Journal of Entomology and Zoology Studies
Available online at www.entomoljournal.com
JEZS Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(2): 961-966

Received: 11-01-2018
Accepted: 12-02-2018

Abroo Ali
Department of Environmental Science, University of Kashmir, Srinagar, Jammu Kashmir, India

GA Bhat
Centre of Research for Development, University of Kashmir, Srinagar, Jammu Kashmir, India

Correspondence
Abroo Ali
Department of Environmental Science, University of Kashmir, Srinagar, Jammu Kashmir, India

Composition and diversity of soil macrofauna in saffron fields of Pampore, Kashmir

Abroo Ali and GA Bhat

Abstract
Saffron (*Crocus sativus* L.) has a significant place in agricultural economy of Kashmir, but it has remained under exploited and unrefined and needs to be managed to increase and sustain its yield. This study assessed the diversity and composition of macrofauna and effect of intercropping on the same. Macro fauna was sampled in transects, for which the ideal size was 40 x 4m in accordance to Anderson and Ingram (1993) [4]. During the study a total of 33 taxa, belonging to 19 families, 9 orders, 5 classes and 2 phyla were recorded. Amid the entire developing season, Shannon wiener index of 0.99 ± 0.05 was recorded for the macro faunal community of the study area. The area was found to be more diverse in terms of genera belonging to order Coleoptera with a diversity index of 0.76 ± 0.13. Results additionally pointed almond intercropping in saffron field did not conspicuously affect the diversity and the composition of soil macrofauna. As no examination in such manner has been directed, it will go about as basic and standard information for future investigations to help decision makers and managers to take wise choices while dealing the saffron agro frameworks, to maintain them.

Keywords: bioindicator, intercrop, diversity, macrofauna, monoculture, soil, saffron

Introduction

Saffron (*Crocus sativus* L.) has a significant place in agricultural economy of Kashmir as it is the most noteworthy estimated flavor and highly priced spice in the world. As revealed by Kamili and Wani (2006) [25], the crop has remained under exploited and unrefined. The intensive cultivation and monoculture of saffron in saffron-growing belts of the Kashmir valley is prompting to nutrient depletion and pest infestations reported in many investigations (Nehvi, 2003; Zaki and Mantoo, 2008; Kirmani, 2010) [35, 52]. What is more, disappointment in irrigation system at time of growing season has expanded the input costs in development of the yield (Munshi *et al*., 2002; Kirmani, 2010; Nehvi and Makhdoomi, 2007b) [33]. This has brought about the region under saffron development from past years. This investigation was an endeavor to investigate the impacts of intercropping almond in the saffron fields.

Monocultures are a case of agro biological systems with low diversity and might be more susceptible to pest or disease outbreaks (Theunissen, 1994; Rusch *et al*., 2016) [46, 42]. Perennial plants intercropped with yearly harvests, can enhance the sustainability of those cropping systems which support low diversity agro ecosystems. Biodiversity conservation in agricultural ecosystems is of growing concern, since it is essential to support and sustain ecosystem services (Altieri, 1999; Norris, 2008) [2, 36].

Bioindication exists as a valued tool, as it empowers the appraisal of protection of an ecosystem in light of the living organisms that it comprises. Soil macro fauna specifically, has been seen to express as delicate markers to modifications in plant cover (Lavelle and Pashanasi, 1989; Mathieu *et al*., 2005; Sileshi *et al*., 2008) [28, 32, 43] and can, thus, have considerable impacts on soil processes. A few investigations utilized arthropods as bioindicators, generally pointing on a particular group. For some arthropods, survival in agrosystems relies upon the suitability of the habitat, which in turn is sturdily affected by agricultural management, along with the characteristics of the surrounding landscape (Jeanneret *et al*., 2003) [23]. Many authors have proposed the deployment of higher taxonomic levels, such as order or family in addition to lower (Balmford *et al*., 1996; Biaggini *et al*., 2007; Cotes *et al*., 2011) [7, 9, 13], to develop bioindication methods. Most farming practices are detrimental having effect on the Soil macro fauna. Cover crops can turn out to be a noteworthy way of conserving beneficial insects and

Stabilizing their populations by giving them the ideal ecological conditions within or near the cropping environment (Landis *et al*., 2000) [27]. In the present examination, the taxonomic level of order and family for the Saffron (*Crocus sativus* L.) helps in providing atleast minimum information in this regard, following diverse criteria. This effort would help to identify the key organisms present, to discover out the pattern in which macrofaunal communities change in diversity and to test the reasonableness as indicators. As no examination in such manner has been directed, it might help in building preliminary standard information for future investigations to help decision makers and managers to take wise choices while dealing the saffron agro frameworks, to maintain them.

Study area

To assemble a good representation four practically identical sites were chosen to describe soil macro fauna with respect presence and absence of intercropping in saffron field.

Table 1: Attributes of study sites

Site	Altitude (a.s.l)	Latitude	Longitude	Attributes
I	1604m	34⁰ 02′ 06.9″ N	74⁰ 55′ 48.0″ E	Saffron cultivated along with Almond (*Prunus amygdalus* Batsch) trees and surrounded by built up.
II	1615m	34⁰ 02′ 10.6″ N	74⁰ 55′ 52.6″ E	Purely used for saffron cultivation and surrounded by built up.
III	1634m	34⁰ 00′ 2.5″ N	74⁰ 57′ 29.7″ E	Saffron cultivated along with Almond (*Prunus amygdalus* Batsch) trees.
IV	1630m	34⁰ 00′ 1.4″ N	74⁰ 57′ 24.6″ E	Purely used for saffron cultivation

Materials and Methods

For sampling soil macro fauna Anderson and Ingram (1993) [4] was followed. Macro fauna were sampled in transects, for which the ideal size was 40 x 4m. Five equally spaced sampling points (for monoliths) were located and marked along transect. The soil from the monolith was removed, macro fauna were hand sorted (Dangerfield, 1997) [15] from each sample and counted. Macro invertebrates were preserved for identification in sample containers containing 70% alcohol and 4% formalin depending upon the type of organisms to be preserved. The invertebrates collected were then isolated into higher taxa (Order and Family), and wherever possible to generic level and identified under binocular microscope, utilizing standard keys and books (Hincks, 1949; Crowson, 1956; Mani, 1962; Riley, 1977; Theodore, 1983; Adam, 1990; Gibb and Oseto, 2006; Chinery, 2007 and Barnard, 2011) [21, 14, 31, 41, 45, 1, 20, 12]. Using the data obtained during sampling, community structure of the macrofauna was determined by the number of species collected, the Shannon–Wiener's diversity index and evenness. The study sites were compared with Bary-Curtis similarity. This investigation was carried out during the growing season of the year 2012.

Results and Discussion

Macro invertebrate Assemblages and Species Composition

In the examination an aggregate of 33 taxa were recorded, belonging to 19 families, 9 orders, 5 classes and 2 phyla from the entire study area during the whole investigation amid the entire growing season. While the species belonged to Phylum Arthropoda representing 93.71% of the aggregate taxa spread over more four classes (Arachinida, Chilopoda, Crustacea and Insecta) in all the study sites, trailed by phylum Annelida 2.86% represented by 1 taxa (*Apporectodae caliginosa*) of class Oligochaeta. Insecta was the most abundant class, accounting for 84.14% of the phylum arthropoda. Significant proportion of Arachinida represented from the orders Lycosidae (*Lycosa* sp. and *Arctosa* sp.), Thomicidae (*Xysticus* spp.), Salticidae and Araneida (*Araneus* sp.) respectively (12.85%), were likewise recorded. Additional arthropod classes such as Chilopoda (2.83%, mainly Geophilidae) and Crustacea represented by 1 taxa (*Mesoniscus* sp.) belonging to the order Isopoda (0.17%). The class Insecta was the largest group that, contributed the majority of taxonomic forms with 23 taxa belonging to 4 different orders, essentially composed of Coleoptera (15.67%, Carabidae, Coccinelidae, Staphylinidae, Scarabaeidae, Curculionidae & Cerambycidae) Hymenoptera (69.04%, mostly ants), Orthoptera (5.75%) and Dermaptera (9.52%) (Table 2).

Table 2: Abundance of soil macrofauna taxa in the study sites, during the whole saffron growing season

Phyllum	Class	Order	Family	Density(Individuals/m^2) study Sites			
				Site I	Site II	Site III	Site IV
Annelida	Oligocheata	Haplotaxida	Lumbricidae	96	112	64	48
Arthropoda	Crustacea	Isopoda	Unidentified	16	0	0	0
	Chilopoda	Geophilomorpha	Geophilidae	80	48	80	48
		Scolopendromorpha	Scolopendridae	0	0	0	16
	Arachinida	Araneida	Lycosidae	224	192	208	192
				0	16	0	0
			Thomicidae	16	32	16	16
				32	16	0	16
			Aaneidae	32	32	32	16
			Salticidae	32	48	32	32
	Insecta	Dermaptera	Ansiolabididae	64	32	160	64
				80	80	176	128
		Orthoptera	Acrididae	16	80	16	32
			Gryllidae	16	64	32	32
				0	0	0	16
		Coleoptera	Carabidae	80	0	0	0
				0	0	16	0

				0	0	16	0
				16	0	0	0
				0	0	16	32
			Staphylinidae	16	32	16	0
				32	0	0	0
			Scarabaeidae	48	64	16	32
			Coccinelidae	48	48	16	32
				0	16	0	16
				16	0	0	0
			Curculionidae	16	32	16	0
			Cerambycidae	16	16	0	0
		Hymenoptera	Apidae	320	224	176	128
				32	48	0	64
			Formicidae	1120	832	992	1072
				448	400	640	512
				0	0	80	80
Larvae (unidentified)				96	144	96	48

Rank Abundance

With rank/abundance plot diminutive contrasting patterns of species richness were displayed. Besides it highlighted that the four sites were similarly rich. The rank/abundance plot for the four sites obviously potrays that sites were having evenness, despite of dominance shown by few species, as observed from steep slopes at few points in the plot (Figure 1).

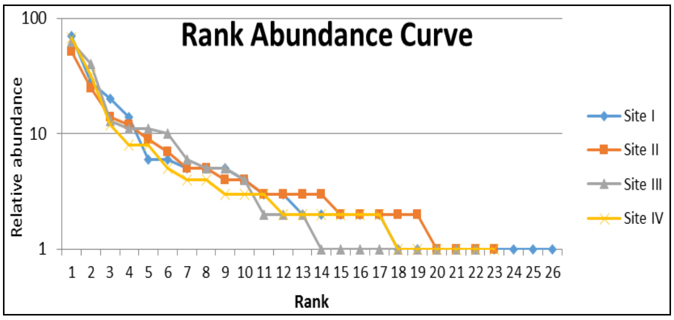

Fig 1: Rank abundance curves for the four sites

The analysis of data obtained on macro invertebrates delineated prominent variaties of macro invertebrate groups at the four sites. At Site I, the total number of taxa detailed was twenty five with Hymenoptera being the most dominant orders with an average relative density (RD) of 63.83%, followed by Araneida (11.17%) and Coleoptera (9.57%) in decreasing order. Among the taxa *Messor himalaynus* was the dominant form with an average of 37.23% contribution, followed by *Myrmica rubra* (14.89%) and *Andrena* sp. (10.64%). The average number of individuals at Site I was 66.84 ind. /m^2.

At Site II, a sum of twenty two taxa were accounted with Hymenoptera representing as the most copious order with 57.67% representation, followed by Araneida (12.88%) and then by Coleoptera (7.98%). *Messor himalaynus* at this site was the dominant taxa with an average density of 31.90%, followed by *Myrmica rubra* (15.34%) and *Andrena* sp. (8.59 %). The average number of individuals at Site II was 57.96 ind. /m^2.

At Site III, twenty one were identified, with Hymenoptera again being the most abundant order with 64.84% density, followed by Dermaptera (11.54%) and Araneida (9.89%). Among the taxa *Messor himalaynus* (34.07%) was the most abundant, being followed by *Myrmica rubra* (21.98%) and *Lycosa* sp. (7.14%) in abundance. Further, on an average the density of macro invertebrates was found to be 64.71 ind. /m^2.

Site IV was represented by a total of twenty two taxa during the period of study. Hymenoptera (69.46%), followed by Araneida (10.18%) and Dermaptera (7.19%) were the most dominant orders. Among the taxa *Messor himalaynus* (40.12%) was the most dominant taxa followed by *Myrmica rubra* (19.16%) and *Lycosa* sp. (7.19%) in decreasing order. The average density of macro invertebrates was found to be 59.38 ind. /m^2 (Table 3).

It was clear from the outcomes that the most dominant order regarding density in the examination amid the investigation was Hymenoptera (which in the study was fundamentally ants), which have diversified into a variety of morphological forms and ways of life and may be the largest order of insects (Gaston 1993, Austin and Dowton 2000) [19, 5], however currently the order positions second or third after the Coleoptera and Lepidoptera (Stork, 1997) [44]. It was almost equally diverse at all the four sites, likewise, Barros *et al.*, (2002) [8] found high numbers of ants in fallows and agro forestry systems relative to other agro ecosystems. As clarified by (Andersen, 1999) [3], ants are modular organisms that are only affected by disturbance if too many “modules” are lost; this implying that habitat disturbance causes widespread destruction of colonies, which happens only with severe habitat transformation, since in saffron fields, least activities are carried year round, this results in higher density associated with the Formicidae. Likewise, because of wide diet spectrum, ants are generalist predators, scavengers and indirect herbivores, but a few have evolved specialized ways of obtaining nutrition (e.g. by raising other insects or fungi within their nests) (Wilson and Holldobler, 2005) [50], their activities reduce the abundance of other predators such as spiders and beetles (Wilson, 1987) [49], as was evident during the study with respect to relative densities of both araneida and coleoptera at the four sites. Ants could be credited as fundamental ecological engineers at study area as earthworms were barely present and termites totally absent, moving expansive volumes of soil as much as earthworms do (Holldobler and Wilson, 1990) [22].

Table 3: Density (mean individuals/meter2) and relative density of the differrent taxa of macoinvertebrates present during the study at the four respective sites.

Group/Order	Genra/ Species	Density (Mean Individuals/Meter^2)				Relative Density			
		Site I	Site II	Site III	Site IV	Site I	Site II	Site III	Site IV
Haplotaxida	*Apporectodae calignosa* (Savigny, 1826)	2.13	2.49	1.42	1.07	3.19	4.29	2.20	1.80
Geophilomorpha	*Necrophloeophagus flavus* (De Geer, 1778)	1.78	1.07	1.78	1.07	2.66	1.84	2.75	1.80
Scolopendromorpha	*Scolopendra morsitans* (Linnaeus, 1758)	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.60
Isopoda	*Mesoniscus* sp.	0.36	0.00	0.00	0.00	0.53	0.00	0.00	0.00
Araneida	*Lycosa* sp. (Latreille, 1804)	4.98	4.27	4.62	4.27	7.45	7.36	7.14	7.19
	Arctosa sp. (Koch, 1847)	0.00	0.36	0.00	0.00	0.00	0.61	0.00	0.00
	Xysticus spp. (Koch, 1835)	0.36	0.71	0.36	0.36	0.53	1.23	0.55	0.60
	Xysticus spp. (Koch, 1835)	0.71	0.36	0.00	0.36	1.06	0.61	0.00	0.60
	Araneus sp. (Clerck, 1757)	0.71	0.71	0.71	0.36	1.06	1.23	1.10	0.60
	Salticidae sp.	0.71	1.07	0.71	0.71	1.06	1.84	1.10	1.20
Coleoptera	*Harpalus* sp. (Latreille, 1802)	1.78	0.00	0.00	0.00	2.66	0.00	0.00	0.00
	Scarites subterraneum (Fabricius, 1775)	0.00	0.00	0.36	0.00	0.00	0.00	0.55	0.00
	NI_1 (Curculionidae)	0.00	0.00	0.36	0.00	0.00	0.00	0.55	0.00
	Galerita sp. (Drury, 1773)	0.36	0.00	0.00	0.00	0.53	0.00	0.00	0.00
	*Carabus nemoralis (*Muller 1764)	0.00	0.00	0.36	0.71	0.00	0.00	0.55	1.20
	Tachyporus hypnorum (Fabricius 1775)	0.36	0.71	0.36	0.00	0.53	1.23	0.55	0.00
	Paederus sp. (Fabricius 1775)	0.71	0.00	0.00	0.00	1.06	0.00	0.00	0.00
	Amphimallus sp. (Reitter,1902)	1.07	1.42	0.36	0.71	1.60	2.45	0.55	1.20
	Coccinella septumpunctata (Linnaeus,1758)	1.07	1.07	0.36	0.71	1.60	1.84	0.55	1.20
	Coccinella novemnotata (Herpst,1793)	0.00	0.36	0.00	0.36	0.00	0.61	0.00	0.60
	Coccinella undecimpuctata (Linnaeus,1758)	0.36	0.00	0.00	0.00	0.53	0.00	0.00	0.00
	NI_2 (Carabidae)	0.36	0.71	0.36	0.00	0.53	1.23	0.55	0.00
	Phymatodes Testaceus (Fabricius 1775)	0.36	0.36	0.00	0.00	0.53	0.61	0.00	0.00
Dermaptera	*Euborella annulipes* (Lucas,1847)	1.42	0.71	3.56	1.42	2.13	1.23	5.49	2.40
	Euborella maritime (Bonelli, 1832)	1.78	1.78	3.91	2.84	2.66	3.07	6.04	4.79
Hymenoptera	*Andrena* sp. (Fabricius, 1775)	7.11	4.98	3.91	2.84	10.64	8.59	6.04	4.79
	Apis cerana (Fabricius, 1793)	0.71	1.07	0.00	1.42	1.06	1.84	0.00	2.40
	Messor himalaynus (Forel)	24.89	18.49	22.04	23.82	37.23	31.90	34.07	40.12
	Myrmica rubra (Linneaus)	9.96	8.89	14.22	11.38	14.89	15.34	21.98	19.16
	Lasius fuliginosus	0.00	0.00	1.78	1.78	0.00	0.00	2.75	2.99
Orthoptera	*Leva* sp.	0.36	1.78	0.36	0.71	0.53	3.07	0.55	1.20
	Gryllulus domesticus (Linnaeus, 1758)	0.36	1.42	0.71	0.71	0.53	2.45	1.10	1.20
	Trilophidia annulata (Thunberg,1815)	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.60
Unidentified arthropod	Larvae	2.13	3.20	2.13	1.07	3.19	5.52	3.30	1.80
Total		66.84	57.96	64.71	59.38	100.00	100.00	100.00	100.00

Macro faunal diversity

The diversity indices were not quite variable with respect to the four sites. With respect to different orders present at four sites, Coleoptera was the most diverse order which was trailed by Araneida, Hymenoptera, Orthoptera and Dermaptera respectively (Table 4).

Macro fauna community of the study area was found to be more diverse in terms of genera belonging to order Coleoptera, Araneida, Hymenoptera, Orthoptera and Dermaptera, in accordance to the findings of Lavelle and Spain, (2001) for main groups of soil macro fauna in terms of their abundance and the importance of their activities. These groups of soil macro fauna (e.g., earthworms, millipedes, isopods, centipedes, spiders, ants, termites and beetles) can fill in as bioindicators of land use and have been frequently used for this purpose in the past (Paoletti *et al*., 1988) [38].

Amid the investigation it was additionally discovered that the sites with almond intercrop were having higher Coleoptera diversity in contrast to the sites without any intercroping with saffron, as flowering plant strips nearby fields help to support beneficial insect biodiversity in agricultural landscapes (Baggen and Gurr, 1998; Dufour, 2000; Carreck and Williams, 2002; Fiedler and Landis, 2007a; Tuell *et al*., 2008) [6, 16, 11, 48], because these plants can provide to be alternate hosts, overwintering habitats, a constant food supply, and appropriate microclimates in order to survive (Johnson and Triplehorn, 2008), during periods when crop flowers are not present, thus maintaining high populations of insect predators. In this way soil beetles which live in the top of the soil layer are well adapted to the ecological conditions and react to environment alterations with qualitative and quantitative changes of their species inventory (Buck and Konzelmann, 1985), as is evident from diversity changes in Coleoptera with intercropping during this study facilitating the evaluation of the sites, likewise according to Bohac, (1999) evaluations of small biotopes with other taxes are limited and soil beetles ensure a relevant evaluation of terrestrial habitats.

Table 4: Diversity indices at the four sites during the study along with shannon index for different orders present at study sites during study.

Diversity indices and evenness measure	Site I	Site II	Site III	Site IV
Shannon index	0.998	1.057	0.95	0.941
Evenness	0.71	0.78	0.71	0.69
Shannon index for Coleoptera	0.869	0.726	0.845	0.587

Shannon index for Araneida	0.472	0.58	0.384	0.433
Shannon index for Hymenoptera	0.443	0.466	0.401	0.481
Shannon index for Dermaptera	0.3	0.26	0.3	0.28
Shannon index for Orthoptera	0.301	0.298	0.276	0.458
Dominance - diversity measures				
Simpsons Diversity (D)	0.179	0.143	0.179	0.207
Simpsons Diversity (1/D)	5.579	6.989	5.587	4.836

Cluster analysis

The Bray–Curtis similarity matrix indicates that Site III and IV (86%) can be grouped relatively closely, similarly the Sites I and II (82%), Site I and IV (82.5%). Sites I and III (80.5%), Site II and IV (78.8%) and Site II and III (76.5%) respectively. Thus all the four sites are not much distant from each other having almost equal similarity in terms of macro fauna taxa (Figure 2).

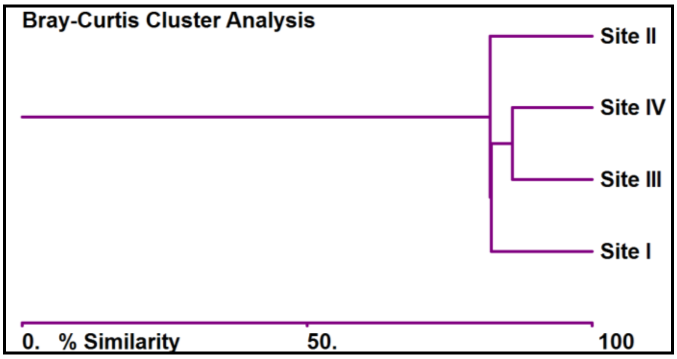

Fig 2: Bary-Cluster Analysis

Conclusions

The sites did not contrast to such an extent to potray these intercrop plantations may support different evenness and consequently diversity. Formicidae, followed by Coleoptera and araneida were the main faunal groups most numerous in the environment evaluated. Utilizing the specific group from macrofauna community seemed to act as a better bioindicator than soil macro fauna community as a general for that purpose, especially Coleoptera and Hymenoptera (formicidae) in terms of diversity and density respectively.

References

1. Adam S. A students text book of zoology vol. 3. The introduction to Arthropoda, Crustacea and Xiphosura. Low priced publications, Delhi-110052. 1990.
2. Altieri MA. The ecological role of biodiversity in agroecosystems. Agric Ecosyst Environ. 1999; 74:19-31.
3. Andersen A. Plant protection in spring cereal production with reduced tillage. II. Effects on pests and beneficial insects. *Crop Prot*. 1999; 18: 651-657.
4. Anderson JM, Ingram JSI. *Tropical Soil Biology and Fertility. A Handbook of Methods*, 2nd ed. CAB International, Wallingford, 1993, 221.
5. Austin AD, Dowton M. The Hymenoptera: an introduction. Pp. 3-7. In AD. Austin and M. Dowton (eds). Hymenoptera: Evolution, Biodiversity and Biological Control. CSIRO Publishing, Collingwood, Victoria, Australia. 2000.
6. Baggen LR, Gurr GM. The influence of food on Copidosoma koehleri (Hymenoptera: Encyrtidae), and the use of flowering plants as a habitat management tool to enhance biological control of potato mot *Phthorimaea operculella* (Lepidoptera: Gelechiidae). *Biological Control*. 1998; 11:9-17, ISSN 1049- 9644.
7. Balmford A, Jayasuriya AH, Green MJB. Using higher-taxon richness as a surrogate for species richness: II. Local applications. *Proceedings of the Royal Society of London B: Biological Sciences*. 1996; *263*(1376):1571-1575.
8. Barros E, Pashanasi B, Constantino R, Lavelle P. Effects of landuse systems on soil macrofauna in Western Amazon basin. *Biol. Fertil. Soils*. 2002; 35:338-347.
9. Biaggini M, Consorti R, Dapporto L, Dellacasa M, Paggetti E, Corti C. The taxonomic level order as a possible tool for rapid assessment of Arthropod diversity in agricultural landscapes. *Agriculture, Ecosystems & Environment*. 2007; 122(2):183-191.
10. Bommarco R, Kleijn D, Potts SG. Ecological intensification: harnessing ecosystem services for food security. Trends Ecol Evol. 2013; 28:230-238.
11. Carreck NL, Williams IH. Food for insect pollinators on farmland: insect visits to flowers of annual seed mixtures. Journal of Insect Conservation. 2002; 6:13-23.
12. Chinery M. *Insects of Britain and Western Europe*. A and C black, London, 2007.
13. Cotes B, Campos M, García PA, Pascual F, Ruano F. Testing the suitability of insect orders as indicators for olive farming systems. *Agricultural and Forest Entomology*. 2011; 13(4):357-364.
14. Crowson RA. *Coleoptera introduction and keys to families, Handbooks for the identification of British insects*, Royal entomological society of London. 1956, 4(1).
15. Dangerfield JM. Abundance and diversity of soil macrofauna in northern Botswana. *J. Trop. Ecol*. 1997; 13:527-538.
16. Dufour R. Farmscaping to enhance biological control, In: NCAT Sustainable Agriculture Project, Available from: https://attra.ncat.org/attra-pub/summaries/summary.php?pub=145. 2000.
17. Eyre MD, Luff ML, Atlihan R, Leifert C. Groundbeetle species (Carabidae, Coleoptera) activity and richness inrelation to crop type, fertility management and crop protection ina farm management comparison trial. *Annals of Applied Biology*. 2012; 161:169-179.
18. Fiedler AK, Landis DA. Plant characteristics associated with natural enemy abundance at Michigan native plants. *Environmental Entomology*. 2007b; 36:878-886.
19. Gaston KJ. Spacial patterns in the description and richness of the Hymenoptera. 277-293. In J. LaSalle and I. D. Gauld (eds). Hymenoptera and Biodiversity. CAB International. Wallingford, United Kingdom. 1993.
20. Gibb TJ, Oseto CY. *Arthropod Collection and Identification Field and Laboratory* Techniques Academic Press, London, UK. 2006.
21. Hincks WD. *Dermaptera and Orthoptera, Handbooks for the identification of british insects*, Royal entomological society of London. 1949, 4(5).
22. Hölldobler B, Wilson EO. *The ants*. Harvard University Press. 1990.
23. Jeanneret P, Schüpbach B, Luka H. Quantifying the impact of landscape and habitat features on biodiversity in cultivated landscapes. *Agriculture, Ecosystems &*

Environment. 2003; 98(1):311-320.
24. Johnson NF, Triplehorn CA. *Borror and DeLong's Introduction to the Study of Insect,* 7th ed., Brooks Cole, Belmont. 2005.
25. Kamili Afifa Shahin, Wani MH. Research priority setting in saffron. A report-SK. University of Agricultural Sciences and Technology of Kashmir. 2006.
26. Kirmani NA, Sofi JA, Bhat MA, Ansar-Ul-Haq S. Sustainable saffron production as influenced by integrated nitrogen management in Typic Hapludalfs of NW Himalayas. *Communications in soil science and plant analysis*. 2014; 45(5):653-668.
27. Landis DA, Wratten SD, Gurr GM. Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology*. 2000; 45: 175-201.
28. Lavelle P, Pashanasi B. Soil macrofauna and land management in Peruvian Amazonia (Yurimaguas, Loreto). *Pedobiologia*. 1989; 22:283-291.
29. Lavelle P, Spain AV. *Soil Ecology*. New York. Boston, London. 2001.
30. Magurran AE. Measuring biological diversity. Blackwell, Oxford, Unite Kingdom. 2004.
31. Mani MS. Introduction to High Altitude Entomology. Methuen and co. ltd., London. 1962.
32. Mathieu J, Rossi JP, Mora P, Lavelle P, Das Martins PF, Rouland C, Grimaldi C. Recovery of soil macrofauna communities after forest clearance in eastern Amazonia, Brazil. *Conservation Biology*. 2005; 19:1598-1605.
33. Munshi AM, Wani SA, Tak GM. Improved cultivation practices for saffron. In: proceedings of seminar-cum-workshop on saffron (Crocus sativus), SKUAST-K, India. 2001-2002, 83-88.
34. Nehvi FA, Makhdoomi MI. Importance of Irrigation in Saffron Production. Indian Farming. 2007; 59:15-16.
35. Nehvi FA. Problems and prospects of saffron improvement in India. In: Proceedings of International seminar on industrial use of biotecnology. 27th September to 1st October. 2003. Islamic Republic of Iran. 2003.
36. Norris K. Agriculture and biodiversity conservation: opportunity knocks. *Conservation letters*. 2008; 1(1):2-11.
37. Paoletti MG. The role of earthworms for assessment of sustainability and as bioindicators. *Agriculture, Ecosystems & Environment*. 1999; 74(1), 137-155.
38. Paoletti MG, Lovane E, Cortese M. Pedofauna bioindicators and heavy metals in five agroecosystems northeastern Itlay. *Rev. ecol. Biol. sol*. 1988; 25:33-58.
39. Plieninger T, Schleyer C, Schaich H, Ohnesorge B, Gerdes H Hernández-Morcillo M, *et al*. Mainstreaming ecosys-tem services through reformed European agricultural policies. Conservation Letters. 2012; 5:281-288.
40. Phoofolo MW, Giles KL, Elliott NC. Effects of relay-intercropping sorghum with winter wheat, alfalfa, and cotton on lady beetle (Coleoptera: Coccinellidae) abundance and species composition. *Environmental entomology*. 2010; 39(3):763-774.
41. Riley ND. Insects in colour, Blandford Press-Poole, Dorset. 1977.
42. Rusch A, Chaplin-Kramer R, Gardiner MM, Hawro V, Holland J, Landis D, Woltz M. Agricultural landscape simplification reduces natural pest control: a quantitative synthesis. *Agriculture, Ecosystems & Environment.* 2016; 221:198-204.
43. Sileshi G, Mafongoya PL, Chintu R, Akinnifesi FK. Mixed-species legume fallows affect faunal abundance and richness and N cycling compared to single species in maize fallow rotations. *Soil Biol. Biochem*. 2008; 40:3065-3075.
44. Stork NE. Measuring global biodiversity and its decline. 41-68. In ML. Reaka-Kudla, DE. Wilson, and E. O.Wilson (eds). Biodiversity 2: Understanding and Protecting Our Biological Resources. Joseph Henry Press, Washington, DC. 1997.
45. Theodore RE. Insects.Granada-London, New York, Toronto, Sydney. 1983.
46. Theunissen J. Intercropping in field vegetable crops: pest management by agrosystem diversification—an overview. *Pest Management Science*. 1994; 42(1):65-68.ntensification. Biol Conserv. 1994; 151:53-59.
47. Tscharntke T, Clough Y, Wanger TC, Jackson L, Motzke I, Perfecto I, Vandermeer J, Whitbread A. Global food security, biodiversity conservation and the future of agricultural I, 2012a.
48. Tuell JK, Fiedler AK, Landis DA, Isaacs R. Visitation by wild and managed bees (Hymenoptera: Apoidea) to Eastern U.S. native plants for use in conservation programs. *Environmental Entomology*. 2008; 37:707-718.
49. Wilson EO. Causes of ecological success: the case of the ants. Journal of Animal Ecology. 1987; 56(1):1-9.
50. Wilson EO, Hölldobler B. The rise of the ants: a phylogenetic and ecological explanation. *Proceedings of the National Academy of Sciences of the United States of America*. 2005; 102(21):7411-7414.
51. Woodcock BA, Redhead J, Vanbergen AJ, Hulmes L, Hul-mes S, Peyton J, *et al*. Impact of habitat type and landscape structure on biomass, species richness and functionaldiversity of ground beetles. *Agriculture Ecosystems & Environ-ment.* 2010; 139:181-186.
52. Zaki FA, Mantoo MA Integrated pest management in saffron, In: Nehvi, FA and Wani SA (Eds) *Saffron production in jammu and Kashmir*, Directorate of Extension Education. Skaust-K, India. 2008, 209-222.