Title: Ecological patterns in Staphylinidae (Insecta: Coleoptera) in cropped and forest areas of the Punjab, Pakistan.

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Abstract

The type of locality and seasons had a strong effect on species composition (richness and abundance) and community structure of rove beetles. This was determined in 3 forest and 8 cultivated areas of the Punjab, Pakistan during January 2008 to December 2009. A total of 2386 specimens belonging to 26 species were captured by using 5 different collection methods, i. e. pitfall traps, flight intercept trap, light trap, Berlese funnel trap and netting. Each area was sampled for four days with an interval of 2 months. The percentage population of different species and Shannon-Wiener diversity evenness indexes was calculated for all 11 localities. Maximum species richness and abundance was observed during rainy season (July-August). Even a single specimen of Paederus fuscipes, Philonthus cinotulus, Philonthus gemellus, Myrmecopora elegans, Tachyporus himalayicus, Astilbus mixtus was not found from forest area during the whole period of collection. Paederus fuscipes was the species with the highest population (16.05%) overall while Tachyporus himalayicus was with lowest (0.22 %). High α-diversity index (20.804) and Shannon-Wiener index value (2.573) was found from Sargodha during 2008 and Gutwala during 2009 and their lowest values (9.76) and (1.82) respectively were found from Rawalpindi during 2008.

Keywords: biodiversity, cropped area, forest area, Punjab, Pakistan, staphylinids

Running Title: Biodiversity of Staphylinidae in cultivated and forest area

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1. Introduction

Rove beetles (Staphylinidae) are a very successful group of insects, found in nearly all terrestrial habitats [1]. The tiny and slender body, with short elytra and movable abdominal segments, enable these beetles to inhibit and move in ecologically different habitats i.e. leaf litter and decaying animal wastes [2]. Many species have well developed wings and can move long distances. Their biodiversity is poorly known in most terrestrial ecosystems, in particular tropical ones [3]. They are found in a variety of habitats, i.e. under stones, under tree bark, near streams [4], in leaf litter and in dung [5], [6]. *Osorius*, *Oxytelus*, *Philonthus*, *Staphylinus*, *Liphocharis*, *Platystethus*, *Tachinus* and *Creophilus* are commonly found genera amongst these habitats [7], [8]. They also occur in nests of birds, ants, termites, and in fungi [9]. Due to the variety of habitats, these beetles act as detrivores, fungivores [10] and parasites of dipterous pupae [11]. Staphylinds also act as predators of aphids [12], Collembolans, thrips, algae [13] and other fauna found in decaying organic matter [14]. Some phytophagous species damage flowers and grass [15]. Some species of Omaliinae and Aleocharinae feed on pollens [16] and also act as pollinators [17]. Swarming rove beetles cause great trouble in the evening and annoyance by getting into human eyes and cause severe irritation. *Paederus fuscipes* has been found to cause dermatitis in US troops in Afghanistan, Northern areas of Pakistan [18], in India [19] and in Iran [20]. These species are well distributed in Pakistan [21]. Because of their flight, staphylinids have been found to disperse actively between natural and cultivated lands [22] where they hibernate and reproduce [23]. So these factors influence species richness besides improving the numerical status [24]. Forest ecosystem plays an important role in maintaining diversity and abundance of leaf litter staphylinids [25]. Due to their presence in a wide range of habitats and in most natural, semi-natural and man-made habitats, they act as important bio-indicators [26].

There is no doubt that a large number of species have been reported from the Indian Sub-continent including Ceylon and Burma [27], but most species have been recorded from areas outside of Pakistan. Rehman and Ghani [28] reported 133 species of rove beetles from pre-partition Punjab mentioned in the Fauna of British India, 131 species have been collected from hilly areas of Simla (India) and only 2 species have been recorded from plains of Lahore (Pakistan) and Shahpur. This shows that these workers did not pay any serious attention at this part of the country. A lot of work has been done and must be done in future to explore the staphylinid fauna in the world but no attention has been paid on these insects in Pakistan except few references, which are reported from NWFP [29], Baluchistan and Sindh [5], [30], [31] and Punjab [21]. In the present study mainly the ecological considerations are given, particularly species richness, evenness, abundance and phenology of Staphylinidae are studied with reference to environmental parameters for each site.

2. Materials and Methods

The present study on biodiversity of staphylinids was carried out during 2008-2009 in different areas of the Punjab. The project focused on collecting staphylinids from cultivated and forest areas by sifting of leaf litter, flight intercept trap (FIT), sweeping of grass, pitfall traps [32], [33] and light traps. Punjab presents an extraordinary diversity of biological environments. For this study, eleven localities from different cropping areas and forests were selected. Using a Magellan GPS (Explorist 660), the positions and altitudes of each locality were recorded (Table 1).

Table: 1

Plot	Locality	Latitude	Longitude	Elevation

No.	name			(m)
1	Lahore	31 14.287	73 59.513	194
2	Sheikhupur	31 34.723	73 29.117	187
3	Faisalabad	31 26.271	73 04.699	183
4	Multan	30 12.534	71 27.813	104
5	Rahim Yar Khan	28 26.450	70 19.712	83
6	Sargodha	32 05.379	72 40.566	183
7	Rawalpindi	33 34.425	73 05.161	496
8	Dera Ghazi Khan	30 18.209	70 43.324	117
9	Changa Manga	31 04.729	73 59.967	196
10	Gutwala	31 28.254	73 12.291	185
11	Muridwala	30 72 03	72 45 65	150

Site 1: cultivated area (Lahore) at 194 m elevation mainly with wheat-vegetables, but maize and sugar cane is also grown on small scale. There are many gardens in this area. Irrigation is through tubewell, sewage water or canal water like other cultivated sites. This site is very close to site 2 and more distant from sites 5 and 8;

Site 2: cultivated area (Sheikhupur) at 187 m elevation with wheat-rice cropping pattern, but people also grow vegetables, maize and sugar cane for their own use. Tubewell and canal water is used for irrigation like that of sites 1, 3, 4, 5, and 6;

Site 3: cultivated area (Faisalabad) at 183 m elevation with a cropping pattern like that of site 1, but with lack of gardens. Sewage, canal and tubewell water is used for irrigation. This area is very close to sites 2, 6, and 10. Here, soils are mostly clayey and loamy like that of site 1 and 2;

Site 4: cultivated area (Multan) at 104 m elevation with cotton and mango growing area of the Punjab. Cropping pattern in this area is wheat-cotton like that of sites 5 and 8 with heavy use of pesticides. Some sandy soils are also present similar to sites 5 and 8;

Table 2: Timetable of the studied plots

Sample collection time	**Locality**
During first week of first month	Faisalabad & Gutwala
During second & third week of first month	Lahore, Changa Manga & Sheikhupur
During fourth week of first month	Sargodha & Rawalpindi
During first week of second month	Muridwala
During second & third week of second month	Multan & Dera Ghazi Khan
During fourth week of second month	Rahim Yar Khan

Site5: cultivated area (Rahim Yar Khan) at 83 m elevation with similar cropping pattern like site 4, but without mango gardens. Soil is mostly sandy, so date plantation is present here. Sand dunes are also present in this area;

Site 6: cultivated area (Sargodha) at 183 m elevation famous for citrus gardens. Normal cropping pattern is wheat-rice or wheat-sugar cane. Hilly area is also present. Most soils are clayey. People use farm yard manures to increase fertility of the soil like other sites in the Punjab. Source of irrigation is tubewell and canal water.

Site 7: cultivated area (Rawalpindi) at 496 m elevation with barani area. Mostly, people use rainfall for irrigation but tubewell water is also used for irrigation purposes. Mostly, people grow wheat and grams. Hilly areas are also present in this site;

Site 8: cultivated area (Dera Ghazi Khan) at 117 m elevation with cropping pattern like that of sites 4 and 5. Use of pesticides is common due to cotton plantation. People depend mostly on rainfall and tubewell water for irrigation,

but few areas have the facility of canal water due to newly built canals. Bushy plantation is also present. Most soils are sandy and hills are also present;

Site 9: forest area (Changa Manga) at 196 m elevation with the largest man made eucalyptus plantations in the Punjab. This site is very close to site 1. For irrigation purposes, canals are built like in other forest sites. This is the mostly disturbed place like site 10 because people come for holidays trips;

Site 10: forest area (Gutwala) at 185 m elevation with manmade eucalyptus plantation and a park for recreation close to site 3. There is also a small zoo. Soil is sandy and clayey. Rainfall and canal water is used for irrigation purposes. Around this site people mostly grow vegetables;

Site 11: forest area (Muridwala) at 150 m elevation with another man made forest of a mixed type of plantation.

Sampling of the staphylinid fauna was performed from January to December in one plot from each cultivated and forest area during the years 2008 and 2009 (Table 2). The traps were installed for four days in each locality every second month. The samples were brought to the Biodiversity Laboratory in Department of Agri-Entomology, University of Agriculture, Faisalabad. Standard techniques for preserving and mounting followed that included clearing in 10 % KOH. Later, the specimens were treated with glacial acetic acid and dehydrated in ascending grades of alcohol and finally mounted in Hoyer's medium. The material was sorted and identified under the microscope using the keys [5]. Other keys [21], [34], [35], [36], [37], [38], [39] web sites and entomological articles were also used to identify the specimens.

2.1 Analysis of Data

For the analysis of the data, dominance of the each species was determined and Shannon diversity and evenness were calculated using natural logarithm [40], [41], [42].

3. Results

3.1 Environmental temperature variation

The data regarding temperature, relative humidity, and soil moisture was taken from meteorological stations close to the sampling sites. It is reasonable to assume that the data taken in the field are not really sufficient to assess these factors, but may provide a general indication of preferences [43]. All the selected sites had a similar temperature range (Table 3). The highest temperature was measured at site 7 (cultivated non irrigated area) followed by site 8 (cultivated irrigated area), i.e. 35°C and 34.6°C respectively. The highest variation of temperature with 21.7°C was recorded at site 1 (12.3°C to 34°C) and the smallest variation with 18.8°C was at site 11 (15.1°C to 33.9°C). All the other sites showed intermediate conditions between these (Table 3).

3.2 Relative humidity variations

Relative humidity variance was similar at all selected sites. During rainy season (July to September) the relative humidity was high and during dry season (November to May) its value was low. The lowest value of relative humidity was recorded from site 8 (26%) during May-June during late dry season. The highest value of R.H (%) was

Table 3. Record of temperature, relative humidity and soil moisture contents by months and sites

Sites	Months	Jan/Feb		Mar/Apr		May/Jun		Jul/Aug		Sep/Oct		Nov/Dec	
		2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
LHR/194m	Temperature	12.3	15	25	24	33.4	34	32.2	30	28	28.9	18	19.1
	R.H (%)	29.7	31.3	32.4	35.6	31	32.8	55	60.3	51.2	53	32.3	31
	S.M.C (%)	47	45.6	52	51	51	49.5	58	56.8	53	52	48	49
SHP/ 187m	Temperature	12.2	14.3	24.7	23.8	33.1	33.7	32	32.6	27.3	28.5	17.2	19.1

	R.H (%)	34	32.4	36.4	38	32.8	36.2	52.6	53.1	43.6	41.8	30	35.3
	S.M.C (%)	45.3	46	48	47.4	49.6	48.8	56	55.1	52	51.2	48.6	46
FSD/ 183m	Temperature	12.7	14.8	24.3	23.5	31.8	33.1	31.9	32.5	27.8	28.5	17.6	18
	R.H (%)	39.2	56.2	42	47.6	39.1	32.5	65.4	65.4	58.4	59	55.4	44.3
	S.M.C (%)	46	45.2	48.2	49	48.7	48.7	52	51.6	51.2	49.1	48	47.6
MTN/104m	Temperature	14.3	16	25.9	24.9	33	34.5	33.5	34.1	29.3	30	19	19.7
	R.H (%)	60	49.2	53.4	47	43	45.2	62.9	57.3	50.1	48.7	51.4	39.6
	S.M.C (%)	38.7	37.1	39	38.5	39.6	39	45.8	42.6	42	39.6	40.2	36
RYK/ 83m	Temperature	13.8	14.4	24.4	24.9	32.3	33	32.9	33.3	28.1	28.9	17.7	18.2
	R.H (%)	46.3	43.7	45	46	39.5	40.2	53.7	56	47	42	37.6	39.3
	S.M.C (%)	35	34.2	37.1	35.6	36	36	42	43.2	40.4	40.6	34	34.8
SGD/183m	Temperature	12.5	12.8	23.9	24	31.4	32	31.5	31.5	27.1	27.4	17.3	17.6
	R.H (%)	36	38.4	42.1	43	40	41.3	59	58.4	42	49.1	37.8	34.9
	S.M.C (%)	28.6	29.4	32.5	34.1	34.8	34.2	45.2	45.3	40	38.9	33.3	32.8
RWP/496m	Temperature	16	18.1	25.3	24.6	34.4	35	30.2	34	28	26.3	19	17.3
	R.H (%)	56	52	48	46.9	35	45	56	56	47.9	45.8	38.7	37.3
	S.M.C (%)	26	27.2	30.1	32.2	30	30.5	36.7	35.6	35	31	30	29.4
DGK/117m	Temperature	15.7	10.4	24.5	24.4	34.4	34.6	34.2	34.3	30	30.1	19.3	19.4
	R.H (%)	35	35.6	28	34	26	30.1	49.5	50	42.1	43.4	32.4	37.5
	S.M.C (%)	27	25.8	32.2	29.6	31.5	30	34.6	34.8	39.2	32	29.8	30.1
CNG/196m	Temperature	12.5	15.1	25.3	24.3	33.6	34.2	32.6	33.3	28.3	29	18.2	19.4
	R.H (%)	30.1	32.9	34.3	32	32	31.5	51.6	51	45	46.7	30.3	30
	S.M.C (%)	25.3	25.3	26	26	25.4	25.4	32.6	32.6	30	30	29.8	29.8
GTW/185m	Temperature	13	15	24.6	23.9	32.2	33.5	32.5	32.9	28	29	17.9	18.6
	R.H (%)	29.1	38.4	41.3	42	38.5	36	57	58.7	27	51.6	48.3	36.6
	S.M.C (%)	23	23.1	25	24.5	23	24	28	30	19	28	16	23
MDW/150m	Temperature	15.1	15.3	23.9	23.7	33.6	33.9	32.9	33.5	29.4	30.1	18.8	19
	R.H (%)	35	34.8	43.3	42	38.9	36.7	53.9	51.8	47	43.7	38	36
	S.M.C (%)	24.2	23.6	25	25.2	24.6	24.6	30	30.2	28.6	28.1	23.8	23

Jan/Feb = January/February; Mar/Apr = March/April; May/Jun = May/June; Jul/Aug = July/August; Sep/Oct = September/October; Nov/Dec = November/December; RH = Relative humidity; SMC = Soil moisture contents; LHR = Lahore; SHP = Sheikhupur; FSD = Faisalabad; MTN = Multan; RYK = Rahim Yar Khan; SGD = Sargodha; RWP = Rawalpindi; DGK = Dera Ghazi Khan; CNG = Changa Manga; GTW= Gutwala; MDW= Murid Wala

recorded from site 3 (65.4%) during July-August. The site 3 had greatest relative humidity variance by 32.9%, i.e., from 32.5% to 65.4% (Table 3).

3.3 Soil moisture contents

Soil moisture variance was similar at all selected sites. During rainy season (July to September) the soil moisture was high and during dry season (November to May) it was low. The lowest value of soil moisture was recorded from site 10 (16%) during November-December during mid dry season. The highest value of soil moisture was recorded from site 1 (58%) during July-August. Site 1 had highest soil moisture variance by 12.4%, i.e., from 45.6% to 58% (Table 3).

3.4 Species Richness

A total of 2386 specimens were collected during the 2 years (2008-2009) belonging to 5 subfamilies, 15 genera and 26 species. All specimens were identified up to species level. Staphylininae was the subfamily with the highest number of species (8), followed by Paederinae (7), Aleocharinae (5), Oxytelinae (4) and Tachyporinae (2). The highest number of species was collected from site 3 (22). Concerning species richness, both sites 6 and 1 are very close to site 3 with 21 and 20 species respectively. The site 7 was the site with the lowest number of species (12). The sites with higher number of species were all cultivated and irrigated sites that provided more resources for staphylinids to live than other sites that were barani (rain fed areas) or forest sites (that were also not irrigated regularly). The sites with high use of insecticides provide lower number of species than sites without insecticide use.

3.5 Abundance

Paederinae, Staphylininae, Oxytelinae, Aleocharinae, and Tachyporinae account for 51%, 25%, 13%, 8%, and 3% of total amount of specimens, respectively. With reference to sites, site 6, site 3, sites 1 and 2 each, and site 10 account for 12.7%, 12.70%, 11.43%, and 5.29% of total amount of specimens, respectively. *Paederus fuscipes* account for the highest number of specimens from cropped areas and even a single specimen was not recorded from forest areas. *Philonthus delicatulus* was the species with the highest number of specimens from the forest areas. *Paederus fuscipes* was the most abundant species overall with 16.05% specimens followed by *Philonthus delicatulus* with 11.8% specimens. *Tachyporus himalayicus* was the species with least (0.22%) abundance overall (Table 4).

3.6 Diversity

During 2008, the highest value of the Shannon diversity index (2.572) was found in site 5 (Rahim Yar Khan), the lowest value (1.82) at site 7 (Rawalpindi). The other localities showed intermediate values. The highest evenness (0.891) was recorded from site 8 (Dera Ghazi Khan) while its value was low in (Lahore) site 1 (0.696) while the value of dominance was highest (0.304) in this locality (Table 5). During 2009, the highest value of Shannon diversity index (2.534) was found at site 6 (Sargodha), the lowest value (1.97) at site 7 (Rawalpindi) while the values for other localities showed intermediate values. The highest evenness (0.863) was recorded from site 4 (Multan) while its value was low (0.793) in site 7 (Rawalpindi) while the value of dominance was highest (0.207) in this locality. Generally the value of α-diversity index was higher during 2009 than 2008. The values of Shannon-Wiener diversity index for different localities were slightly higher in 2008 than 2009

Table 4. List of species in percentage (%) of staphylinid beetles collected from cropped & forest areas of the Punjab, Pakistan during 2008-2009.

Species	Cropped Area		Forest Area		Overall
	2008	2009	2008	2009	Average

Oxytelus ferrugineus	2.60	3.30	1.85	1.98	2.43
Oxytelus sordidus	5.00	5.00	2.96	1.32	3.57
Oxytelus varipennis	5.10	6.20	2.59	1.51	3.88
Platystethus cornutus	1.40	1.70	1.11	0.66	1.22
Paederus fuscipes	33.60	30.60	0.00	0.00	16.05
Paederus tumulus	5.30	6.00	4.20	6.62	5.33
Paederus pubescens	8.20	7.50	0.40	0.33	4.11
Paederus basalis	5.20	4.90	9.20	10.92	7.55
Stilicus ceylanesis	3.01	3.70	5.19	4.64	4.13
Astenus sp.	1.41	1.10	8.52	6.95	4.51
Cryptobium abdominalis	2.00	1.80	0.00	0.66	1.11
Philonthus delicatulus	4.61	5.90	17.78	18.87	11.80
Philonthus cinotulus	2.40	3.00	0.00	0.00	1.35
Philonthus gemellus	1.50	1.70	0.00	0.00	0.80
Philonthus minutes	1.50	1.40	6.67	5.30	3.72
Leptacinus parumpunctatus	2.30	1.80	11.48	9.27	6.21
Staphylinus sp.	1.90	1.71	4.81	5.63	3.51
Aleochara clavicornis	1.70	2.60	4.81	4.97	3.52
Aleochara puberula	1.20	1.51	0.00	0.66	0.84
Myrmecopora elegans	1.90	1.60	0.00	0.00	0.90
Tachyporus himalayicus	0.51	0.40	0.00	0.00	0.22
Tachinomorphus ceylonicus	0.80	1.10	6.75	6.67	3.83
Philonthus thermarum	0.90	0.90	6.50	9.27	4.39
Aleochara sp.	1.71	1.20	0.00	0.00	0.72
Platyprosopis sp.	1.60	1.41	4.81	3.64	2.86
Astilbus mixtus	2.90	2.11	0.00	0.00	1.25

while the dominance was higher in 2009 (Table 5). Shannon diversity (H′) refers to both species richness and abundance.

Table 5. Richness measures of Staphylinids in the cropped & forest areas of the Punjab

	2008				2009			
Sites	(H')	(J')	(D)	α	(H')	(J')	(D)	α
LHR	1.838	0.696	0.304	13.794	2.5	0.835	0.165	19.801
SHP	2.396	0.846	0.154	16.798	2.416	0.853	0.147	16.795
FSD	2.388	0.784	0.216	20.799	2.419	0.795	0.205	20.801
MTN	2.551	0.866	0.134	18.766	2.495	0.863	0.137	17.772
RYK	2.572	0.890	0.110	17.773	2.459	0.835	0.165	18.778
SGD	2.504	0.822	0.178	20.804	2.534	0.832	0.168	20.798
RWP	1.82	0.790	0.210	9.760	1.97	0.793	0.207	11.770
CNG	2.524	0.91	0.09	15.793	2.523	0.91	0.09	15.780
GTW	2.427	0.875	0.125	15.737	2.573	0.874	0.126	18.772
MDW	2.463	0.869	0.131	16.782	2.47	0.891	0.109	15.789

H′= Shanon diversity; J′= Evenness; D= Dominance; α= Diversity index; LHR = Lahore; SHP = Sheikhupur; FSD = Faisalabad; MTN = Multan; RYK = Rahim Yar Khan; SGD = Sargodha; RWP = Rawalpindi; DGK = Dera Ghazi Khan; CNG = Changa Manga; GTW= Gutwala; MDW= Murid Wala

3.7 Species distribution in the study area and biological comments

Some species like *Paederus fuscipes*, *Philonthus cinotulus*, *Philonthus gemellus*, *Myrmecopora elegans*, *Tachyporus himalyicus* and *Astilbus mixitus* were found exclusively in cropping areas. No species was found to be the site exclusive but some species were found only in cropped areas and some were found to be confined up to forest areas only.

3.8 Phenology

Some species were found to be associated with some crops like *Paederus fuscipes* was found mostly from maize (may be due to more aphids) and berseem or with cropping patterns and some were found to be associated with humus (organic matter) in the soil but all species were found to be dependent on moisture contents in the soil. The highest number of species and their abundances were collected during rainy season (July-August) except site 10 where the highest number of specimens was collected during March-April (Figure 1). Some places have similar temperature and soil moisture but different number of specimens, this was due to different crops and their sowing and harvesting time (Table 6) or other biotic factors like prey availability or less disturbance.

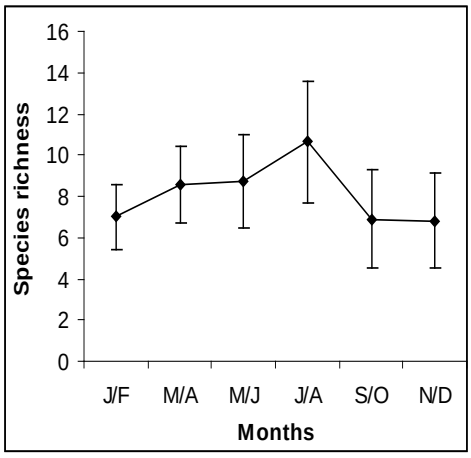
Table 6: General sowing and harvesting periods of different crops in the Punjab

Crop	General Sowing period	Harvesting period	Duration of crop (days)

Wheat	November to December	April	160
Maize	February and July	May and October	100
Cotton	End of April to June	November	180
Rice	May to June	October	150
Berseem	October	March	180
Summer vegetables	February to March	June to July	120
Winter vegetables	September to October	December to January	120

4. Discussion

There was a serious need of information about the most essential aspects of biodiversity of staphylinid beetles in cropped and forest areas of Pakistan, including, specifically, the number of species present. Information on beetle's diversity in the Punjab was generally available for many habitat types, but the information on the most diversified group of insects, i.e rove beetles, was missing. This is the first study on rove beetle biodiversity in the Punjab, and one of only a few studies in Pakistan to account richness of staphylinids. Although a high richness of staphylinid species was found, it was evident that we had sampled only a small portion of the total staphylinid diversity in cropped and forest areas of the Punjab.



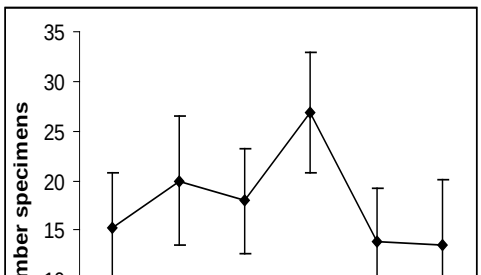


Figure 1: Species richness during different months of the years 2008 and 2009.

4.1 Staphylinid biodiversity

The main part of this study was to give a first estimate of the staphylinid diversity of the Punjab, Pakistan. During 2008 and 2009, the eleven selected localities were sampled for 730 days, with five different collecting methods. From these collecting methods, 5 sub-families, 16 genera, 26 species and about 2386 specimens were caught during 2008 and 2009. In these 11 localities, 8 were from cropped areas and 3 were from forest areas. Although the traps were installed for only four days during each visit in every second month at each locality, the results indicate a low diversity as well as medium abundance of staphylinids. Few species were found in large numbers (*Paederus fuscipes*, *Philonthus delicatulus*, *Paederus pubescens*, *Paederus basalis and Paederus tamulus*) and only one species was found with very low numbers (*Tachyporus himalyicus*). Although the frequency relation between species was interesting, this value must be interpreted with care, because it largely depends upon the efficiency of traps. No other study in the Punjab, Pakistan, was available so if we compared our work with other scientists in the world then it was found that similar results were found in Mexico by some scientists [43], [44], [45]. They also found subfamily Staphylininae with highest number of species like us.

As indicated from the results, the traps efficiency was very unequal, because intercept traps and attractive

traps were used together. Mostly specimens were caught with pitfall traps followed by Berlese funnel. Least numbers were caught with flight intercept traps and light traps. As some species were not attracted by traps so sweep nets and hand collection were also used to enrich the collection. Shannon-Wiener index (H′) and Simpson's index (D) are the two diversity measures that are theoretically independent of sample size. But these indices should be implemented with caution, because they are relatively insensitive to climatic influence compared with α, that is badly affected by small sample, species dominance and presence of rare species [46], [47], [48], [49].These indices are sensitive to the changes in the species abundance of the dominant species in a sample while the α index mainly deals with the species that are in between the species frequency distribution. Due to this reason, α is less influenced by one or two very abundant species [50], [51]. Because α mostly depends up on species abundance in compliance to a log-series frequency allocation. Shannon-Wiener (H′) index and α index were calculated from data in the present research work for comparison with other works and Simpsons' index was not calculated. In the present study, H′ was generally found 1.9 - 2.5, while Shah *et al*. [52] found this value less than 2.0, Lubke [53] studied that H′ varied from 2.2 to 2.4 in wheat fields and Kromp and Steinberger [54] reported a value of 4.1 from wheat in Australia. Dritschilo and Wanner [55] reported that H′ varied from 1.3-2.3 in maize fields and 1.3-1.7 from conventional fields. However, any idea from this discussion have to be treated with caution because of poor practical performance of H′ that is widely used in biodiversity studies despite its well-known shortcomings [52]. There were no previous studies about diversity indices of staphylinids from our agroecosystems that might be referred to difficult identification of staphylinids [52], [56]. Usually values ranged between 1.5 to 3.5 and rarely exceeded 4.5 [43], [57]. Our results corresponded to these results during both years (2008-2009). Evenness (J′) indicated that the distribution pattern and its value ranged from 0 to 1 [43], [57]. In Ireland, 15 common staphylinid species were found from cereals in pitfall trapping by Good and Giller [14]. In the present study, the common staphylinid species, *Paederus fuscipes*, was more abundant in maize and berseem and was collected through pitfall trapping. Possibly, the reason for this may be more humid microclimate due to higher crop densities [58]. There was less difference in Shannon-Wiener index values between the two years. My findings are consistent with others, which have indicated greater abundances with organic systems but no differences between organic and conventional annual farming systems using the Shannon-Wiener index [59]. All 26 species were present in cropped areas while only 17 species were found in the forest areas. This difference in species can be referred to biotic factors, e.g. different crops, and abiotic factors, e.g. temperature, relative humidity, and soil moisture.

4.2 Effect of abiotic factors on rove beetles

The results indicate that there was a positive correlation between decaying organic matter especially dung, soil moisture contents and staphylinid population. It was also shown by the results that there was a difference between staphylinid communities in cropped area and in the forest. This difference in species composition was due to biotic factors such as different crops and abiotic factors such as temperature, relative humidity and soil moisture contents. These results are in accordance with the resuls of other scientists [60], [61], [62], [63], [64]. Seasons also affect the staphylinid population, e.g. by rain fall. Months receiving more rainfall (July-August) normally showed maximum staphylinid abundance. Months with less rain fall or with

no rain fall indicated lower abundance, i.e. in May, September or October. There was normally a maximum abundance and a maximum diversity during July-August. These results are consistent with the results of other scientists [6]. It was clear from our results that most species were not strongly associated with a particular season [65].

5. Conclusion

From this study, it was concluded that biotic (soft bodied insects, crop type) and abiotic (temperature, soil moisture contents, rain fall, type of locality) factors significantly affect the activity of rove beetles. Abundance and diversity of rove beetles was found to be affected by different seasons and months of the year. Months receiving more rainfall (July-August) normally showed maximum staphylinid abundance.

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