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Diversity and Abundance of Soil Arthropods in Floriculture, Orchard and Agriculture Crops

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Abstract: Study of soil arthropods is crucial for understanding soil health, which is essential for both ecosystem stability and agricultural productivity. The experiment was conducted to assess soil arthropods diversity and abundance in different crops (Floriculture block, Orchard block, Northern block and Southern block) with varying soil types at the Agricultural College farm, Bapatla during 2021-22. A total of 6248 individual soil arthropods were recorded from all the cropping systems belonging to 4 classes, 7 orders and 15 families. Sampling data was collected and extracted using pitfall traps (macro-arthropods) and Berlese funnels (micro-arthropods) and the data was analysed using Shannon-Weiner diversity index, Simpson's index, Relative abundance, Evenness, Sorenson's similarity index and Kruskal-Wallis test. The results showed that Floriculture block had the highest Shannon-Weiner diversity (2.29), Simpson's index (0.87) and Evenness (0.70) among the blocks. Northern block had the lowest Shannon-Weiner diversity (2.00), Simpson's index (0.78) and Evenness (0.57). Arthropods in the order Coleoptera made up the largest fraction of arthropods in all the blocks. Sorenson's similarity index showed more similarity between Floriculture block and Northern block (74%). The Kruskal-Wallis test revealed significant differences in arthropod distribution among the four blocks, suggesting that soil type and land use influence soil arthropod community structure.

Keywords: Berlese funnel, Biodiversity indices, Kruskal-Wallis test, Pitfall traps, Soil types

The soil is a dynamic, diverse, and highly heterogeneous system that sustains a variety of natural niches, is home to a wide range of living things, and performs essential ecosystem functions (Goncalves and Pereira 2012). It is estimated that about 3,60,000 species accounting for nearly 23 per cent of all documented organisms inhabit the soil with 85 per cent of those species being arthropods (Culliney 2013). Edaphic fauna form an integral component of the agricultural environment and is highly sensitive to disturbances arising from crop and soil management practices. The abundance and dispersal of soil arthropods are influenced by geographic location, climate, soil physical characteristics, litter type and depth, and other abiotic elements like temperature, moisture, and light (Mir 2000).

The soil arthropods are diverse and important for ecosystem functioning. They serve as predators and are crucial in the decomposition of organic matter, nutrient cycling, mobilization of nutrients, regulation of microbial population by predation or dispersion of propagules into environment, disease management, agrochemical degradation, soil structure maintenance, development of soil physio-chemical characteristics and other functions (Toyota et al., 2013, Roy et al., 2011). Owing to these multifaceted roles, they are often referred to as “litter transformers” and “ecosystem engineers”. Biodiversity of soil arthropods is essential for the survival of life on the earth in the long run. It shields the soil from the ecosystem's disruption and stress. Hence, soil arthropod diversity can be used as a sign of soil stability. From this point of view, it is essential to monitor the soil biodiversity in agricultural areas (Rossi et al., 2006). In this context, the present study was undertaken to determine the diversity and abundance of soil arthropods in various blocks of the Agricultural College farm, Bapatla representing varied soil types.

MATERIAL AND METHODS

Study site: The experiment was conducted at the Agricultural College farm, Bapatla during September, 2021 to February, 2022. The College farm consisted of four different blocks representing different cropping systems *viz*., Floriculture block (Perennial flower crops), Orchard block (Banana+ groundnut+ lady's finger), Southern block (Millets + groundnut) and Northern block (Maize) which consisted of different types of soils *viz*., sandy, sandy clay loam, loamy sand and clay soils, respectively. An area of one acre was selected in each block for enumeration of soil micro and macro-arthropods.

Sampling method for soil arthropods: Five soil samples were collected randomly from each block at monthly intervals using a core auger which was placed on the surface of the soil and pressed downwards and turned in clockwise direction to a depth of 10-15 cm in the morning hours between 8:00 am to 10:00 am. A total of 120 samples were collected from all the four blocks during the study period. Soil sample collection was done by slightly modifying the procedure given by Ying-hua et al. (2013). Each soil samples was placed in the polythene bags and brought to the laboratory for extraction of micro-arthropods within 2 hours of sample collection. Micro-arthropods were extracted using Berlese funnel with the beaker filled with 10 ml of 75 per cent ethyl alcohol and funnel with 20 mesh was placed over a glass beaker. The electric bulbs (100 W) were switched-on for 48 hours to generate heat that led the micro-arthropods to move down passing through the sieve of the funnel and get collected in glass beakers. The arthropod samples collected in the glass beakers were labelled and sent for identification.

Macro-arthropods were collected by placing pitfall traps at seven randomly selected areas in each block. Each trap was added with 75 per cent ethyl alcohol as killing agent. Later, the debris was placed over the pitfall trap so that the area around the pitfall trap matched the surrounding soil surface as described by Albajes et al. (2009) and Cheli and Corley (2010).

Identification: Collembolans were sent for identification to Biosystematics division of Entomology at Banaras Hindu University, Varanasi (UP) and mites to All India Network Project on Agricultural Acarology (AINPAA), University of Agricultural Sciences, Gandhi Krishi Vignana Kendra (GKVK), Bangalore. The coleopterans and spiders were identified at ICAR-NBAIR, Bangalore.

Determination of soil parameters: Soil moisture was estimated by the gravimetric method (Reynolds 1970), soil temperature was recorded by using the method given by (Srivastava 2009) and organic carbon content of the soil was determined by rapid titration method given by Walkley and Black (1934).

Statistical analysis: The data recorded during the study period was compiled and analyzed for statistical significance using Alpha diversity indices (Shannon–Wiener, Simpson's, relative abundance and Evenness), Beta diversity (Sorenson's similarity) index, Kruskal- Wallis test and Correlation. Diversity indices were computed using PAST software program (Hammer et al., 2001) and Kruskal-Wallis test and Correlation analyses were performed using SPSS software.

Alpha Diversity Indices

Shannon-Weiner diversity index: The abundance and diversity of insect community was commuted using Shannon's diversity index (H) (Humphries et al., 1996).

$$H = -\sum_{i=1}^{s} p_i \ln(p_i)$$

Where,

H = the Shannon-Weiner diversity index value

p_i = the proportion of individuals found in the i^{th} species

ln = the natural logarithm

s = the no. of species in the community.

Simpson's index:

$D = \sum n_i(n_i-1)/N(N-1)$

Where,

"n_i" is the no. of individuals in "1^{th}" species and

"N" is the total no. of individuals in the sample.

Relative abundance:

$$\text{Relative abundance (\%)} = \frac{\text{Abundance of particular soil arthropod category}}{\text{Total abundance}} \times 100$$

Evenness: (Pielou 1969).

Evenness = H / ln(N)

Where,

H is the Shannon-Weiner diversity index

N is the no. of categories in the community

Beta Diversity Index- Sorensen Similarity Index: It measures similarity in species composition for two sites (Magurran 2004).

$$C_s = \frac{2ab}{a+b}$$

Where a is the no. of species found in site A, b is the no. of species in site B and ab is the no. of species shared by the two sites.

RESULTS AND DISCUSSION

The soil arthropods were collected for a period of six months from September, 2021 to February, 2022 from four blocks of the Agricultural College Farm, Bapatla. A total of 6,248 individuals, representing 4 classes, 7 orders and 15 families, were recorded across all blocks among these 3,333 individuals were recorded from the Floriculture block, representing two classes (Insecta and Arachnida) of arthropods. With 1820 individuals, the Coleoptera order of the class Insecta accounted for the majority of the arthropods in the soil (54.6%) of all the arthropods that were collected. The smallest order of soil arthropods was Hymenoptera (Formicidae) with 187 (5.61%) individuals throughout the sampling period (Fig. 1a).

Throughout the study period, there was flora on the floriculture block and the falling leaves might have provided food for the soil arthropods. The outcomes coincided with those of Roy et al. (2021). However, more species and more evenness were observed in December, the Shannon-Weiner diversity index (H) was highest in December (2.33) and lowest in the February (2.09). Simpson's index (1-D) was at its highest in November and December (0.88) and at its lowest in February (0.83). Evenness (J) was discovered to be highest in January (0.77) and lowest in February (0.68) (Table 1). Continuous vegetation and accumulated litter in the perennial flower crops likely enhanced arthropod diversity in this block.

In orchard block, 1,152 individuals were recorded (Fig. 1b). Coleoptera were the highest population of the soil arthropods with 485 individuals made up 42.10 per cent of the total. The suitable conditions for the presence of higher soil arthropod-diversity in the Orchard block could be attributed to relatively undisturbed nature of soil under banana plantation which occupied more area in the study area. November had the highest Shannon-Weiner diversity index (2.36) coinciding with the post-rainy period, and February had the lowest (1.48). Simpson's index (1-D) peaked in the November (0.89) and at its lowest point in February (0.71). January (0.80) had the highest Evenness (J), while October had the lowest evenness (Table 1). The highest number of soil arthropods in November may be due to the high rainfall that indirectly might have resulted in low soil temperature.

However, 804 individuals were collected from the southern block (Fig. 1c). Coleoptera was the group of organisms that had been collected in the greatest number with 326 individuals (40.54%) of the total number of soil arthropods. The smaller groups were the Chilopoda (1.49%) and Diplopoda (1.74%). Shannon-Weiner diversity index peaked in September (2.33), followed by October (2.28) and reached the lowest in February (1.59). September (0.88) had the highest Simpson's index (1-D), followed by October (0.87) and February had the lowest Simpson's index (0.74). January had the highest evenness (J) (0.87) while December had the lowest (0.64) (Table 1). The peak population of soil arthropods was in September, this might be accounted to the presence of vegetation in the form of *kharif* millets at harvest stage and the soil was in undisturbed condition. Furthermore, the decrease in the population in November can be attributed to ploughing of soil for the preparation of land for *rabi* crops. Although, high rainfall was received in November, the population was less due to the fact of preparatory cultivation in November. The present findings were in accordance with Zayadi et al. (2013) and Ahmed et al. (2016).

From the Northern block, 959 arthropods were collected (Fig 1d). Coleopterans accounting for 58.08 per cent (557) of the total soil arthropods. The other minor category of soil arthropods was Diplopoda (1.25%). September had the highest Shannon-Weiner diversity index (2.09) and February had the lowest (1.47) (Table 1). The results conform to the findings of Mahajan and Singh (1981) who recorded the maximum population during the monsoon months when the soil moisture was high and soil temperature was low. The results were also identical with those of Anjumoni (2016) who reported that highest population of soil arthropod in the monsoon month of August and lowest in April. Simpson's index (1-D) was at its highest point in September (0.79) and its lowest in February (0.72). October (0.55) had the lowest evenness (J), while February had the greatest (0.72).

Comparative analysis revealed that Coleoptera (51.02%)

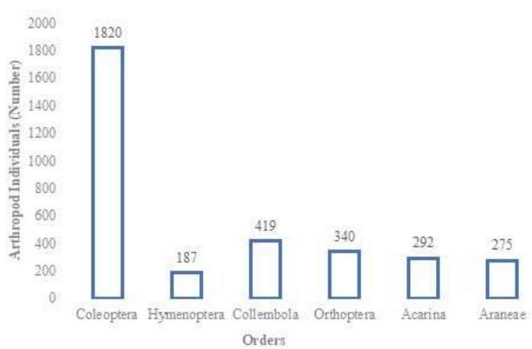

Fig 1a. Different Orders of Soil arthropods in Floriculture block

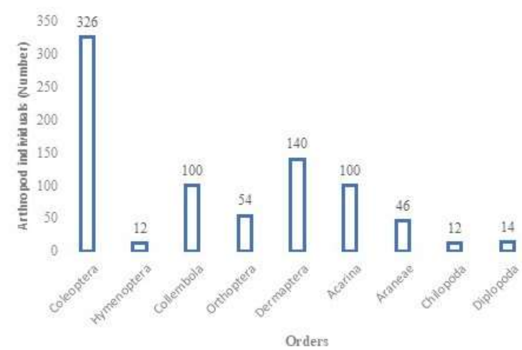

Fig 1c. Different Orders of Soil arthropods in Southern block

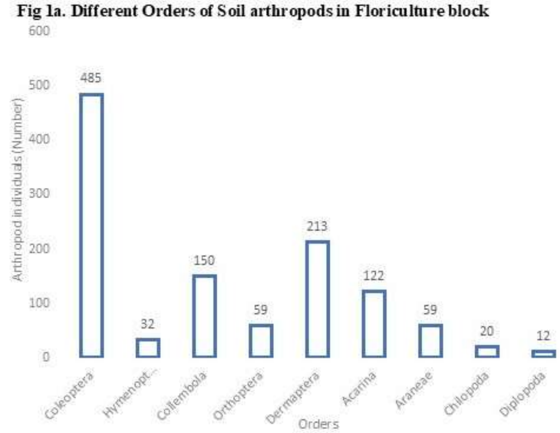

Fig 1b. Different Orders of Soil arthropods in Orchard block

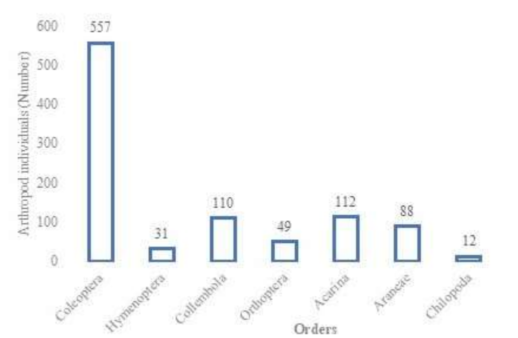

Fig 1d. Different Orders of Soil arthropods in Northern block

was the most dominant order, followed by Collembola (12.46%), Orthoptera (8.06%), Dermaptera (5.65%) and Hymenoptera (4.19%) (Table 2). Two families were identified in the order Collembola *i.e*., Hypogastruridae and Onychiuridae. Among Arachnids, Acari (10.01%) were most abundant and 7.49 per cent of Araneae were recorded. In the Acari, two suborders Mesostigmata and Oribatida were identified. Chilopoda (0.70%) and Diplopoda (0.42%) were the other minor groups recorded during the study period. Among the blocks, Shannon-Weiner diversity index was higher in foriculture block (2.29) followed by Orchard block, Southern block and Northern block. Simpson's index (1-D) was highest in floriculture and orchard blocks (0.87 each), followed by Southern and Northern blocks. The evenness was maximum in Floriculture block (0.70), followed by southern block, orchard block and northern block. The diversity was more in the Floriculture block that may be attributed to the fact that it was an undisturbed land with perennial flower crops for few years which supports stable soil microclimates and organic matter accumulation. Orchard block also had highest diversity as most of the land was undisturbed with fruit trees. Wale and Yesuf (2022) also reported that soil arthropods were more abundant in undisturbed habitats than in the disturbed habitats. Similar findings were reported by Sanalkumar et al. (2012), Holland and Reynolds (2003), Piffner and Luka (2000) and Maribie et al. (2011).

The soil parameters like soil temperature, soil moisture and organic carbon varied from one block to another block. The average soil temperature was more in the southern block (24.6°C) and low in the floriculture block (24.12°C), this could be due to the continuous irrigation given in the floriculture block. This might be the reason for the greater number of soil arthropods in the floriculture block and less number in the southern block. The soil moisture content showed a drastic change among the four blocks and was highest in the northern block (25.32%) and lowest in the floriculture block, Organic carbon content was high in the northern block and orchard block (0.51%) and low in the floriculture block (0.17%). Even though there was less moisture content and less organic carbon in the floriculture block, there were a greater number of soil arthropods. This could be due to the undisturbed nature of the land in the floriculture block and the loose sandy soil which facilitates the easy movement of the soil arthropods. There was also less utilisation of chemical pesticides in the Floriculture block and it was comparatively more in case of other blocks with field crops (Table 3).

Correlation coefficients (Table 4) indicated a negative

Table 1. Diversity indices of soil arthropods in different blocks

Floriculture block	September	October	November	December	January	February
Total no. of individuals	713	694	752	498	378	298
Shannon-Weiner Diversity index	2.27	2.27	2.31	2.33	2.22	2.09
Simpson's index	0.86	0.87	0.88	0.88	0.87	0.83
Evenness	0.69	0.75	0.72	0.73	0.77	0.68
Orchard block						
Total no. of individuals	274	224	346	159	86	63
Shannon-Weiner Diversity index	2.24	2.20	2.36	2.07	1.86	1.48
Simpson's index	0.86	0.86	0.89	0.86	0.82	0.71
Evenness	0.67	0.64	0.75	0.79	0.80	0.73
Southern block						
Total no. of individuals	222	197	150	115	68	52
Shannon-Weiner Diversity index	2.33	2.28	2.10	1.96	1.66	1.59
Simpson's index	0.88	0.87	0.85	0.82	0.79	0.74
Evenness	0.79	0.75	0.68	0.64	0.87	0.70
Northern block						
Total no. of individuals	280	232	153	135	88	71
Shannon-Weiner Diversity index	2.09	1.966	1.98	1.876	1.753	1.47
Simpson's index	0.79	0.77	0.78	0.75	0.76	0.72
Evenness	0.62	0.55	0.60	0.59	0.72	0.72
Mean values of soil arthropods	4.32	3.95	2.84	2.54	1.96	1.24

Table 2. Comparison of the diversity of soil arthropods in different blocks

Class	Order	Family	Floriculture block	Orchard block	Southern block	Northern block	Total	Relative abundance (%)	
Insecta	Coleoptera	Tenebrionidae	327	263	180	65	835	51.02	26.19
		Carabidae	889	0	0	0	889		27.88
		Staphylinidae	371	59	0	52	482		15.11
		Elateridae	196	0	0	0	196		6.14
		Scarabaeidae	0	163	146	413	722		22.64
		Bostrichidae	0	0	0	27	27		0.84
		Unknown	37	0	0	0	37		1.16
		Sub total	1820	485	326	557	3188		100
	Hymenoptera	Formicidae	187	32	12	31	262	4.19	
	Collembola	Hypogastruridae	321	128	74	80	603	12.46	77.40
		Onychiuridae	98	22	26	30	176		22.59
		Sub total	419	150	100	110	779		100
	Orthoptera	Acrididae	285	18	15	10	328	8.06	65.33
		Gryllidae	47	41	39	39	166		33.06
		Gryllotalpidae	8	0	0	0	8		1.59
		Sub total	340	59	54	49	502		100
	Dermaptera	Earwigs	0	213	140	0	353	5.65	
Arachnida	Acarina (Mesostigmata)	Laelapidae	207	82	69	79	437	10.01	69.80
		Dinychidae	3	0	0	0	3		0.04
	Oribatida		82	40	31	33	186		29.71
		Sub total	292	122	100	112	626		100
	Araneae	Araneidae	275	59	46	88	468	7.49	
Chilopoda		Centipedes	0	20	12	12	44	0.70	
Diplopoda		Millipedes	0	12	14	0	26	0.42	
Total no. of individuals			3333	1152	804	959	6248		
Shannon-Weiner Diversity index			2.29	2.26	2.19	2.00			
Simpson's index			0.87	0.87	0.86	0.78			
Evenness			0.70	0.68	0.69	0.57			

Table 3. Rainfall and soil parameters data in different blocks

Month	SMW	Rainfall (mm)/ week	Floriculture block			Orchard block			Southern block			Northern block		
			Soil temperature (°C)	Soil moisture (%)	OC (%)	Soil temperature (°C)	Soil moisture (%)	OC (%)	Soil temperature (°C)	Soil moisture (%)	OC (%)	Soil temperature (°C)	Soil moisture (%)	OC (%)
Sept-2021	39	204.50	23.20	9.43	0.20	23.80	24.40	0.62	23.80	12.24	0.39	24.00	26.87	0.55
Oct-2021	43	178.40	24.20	8.24	0.18	23.80	24.00	0.59	24.00	11.68	0.37	24.20	25.63	0.54
Nov-2021	47	276.00	22.80	9.62	0.18	23.60	24.80	0.54	23.50	13.22	0.37	23.20	27.00	0.54
Dec-2021	52	0.00	25.00	7.23	0.16	24.00	23.80	0.48	24.40	11.60	0.35	24.50	24.97	0.54
Jan-2022	04	60.30	24.50	8.66	0.16	24.60	24.00	0.45	25.40	9.86	0.34	25.00	24.45	0.45
Feb-2022	08	0.00	25.00	5.25	0.16	26.00	22.24	0.42	26.50	8.46	0.26	26.00	23.00	0.45
Mean			24.12	8.07	0.17	24.3	23.87	0.51	24.6	11.18	0.35	24.50	25.32	0.51

Plate 1. Soil micro-arthropods collected in berlese funnel: (a) Acarina- *Androlaelaps sp*., F: Laelapidae, SO: Mesostigmata (b), Acarina -F: Dinychidae, SO: Mesostigmata (c), Acarina -SO: Oribatida (d), Collembola- *Hypogastrura sp*., F: Hypogastruridae (e), Collembola-*Onychiurus sp*., F: Onychiuridae

Plate 2. Soil macro-arthropods collected in the pitfall traps: (a, b, c), Coleoptera- Carabidae, Scarabaeidae; (d), *Onthophagus sp.;* (e), *Sisyphus sp.;* (f), Bostrychidae; (g), Tenebrionidae; (h) , Elateridae; (i), Staphylinidae; (j), Hymenoptera- Formicidae; (k), Dermaptera; (l), Araneae; (m), Acrididae; (n), Gryllidae; (o), Gryllotalpidae; (p), Chilopoda; (q), Diplopoda

Table 4. Correlation of rainfall and soil parameters with soil arthropods in different blocks

Parameters	Floriculture block	Orchard block	Southern block	Northern block
Rainfall	0.858*	0.917**	0.741	0.694
Soil temperature	-0.838*	-0.821*	-0.815*	-0.704
Soil moisture	0.773	0.818*	0.741	0.812*
Organic carbon	0.768	0.787	0.822*	0.830*

*Significant at 5% level; ** Significant at 1% level

relationship between soil temperature and arthropod abundance in all blocks, with significant negative correlations in all except the northern block. Soil moisture and organic carbon showed positive correlation with soil arthropod populations. The increase in the total number of arthropods recovered may be as a result of increase in the soil moisture content due to more rainfall and decrease in temperature. Sorenson's similarity index revealed that the floriculture block which had the highest diversity of soil arthropods showed more similarity with northern block *i.e.,* 0.74 (74%), 0.71 (71%) similarity with Orchard block and 0.66 (66%) similarity with Southern block. Kruskal-Wallis test revealed a significant difference between the mean values of soil arthropods across the four blocks indicating that the distribution of soil arthropods varied significantly with soil type and cropping pattern.

CONCLUSION

The study clearly demonstrates that soil arthropod diversity and abundance are influenced by soil type, moisture, temperature, vegetation cover and management intensity. Undisturbed and perennial systems such as floriculture and orchard blocks supported greater diversity, emphasizing the ecological importance of maintaining habitat stability for soil biodiversity conservation.

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