinus	0.07(02)	-	0.04(02)
Aphthona flava	0.37(10)	-	0.18(10)
Hispa atra	0.04(01)	-	0.02(01)
Raphidopala foveicollis	0.07(02)	-	0.04(02)
Anthicidae	0.18(05)	0.37(11)	0.28(16)
Anthicus floralis	0.18(05)	0.37(11)	0.28(16)
Curculionidae	1.52(41)	0.41(12)	0.94(53)
Tanymecus palliatus	0.15(04)	0.03(01)	0.09(05)
Sipalinus gigas	0.04(01)	0.07(02)	0.05(03)
Anthonomus spp.	0.41(11)	0.30(09)	0.35(20)
Hypera postica	0.89(24)	-	0.42(24)
Sphenophorus spp.	0.04(01)	-	0.02(01)
Dermestidae	0.04(01)	-	0.02(01)
Dermestidae larvae	0.04(01)	-	0.02(01)
Bostrichidae	0.07(02)	-	0.04(02)
Rhyzopertha dominica	0.07(02)	-	0.04(02)
Tenebroinidae	0.41(11)	-	0.19(11)
Mesostena angustata	0.04(01)	-	0.02(01)
Gonocephalum granulatum	0.07(02)	-	0.04(02)
Tenebrio molitor	0.07(02)	-	0.04(02)
Gonocephalum elderi	0.04(01)	-	0.02(01)
Tribolium castaneum	0.15(04)	-	0.07(04)
Eleodes spp.	0.04(01)	-	0.02(01)
Scarabaeidae	0.11(03)	0.03(01)	0.07(04)
Phyllophaga spp. Larvae	0.11(03)	0.03(01)	0.07(04)
(c) Diptera	4.07(110)	28.39(841)	16.79(951)
Culicidae	0.78(21)	5.74(170)	3.37(191)
Culex pipiens	0.74(20)	3.88(115)	2.38(135)
Aedes dorsalis	0.04(01)	1.79(53)	0.95(54)
Anopheles pseudostigmaticus	-	0.07(02)	0.04(02)
Simuliidae	-	0.14(04)	0.07(04)
Simulium aureum	-	0.14(04)	0.07(04)
Anisopodidae	-	0.10(03)	0.05(03)
Sylvicola spp.	-	0.10(03)	0.05(03)
Bibionidae	-	0.14(04)	0.07(04)
Bibio marci	-	0.14(04)	0.07(04)
Chloropidae	0.22(06)	6.48(192)	3.50(198)
Anatrichus erinaceus	0.18(05)	2.87(85)	1.59(90)
Oscinella frit	-	3.41(101)	1.78(101)
Chlorops sp.	0.04(01)	0.14(04)	0.09(05)
Hippelates spp.	-	0.07(02)	0.04(02)
Syrphidae	0.70(19)	0.51(15)	0.60(34)
Melanostoma mellinum	0.63(17)	0.41(12)	0.51(29)
Episyphus balteats	0.07(02)	0.10(03)	0.09(05)
Milichiidae	0.04(01)	0.14(04)	0.09(05)
Phyllomyza spp.	0.04(01)	0.14(04)	0.09(05)
Muscidae	0.15(04)	1.96(58)	1.09(62)
Musca domestica	0.15(04)	1.69(50)	0.95(54)
Musca antumnalis	-	0.27(08)	0.14(08)
Calliphoridae	0.22(06)	0.37(11)	0.30(17)
Lucilia sericata	0.22(06)	0.37(11)	0.30(17)
Dolichopodidæ	1.29(35)	5.98(117)	3.74(212)
Dolichopus plumipes	1.29(35)	5.98(117)	3.74(212)

Annexure Table 1a: Continued

Chironomidae	0.11(03)	2.30(68)	1.25(71)
Chironomus grande	0.07(02)	2.30(68)	1.24(70)
Chironomus sp.	0.04(01)	-	0.02(01)
Phoridae	0.18(05)	-	0.09(05)
Melaloncha sp.	0.18(05)	-	0.09(05)
Techinidae	-	0.07(02)	0.05(03)
Tachina fera	-	0.07(02)	0.04(02)
Ceromya bicolor	-	0.03(01)	0.02(01)
Empididae	0.04(01)	1.59(47)	0.85(48)
Empis chioptera	-	0.27(08)	0.14(08)
Empis pennipes	0.04(01)	1.22(36)	0.65(37)
Platypalpus agilis	-	0.10(03)	0.05(03)
Agromyzidae	0.22(06)	0.54(16)	0.39(22)
Calycomyza spp.	0.22(06)	0.41(12)	0.32(18)
Agromyza ambigua	-	0.14(04)	0.07(04)
Heleomyzidae	0.04(01)	0.03(01)	0.04(02)
Suillia parva	0.04(01)	0.03(01)	0.04(02)
Stratiomyidae	0.00	1.49(44)	0.78(44)
Sargus bipunctatus	-	1.49(44)	0.78(44)
Psychodidae	-	0.03(01)	0.02(01)
Moscas polilla	-	0.03(01)	0.02(01)
Drosophilidae	0.04(01)	0.68(20)	0.37(21)
Drosophila melanogaster	0.04(01)	0.68(20)	0.37(21)
Asilidae	0.00	0.03(01)	0.02(01)
Triorla interrupta	-	0.03(01)	0.02(01)
Ulidiidae	0.04(01)	-	0.02(01)
Euxesta stigmatias	0.04(01)	-	0.02(01)
Lauxaniidae	-	3.38(100)	0.04(02)
Minettia spp.	-	0.07(02)	0.04(02)
(d) Orthoptera	0.48(13)	19.24(570)	10.29(583)
Tetrigidae	0.04(01)	0.68(20)	0.37(21)
Tetrix subulata	-	0.07(02)	0.04(02)
Tetrix brunneri	-	0.61(18)	0.32(18)
Tetrigidae nymph	0.04(01)	-	0.02(01)
Acrididae	0.04(01)	8.20(243)	4.31(244)
Acrididae nymph	-	5.47(162)	2.86(162)
Schistocerca rubiginosa	-	0.07(02)	0.04(02)
Schistocerca nitens	0.04(01)	0.41(12)	0.23(13)
Melanoplus sanguinipes	-	0.03(01)	0.02(01)
Melanoplus bivittatus	-	1.11(33)	0.58(33)
Acrida hungarica	-	0.81(24)	0.42(24)
Aiolopus thalassinus	-	0.17(05)	0.09(05)
Acrida cinerea	-	0.14(04)	0.07(04)
Tettigoniidae	0.04(01)	0.44(13)	0.25(14)
Tettigonia viridissima	-	0.14(04)	0.07(04)
Neoconocephalus triops	-	0.03(01)	0.02(01)
Tettigoniidae nymph	-	0.27(08)	0.14(08)
Microcentrum californicum	0.04(01)	-	0.02(01)
Gryllidae	0.37(10)	9.93(294)	5.37(304)
Acheta domesticus	0.04(01)	4.32(128)	2.28(129)
Acheta spp.	-	0.14(04)	0.07(04)
Phyllopalpus pulchellus	0.07(02)	5.17(153)	2.74(155)
Gryllodes supplicans	-	0.30(09)	0.16(09)
Gryllidae nymph	0.26(07)	-	0.12(07)

Annexure Table 1a: Continued

Araneae	6.92(187)	7.66(227)	7.31(414)
Oonopidae	0.22(06)	0.78(23)	0.51(29)
Oonops pulcher	0.15(04)	0.44(13)	0.30(17)
Tapinesthis cespitum	0.04(01)	0.24(07)	0.14(08)
Oonops domesticus	-	0.03(01)	0.02(01)
Yumates nesophila	-	0.03(01)	0.02(01)
Maymene ambita	-	0.03(01)	0.02(01)
Opopaea sp.	0.04(01)	-	0.02(01)
Clubionidae	4.07(110)	0.10(03)	1.99(113)
Clubiona phargmitis	1.55(42)	0.10(03)	0.79(45)
Clubiona lutescens	1.37(37)	-	0.65(37)
Clubiona caerulescens	0.07(02)	-	0.04(02)
Clubiona pacifica	0.15(04)	-	0.07(04)
Clubiona riparia	0.04(01)	-	0.02(01)
Clubiona rostrata	0.04(01)	-	0.02(01)
Clubi spp.	0.30(08)	-	0.14(08)
Clubiona decora	0.55(15)	-	0.26(15)
Oxypidae	0.37(10)	5.13(152)	2.86(162)
Oxyopes sertatus	0.04(01)	3.00(89)	1.59(90)
Oxyopes javanus	0.33(09)	2.13(63)	1.27(72)
Theridiidae	0.37(10)	0.30(09)	0.34(19)
Theridion sp.	0.18(05)	0.30(09)	0.25(14)
Steatoda grossa	0.04(01)	0.00	0.02(01)
Theri spp.	0.15(04)	0.00	0.07(04)
Miturgidae	0.74(20)	0.17(05)	0.44(25)
Cheiracanthium vire	0.26(07)	0.17(05)	0.21(12)
Cheiracanthium uncinatum	0.07(02)	0.00	0.04(02)
Cheriacanthium inclusum	0.41(11)	0.00	0.19(11)
Salticidae	0.18(05)	0.10(03)	0.14(08)
Telamonia vlijmi	0.11(03)	0.03(01)	0.07(04)
Tegeneria sp.	0.04(01)	0.03(01)	0.04(02)
Collinus spp .	0.000	0.03(01)	0.02(01)
Synemosyna formica	0.04(01)	-	0.02(01)
Lycosidae	0.48(13)	-	0.23(13)
Lycosa spp.	0.48(13)	-	0.23(13)
Dysderidae	0.11(03)	-	0.05(03)
Dysdera crocata	0.11(03)	-	0.05(03)
Aranaeidae	0.04(01)	0.03(01)	0.04(02)
Araneus diadematus	0.04(01)	0.03(01)	0.04(02)
Tengellidae	0.07(02)	0.03(01)	0.05(03)
Titiotus spp	0.07(02)	0.03(01)	0.05(03)
Pholcidae	0.07(02)	0.00	0.04(02)
Holocnemus pluchei	0.07(02)	0.00	0.04(02)
Thomisidae	0.11(03)	0.78(23)	0.46(26)
Misumenops importinos	-	0.17(05)	0.09(05)
Xysticus atrimaculatus	0.11(03)	0.27(08)	0.19(11)
Ruptued morpho species	-	0.34(10)	0.18(10)
Mysmemidae	0.07(02)	0.24(07)	0.16(09)
Mysmena tasmaniae	0.07(02)	0.24(07)	0.16(09)

Annexure Table 1b: Relative abundance (%) of macroinvertebrates belonging to order (f) Hymenoptera, (g) Pulmonata and (h) Lepidoptera in (i) sugarcane and its associated weeds

Order/Family/ Species	Sugarcane	Weeds	Total
Pulmonata	5.73(155)	1.76(52)	3.65(207)
Bradybaenidae	1.00(27)	0.41(12)	0.69(39)
Bradybaena similaris	1.00(27)	0.41(12)	0.69(39)
Hygromiidae	2.29(62)	0.64(19)	1.43(81)
Hellicela itala	0.81(22)	0.00	0.39(22)
Candidula unifasciata	0.44(12)	0.07(02)	0.25(14)
Candidula gigaxii	1.00(27)	0.44(13)	0.71(40)
Cernuella virgata	0.04(01)	0.14(04)	0.09(05)
Vertginidae	-	0.17(05)	0.09(05)
Columella edentula	-	0.17(05)	0.09(05)
Helicidae	1.15(31)	0.20(06)	0.65(37)
Cepaea nemoralis	1.11(30)	0.20(06)	0.64(36)
Helix lucorum	0.04(01)	-	0.02(01)
Succineidae	0.15(04)	-	0.07(04)
Oxyloma sp.	0.04(01)	-	0.02(01)
Succinella oblonga	0.11(03)	-	0.05(03)
Oxychilidae	0.89(24)	0.07(02)	0.46(26)
Aegopinella nitidula	0.26(07)	0.03(01)	0.14(08)
Oxychilus cellarius	0.63(17)	0.03(01)	0.32(18)
Zonitidae	0.04(01)	0.10(03)	0.07(04)
Zonitoides sp.	0.04(01)	0.10(03)	0.07(04)
Punctidae	-	0.14(04)	0.07(04)
Punctum pygmaeum	-	0.14(04)	0.07(04)
Ferussaciidae	0.11(03)	0.03(01)	0.07(04)
Cecilioides acicula	0.11(03)	0.03(01)	0.07(04)
Lymnaeidae	0.11(03)	-	0.05(03)
Galba truncatula	0.11(03)	-	0.05(03)
Lepidoptera	1.22(33)	2.26(67)	1.77(100)
Arctiidae	0.07(02)	0.03(01)	0.05(03)
Pyrrharctia isabella	0.00	0.03(01)	0.02(01)
Lophocampa argentata larvae	0.07(02)	-	0.04(02)
Noctuidae	0.74(20)	0.57(17)	0.65(37)
Helicoverpa zea	-	0.17(05)	0.09(05)
Helicoverpa armigera	0.26(07)	0.30(09)	0.28(16)
Thysanoplusia aureopicta	0.07(02)	0.10(03)	0.09(05)
Agrotis ipsilon larvae	0.37(10)	0.00	0.18(10)
Mocis frugalis	0.04(01)	0.00	0.02(01)
Sepsidae	-	1.38(41)	0.72(41)
Sepsid spp.	-	1.38(41)	0.72(41)
Cecidomyiidae	-	0.03(01)	0.02(01)
Rhopalomyia californica	-	0.03(01)	0.02(01)
Geometridae	0.11(03)	0.14(04)	0.12(07)
Macaria sp.Larvae	-	0.03(01)	0.02(01)
Operoptera brumata	-	0.10(03)	0.05(03)
Operoptera brumata larvae	0.11(03)	-	0.05(03)
Crambidae	0.04(01)	0.10(03)	0.07(04)
Palpita flegia	0.04(01)	0.10(03)	0.07(04)
Pyralidae	0.15(04)	-	0.07(04)
Pyralidae caterpillar	0.15(04)	-	0.07(04)
Tineidae	0.04(01)	-	0.02(01)
Tineidae nymph	0.04(01)	-	0.02(01)
Saturniidae	0.07(02)	-	0.04(02)
Eacles imperialis	0.07(02)	-	0.04(02)
Hymenoptera	5.88(159)	3.48(103)	4.62(262)
Sphecidae	0.04(01)	0.17(05)	0.11(06)
Eremnophila aureonotatea	0.04(01)	0.17(05)	0.11(06)
Braconidae	0.11(03)	0.03(01)	0.07(04)
Cotesia flavipes	0.07(02)	0.03(01)	0.05(03)
Cotesia spp.	0.04(01)	0.00	0.02(01)

Annexure Table 1b:

Ichneumonidae	0.15(04)	0.30(09)	0.23(13)
Ichneumon sarcitorius	0.11(03)	0.24(07)	0.18(10)
Ichneumonidae spp.	0.00	0.03(01)	0.02(01)
Coelichneumon rudis	0.04(01)	0.03(01)	0.04(02)
Formicidae	5.48(148)	2.46(73)	3.90(221)
Lasius niger	-	0.14(04)	0.07(04)
Solenopsis molesta	0.07(02)	-	0.04(02)
Solenopsis invicta	1.63(44)	1.25(37)	1.43(81)
Solenopsis xyloni	0.48(13)	0.03(01)	0.25(14)
Linepithema humile	0.30(08)	-	0.14(08)
Formica fusca	0.30(08)	0.30(09)	0.30(17)
Formica incerta	0.11(03)	0.00	0.05(03)
Polyrachis sp.	0.67(18)	0.07(02)	0.35(20)
Cephalotes atratus	0.30(08)	0.17(05)	0.23(13)
Camponotus fallax	0.44(12)	0.10(03)	0.26(15)
Camponotus pennsylvanicus	0.78(21)	0.00	0.37(21)
Camponotus spp.	-	0.27(08)	0.14(8)
Dolichoderus taschenbergi	0.07(02)	0.03(01)	0.05(03)
Tapinoma sessile	0.15(04)	0.03(01)	0.09(05)
Monomorium minimum	0.18(05)	0.07(02)	0.12(7)
Apidae	0.04(01)	0.44(13)	0.25(14)
Apis mellifera	0.04(01)	0.44(13)	0.25(14)
Vespidae	0.04(01)	0.07(02)	0.05(03)
Polistes spp.	-	0.07(02)	0.04(02)
Vespa spp.	0.04(01)	-	0.02(01)
Trichogrammatidae	0.04(01)	-	0.02(01)
Trichogramma spp.	0.04(01)	-	0.02(01)

Annexure Table 1c: Relative abundance (%) of macroinvertebrates belonong to order Isopoda, Mantodea, Blattaria, Neuroptera, Odonata, Dermaptera and Thysanura in sugarcane and its associated weeds

Order/Family/ Species	Sugarcane	Weeds	Total
Odonata	0.07(02)	-	0.04(02)
Aeshnidae	0.04(01)	-	0.02(01)
Gynacantha nervosa	0.04(01)	-	0.02(01)
Lestidae	0.04(01)	-	0.02(01)
Lestes sp.	0.04(01)	-	0.02(01)
Dermaptera	0.07(02)	-	0.04(02)
Anisolabididae	0.04(01)	-	0.02(01)
Euborellia annulipes	0.04(01)	-	0.02(01)
Forficulidae	0.04(01)	-	0.02(01)
Forficula auricularia	0.04(01)	-	0.02(01)
Thysanura	-	0.07(02)	0.04(02)
Machilidae	-	0.07(02)	0.04(02)
Petrobius brevistylis	-	0.07(02)	0.04(02)
Mantodea	0.15(04)	4.66(138)	2.51(142)
Mantidae	0.15(04)	4.66(138)	2.51(142)
Thesprotia graminis	0.15(04)	4.66(138)	2.51(142)
Blattaria	1.11(30)	0.41(12)	0.74(42)
Blattellidae	1.11(30)	0.41(12)	0.74(42)
Blattella asahinai	1.11(30)	0.41(12)	0.74(42)
Neuroptera	0.11(03)	0.10(03)	0.09(05)
Chrysopidae	0.11(03)	0.07(02)	0.09(05)
Chrysoperla carnea	0.11(03)	0.03(01)	0.07(04)
Chrysopidae larvae	-	0.03(01)	0.02(01)
Isopoda	8.36(226)	0.24(07)	4.11(233)
Porcellionidae	7.14(193)	0.24(07)	3.53(200)
Porcellio scaber	7.14(193)	0.24(07)	3.53(200)
Armadillidiidae	1.22(33)	-	0.58(33)
Armadillidium nasatum	0.52(14)	-	0.25(14)
Armadillidium vulgare	0.70(19)	-	0.34(19)
Total number of speciemans (a+b+c)	2703	2962	5665

Table 4: Relative abundance (%) of macro-invertebrates recorded from sugarcane and its associated weeds in Punjab (Pakistan). (n is the number of individuals of each order)

	Crop				Weeds			
Phylum/Order	Autumn	Winter	Spring	Total	Autumn	Winter	Spring	Total
Arthropoda	98.37(301)	96.96(797)	92.06(1450)	94.27(2548)	96.25(282)	98.08(1072)	98.73(1556)	98.24(2910)
Thysanura	-	-	-	-	-	-	0.13(02)	0.07(02)
Odonata	-	0.12(01)	0.06(01)	0.07(02)	-	-	-	-
Orthoptera	0.65(02)	0.73(06)	0.32(05)	0.48(13)	23.89(70)	20.68(226)	24.81(391)	23.19(687)
Dermaptera	-	0.12(01)	0.06(01)	0.07(02)	-	-	-	-
Mantodea	-	0.12(01)	0.19(03)	0.15(04)	0.68(02)	0.73(08)	0.70(11)	0.71(21)
Blattaria	0.98(03)	2.43(20)	0.44(07)	1.11(30)	-	-	0.76(12)	0.41(12)
Hemiptera	37.91(116)	41.24(339)	35.24(555)	37.37(1010)	25.94(76)	22.69(248)	23.22(366)	23.30(690)
Coleoptera	27.12(83)	17.76(146)	34.29(540)	28.45(769)	6.83(20)	9.06(99)	8.38(132)	8.47(251)
Neuroptera	0.33(01)	-	0.13(02)	0.11(03)	0.34(01)	0.09(01)	0.00	0.07(02)
Hymenoptera	5.56(17)	6.08(50)	5.84(92)	5.88(159)	4.78(14)	4.21(46)	2.73(43)	3.48(103)
Lepidoptera	3.59(11)	1.58(13)	0.57(09)	1.22(33)	-	2.20(24)	2.73(43)	2.26(67)
Diptera	3.92(12)	1.82(15)	5.27(83)	4.07(110)	19.45(57)	29.46(322)	29.31(462)	28.39(841)
Araneae	13.07(40)	13.38(110)	2.35(37)	6.92(187)	13.65(40)	8.87(97)	5.71(90)	7.66(227)
Isopoda	5.23(16)	11.56(95)	7.30(115)	8.36(226)	0.68(02)	0.09(01)	0.25(04)	0.24(07)
Pulmonata	1.63(05)	3.04(25)	7.94(125)	5.73(155)	3.75(11)	1.92(21)	1.27(20)	1.76(52)
	306	822	1575	2703	293	1093	1576	2962

Table 5a: Temporal variations in richness, diversity and evenness values for macro-invertebrates recorded from sugarcane fields in Faisalabad district.

	Sugarcane			Weeds					
Seasons	S	H´	E	S	H´	E	*df*	t-value	*p*-value
Autumn	56	3.188	0.433	66	3.589	0.548	>120	3.593	<0.001***
Winter	48	2.624	0.287	70	3.479	0.463	>120	9.017	<0.001***
Spring	86	3.095	0.256	118	4.130	0.527	>120	15.807	<0.001***

Richness (S), Diversity (H´), Evenness (E)

Table 5b: A comparison of diversity of foliage macro-invertebrates recorded from Sugarcane fields in autumn, winter and spring

	Sugarcane			Weeds		
	Autumn	Winter	Spring	Autumn	Winter	Spring
Autumn						
Winter	<0.001***			0.443ns		
Spring	0.868ns	<0.001***		<0.001***	<0.001***	

Habitat Related Variation: Edge and center of the fields were varied in crop plant density, weeds diversity and density as well as field periphery constituted vast diversity of weed species. Two quadrates were taken from a transect from edge (at o meter distance) and at the center (Five meter inside the field).

Arthropods constituted more than 93% of all the macro-invertebrates recorded from the edges as well as center of the sugarcane-weed agro-ecosystem. Hemiptera (31.47%), Coleoptera (30.13%), Isopoda (8.27%), Araneae (7.87%) and Hymenoptera (6.80%) were the most dominant arthropod groups recorded from the edge of the sugarcane while Diptera (26.93%), Hemiptera (24.41%), Orthoptera (22.45%), Coleoptera (8.87%) and Araneae (7.37%) were dominant at the edge of the weeds. Hemiptera (44.76%), Coleoptera (26.29%) and Isopoda (8.49 %) were the most abundant macroinvertebrate orders in the center of the cane while Diptera (32.23%), Orthoptera (25.15%), Hemiptera (20.39%) and Araneae (8.425%) were dominant in the center of weeds (Table 2).

Comparison of the diversity (H') values indicated a highly significant difference in species richness (S) and evenness (E) in all the habitat combinations (Table 4). The diversity (H'), richness (S) and evenness (E) was higher at the edge than the center of both habitats under consideration (Table 3).

Season Related Variation: A two-year catch of the macro-invertebrates from the sugarcane and its associated weeds was pooled season-wise. Hemipterans emerged as

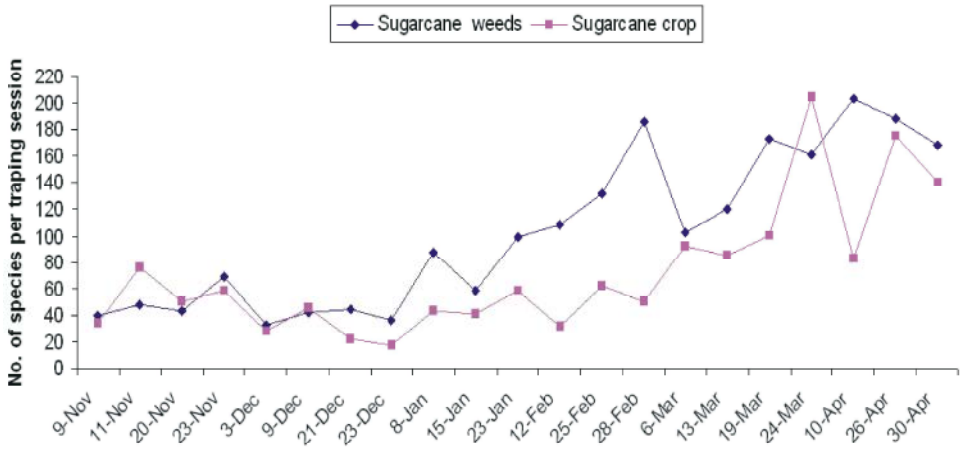

Fig. 3: Seasonal dynamics of macro-invertebrates of sugarcane fields edge

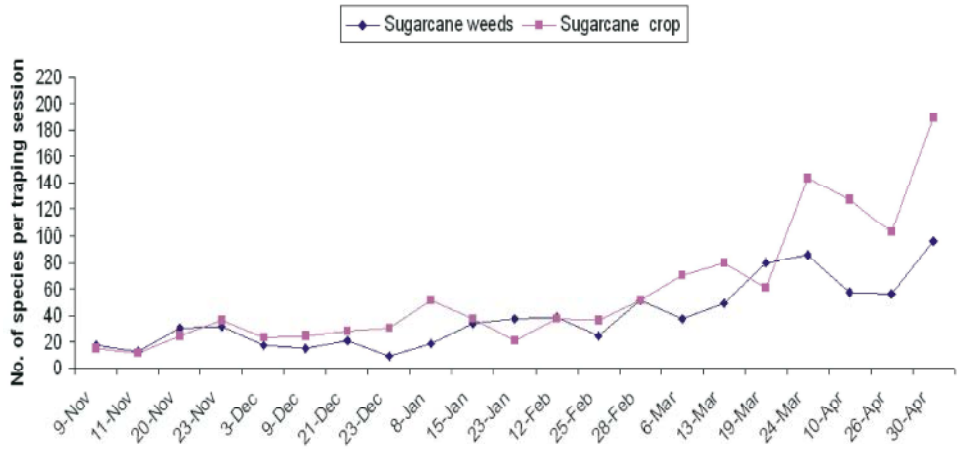

Fig. 4: Seasonal dynamics of macro-invertebrates of sugarcane fields center

the commonest macro-invertebrates in both sugarcane and its associated weeds throughout the study period. Coleoptera and Araneae were the other most recorded arthropods in sugarcane except in spring when Isopdes replaced Araneae (Table 4). Orthopterans and dipterans, in addition to hemipterans, were the most abundant macro-invertebrates in weeds but their order of abundance varied in each season. Dipterans were most abundant in winter and spring while hemiptrans were the most recorded in autumn from the weeds. Phonological patterns for the two years data of macro-invertebrates in the edges and enters of the fields between sugarcane and its associated weeds have been depicted in Figure 3 and 4.

The richness (S), diversity (H') and evenness (E) of macro-invertebrate populations was significantly higher in weeds than sugarcane in all the seasonal samples (Table 5a). A comparison of these values for three seasonal samples of cane showed that macro invertebrate diversity in autumn and spring was statistically same but significantly higher than winter whereas in weeds it was same during autumn and winter but significantly lesser than spring (Table 5b).

DISCUSSION

This study highlights the diversity of foliage macro-invertebrates in a sugarcane-weed based agro-ecosystem. A total of 232 species of macro-invertebrates comprising of 178 species of insects (79 Families; 12 Orders), 35 species of arachnids (13 Families; one Order), 16 species of Pulmonates (10 Families; One Order) and three species of isopods (2 Families; One Order) were recorded during the present study. The number of insect species recorded from similar habitat during the present study was higher than [10, 12] Kumarasinghe [10] from sugarcane in Sri Lanka, documented 103 insect species associated with sugarcane comprising of Coleopteran

(31 spp), Dictyoptera (2spp), Diptera (5spp), Hemiptera (12spp), Homoptera (18spp), Hymenoptera (7spp), Isoptera (3spp), Lepidoptera (13spp), Orthoptera (9 spp) and one species of each of Thysanoptera, Neuroptera and Trichoptera. Ahmed *et al*. [12] recorded 117 species of insects belonging to 10 Orders. The arachnid richness was higher than Ghafoor and Mahmood [21] but lower than Young and Edwards [9]. Ghafoor and Mahmood [21] recorded 22 species belonging to seven Families while Young and Edwards [9] recorded 137 species of spider from sugarcane fields.

The species richness of macro-invertebrate population was recorded higher because during the recent study, 12 sampling areas all around the City was taken, samples were brought on weekly basis for two consecutive years in comparison to Ahmed *et al*. [12], three sampling areas, samples were taken on fortnightly basis and study duration was one year. The similar is in the case of arachnid richness as [21] studied two sampling localities for one year.

Abbas *et al*. [8] conducted their study in Faisalabad district and documented 2204 specimens of coccinellids belonging to twelve species but the present study reported nine species of coccinellids. This variation in number of species is due to only two crops were sampled in the present study (wheat and sugarcane) while Abbas *et al*. [8] studied five agricultural crops *viz* wheat, sugarcane, fodder, maize and vegetable.

Genetically and ecologically diverse agro-ecosystems often are more productive than simpler ones [22]. Weeds are important component of agricultural areas that act as major drivers of macro-invertebrate diversity [7, 8]. These unwanted plants are usually eradicated in intensive agriculture practices to (a) reduce competition among crop plants and weeds and (b) to increase net yield [23]. Comprising phytomporphic heterogeneity that serves as an alternative food for phytophagus macro-invertebrates [7]. Weeds provide shelter and optimum microclimate suitability for arthropod populations, thereby enhancing biodiversity of the agro-ecosystems [24]. The present study also supported the same ideas. Weeds harboured more foliage macro-invertebrates (n = 2962) than the crop (n = 2703) itself. The abundance on weeds was recorded higher than crop but both support different groups of macro-invertebrates yet some were little fluctuated on them. Orthoptera and Diptera were abundant on weeds while on crop Hemiptera and Coleoptera were recorded abundant macro-invertebrate groups. Crop and weeds were significantly different in terms of macro-invertebrates abundance and diversity, weeds being more diverse than crop itself.

Field margins had major impact on the abundance and diversity of various invertebrate taxa [25; Present study]. These margins harboured diverse assemblage of annual, biennial and perennial plants which served as shelter as well as alternate food sources. Macro-invertebrate abundances and diversity were also influenced by seasonality which is a combined effect of a number of factors such as temperature, humidity, day light, vegetation diversity and food availability [26, 27, Present study].

The present study confirmed that weeds offer phytomorphic heterogeneity to support macro invertebrate diversity while field margins ensure this diversity and warrant increased agricultural production.

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