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Diversity and Abundance of Foliar Arthropods in Different Crop Ecosystems

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ABSTRACT

A study on the diversity and abundance of arthropods was carried out at the Agricultural College Farm, Bapatla in Sorghum, Maize and Bengal gram agricultural ecosystems during November, 2021 to February, 2022. Sampling data was recorded by visual count method by following 'W' pattern at weekly interval. Diversity of arthropods was analyzed by Shannon-Weiner diversity index, Simpson's index, Relative abundance and Evenness. The results revealed that maize crop had the highest Shannon-Weiner diversity (1.616) and Simpson's index (0.774). Arthropods in the Araneae and Aphididae family made up the largest fraction of arthropods in the maize crop. Evenness was similar in all the three crops (0.5). Bengal gram had the lowest Shannon-Weiner diversity (1.262) and Simpson's index (0.668).

Key words: *Arthropods, Diversity, Sorghum, Maize, Bengal gram and Diversity indices.*

Biodiversity is essential for the survival of life on the earth in the long run. Arthropods are extremely sensitive to changes in their habitat and play important roles in many ecosystem processes. Arthropods can be used to assess and create solid ecosystem management strategies since they are reliable indicators of the overall biodiversity and ecological integrity.

Many species of arthropods found in different habitats are beneficial as natural control agents against pests, others are important in the diet of birds, most remain unstudied and their functions are yet unknown in the agro-ecosystem, but should be protected as a part of the general commitment to preserving biodiversity (Sreenivasa, 2021.). Furthermore, the diversity and abundance of arthropods are reducing due to increase in the intensive agricultural production methods, involving widespread use of herbicides and insecticides and this has raised concern over the potential of agricultural practices on the arthropod diversity (Aebischer, 1991 and Gowtham Kumar *et al*., 2021.).

In the agroecosystem, arthropods are found in large numbers and their number influenced by season, humidity, rainfall, temperature, surrounding crop, and agronomic practices. The community's stability depends on both the diversity and complexity of species. Furthermore, pest control requires an understanding of species diversity and abundance at various times (Nawanich *et al*., 2010).

The objective of this study was to determine the arthropod diversity and seasonal abundance on different agricultural crops.

MATERIAL AND METHODS

The experiment was conducted at the Agricultural College Farm, Bapatla during November, 2021 to February, 2022. The three crop ecosystems *viz.*, Sorghum (Coarse millet), Maize (Cereal) and Bengal gram (Pulse) crops that were cultivated for other experiments in the College Farm from November, 2021 to February, 2022 were considered for the study. Foliar arthropods were collected from ten randomly selected spots at weekly intervals in all the three crops by following "W" pattern. At each spot four plants were examined. Larval counts were made by shaking the plant gently in Sorghum, Maize and Bengal gram. The aphids were counted as number of aphids per 1 cm^2 leaf area from three leaves (upper, middle, lower) of each plant, and the number recorded as mean number per plant (Paul *et al.*, 2020). The population of arthropods were recorded and expressed as number per plant. Similarly, observations on natural enemies were made and they were collected by hand picking and by using insect nets and expressed as number per plant. Mean

population of major pests and natural enemies were calculated to establish the relation between the population of different arthropods with the abiotic factors and to calculate the significant difference between the three crops. Kruskal-Wallis test was used to find out the significant difference among three crops. Diversity of arthropods found in three crops were analysed by the Shannon-Wiener diversity index, Simpson's index, Relative abundance and Evenness.

Shannon-Weiner Diversity Index: The abundance and diversity of insect community was commuted using Shannon's diversity index (H) that accounted for both abundance and evenness of the species (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 number of species in the community.

Simpson's Index (1-D): Simpson's diversity index (D) determines the concentration of different taxa in the population (richness).

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

Where,

"n_i" is the number of individuals in "i^{th}" species and

"N" is the total number of individuals in the sample.

Relative Abundance: To calculate the particular kind of arthropods relative to the total number of arthropods in that particular area.

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

Evenness: With a view to understand the measure of similarity of the abundance of different categories (Pielou, 1969).

$$\text{Evenness} = H / \ln(N)$$

Where,

H is the Shannon-Weiner diversity index

N is the number of categories in the community

RESULTS AND DISCUSSION

The collected foliar arthropods from the three crop ecosystems were organized into three functional groups in accordance to their feeding habits: phytophagous insects, natural enemies and other arthropods (those considered as neither pests nor natural enemies). In all the three crops, totally 1664 arthropods were collected and they were divided into two classes and eight orders.

In the sorghum crop, a total of 525 individuals were observed. Out of these, the phytophagous insects found were lepidopteran larvae, fall army worm *Spodoptera frugiperda* (J.E Smith) with 152 individuals found throughout the crop period constituting 28.95 per cent of the total foliar arthropods collected. The natural enemies found were Coccinellidae, Chrysopidae, Odonata (Dragonflies, Damselflies), Hymenoptera and Araneae. The major natural enemies found in the crop were Coccinellidae with 155 individuals and Araneae with 144 individuals throughout the crop period which constituted about 29.52 and 27.43 per cent, respectively. Diptera was recorded only with 8 individuals constituting about 1.52 per cent and Hemiptera (Pyrrhocoreidae) with 48 individuals constituting 9.14 per cent were the other arthropods noted in the sorghum crop. Some families have very low frequencies of less than 5 per cent which included Neuroptera (0.57%), Odonata (2.09%), Hymenoptera (0.76%) and Diptera (1.52%) (Table 1).

The major pest fall army worm was found throughout the crop period with two peaks during the 48th SMW and 1st SMW with 0.4 larvae/plant and 0.42 larvae/plant, respectively. The use of insecticides for the control of fall army worm in the 48th SMW and 1st SMW might have resulted in the decrease of the fall army worm population in 49th SMW and 2nd SMW and the same reason may be attributed for the decrease of natural enemies in 49th SMW and 2nd SMW (Table 2 and Figure 1). The larval population was positively correlated with minimum temperature (0.138), morning RH (0.175),

evening RH (0.358), rainfall (0.337) and negatively correlated with maximum temperature (-0.473) (Table 3). The findings were in line with Sunitha *et al.* (2021) who stated that in sorghum minimum temperature, morning RH, evening RH showed positive correlation with larval population.

Natural enemies Coccinellidae and Araneae were also found throughout the crop period and the peak populations were found at 1st SMW with 0.6 coccinellids/plant and 0.5 spiders/plant, respectively (Table 2 and Figure 1) when the maximum temperature, minimum temperature, morning RH, evening RH and rainfall were 29.7 !, 18.04 !, 86 per cent, 69.57 per cent and 0 mm, respectively. The number of coccinellids were high during the early crop period which might be due to more availability of pest population and may also be due to less number of chemical sprayings during the early crop period. Patil and Gaikwad (2019) reported that number of coccinellids on young crop was more than in a mature one as the pest population was more due to more sap and juice contents in the young crop.

The coccinellid population was significantly negatively correlated with maximum temperature (-0.566*), negatively correlated with minimum temperature (-0.339), morning RH (-0.301), evening RH (-0.105) and rainfall (-0.112). Spider population showed significant negative correlation with morning RH (-0.619*), negatively correlated with maximum temperature (-0.436), minimum temperature (-0.501), evening RH (-0.341) and rainfall (-0.279) (Table 3). In the maize crop ecosystem, a total of 791 foliar arthropods were collected. Lepidoptera (20.23%) which included only fall army worm (*Spodoptera frugiperda*) belonged to Noctuidae family and Hemiptera (25.92%) included Aphididae and Pentatomidae. About 160 fall army worm individuals and 201 aphid individuals were the major phytophagous pests found in the maize crop. Pentatomid bugs were only 4 in number and their role in the crop was not known. Diptera (0.75%) were the other arthropods found in the crop. The natural enemies found in the crop were Coccinellidae, Araneae, Odonata (Dragonflies, Damselflies), Neuroptera (Chrysopidae) and Hymenoptera. Majorly coccinellids and spiders were found throughout the crop period contributing 23.51 per cent and 25.28 per cent, respectively (Table 1).

The population of FAW was observed from 46th SMW to 8th SMW. At 46th SMW 0.2 larvae/plant was observed and the peak population was observed at 48th SMW and 2nd SMW with 0.42 and 0.46 larvae/plant, respectively (Table 2 and Figure 2). Because of the usage of the insecticides for the control of fall army worm from 48th SMW the population suddenly decreased to 0.2 larva/ plant at 49th SMW. The above findings were similar to Kumar *et al.* (2020) who concluded that the larval population was maximum in November month and the population gradually decreased from month of December in Tamil Nadu district.

The correlation coefficient was negatively significant with maximum temperature (-0.621*) and showed negative correlation with morning RH (-0.044) and positively correlated with minimum temperature (0.055), evening RH (0.158) and rainfall (0.374) (Table 3.). Similar results were noticed by Kumar *et al.* (2020) who concluded that relative humidity showed negative correlation with FAW larval population.

The aphid population was observed from reproductive stage till harvesting. The peak population of the aphid was observed at 4th SMW with 1.2 aphids/cm^2 (Table 2 and Figure 2) when the maximum temperature, minimum temperature, morning RH, evening RH and rainfall are 29.98 °C, 19.27 , 84.86 per cent, 56.43 per cent and 0 mm, respectively. The population of aphids increased suddenly at 4th SMW, this might be due to the reduction in the coccinellid population after 3rd SMW which predate on aphid population and thereafter the population of aphids decreased from 5th SMW which could be due to unfavourable environmental conditions during that period.

Aphid population was in significant negative correlation with morning RH (-0.675**), negatively correlated with minimum temperature (-0.238), evening RH (-0.498) and rainfall (-0.286), while maximum temperature (0.040) was positively correlated (Table 4). The similar results were given by Paul *et al.* (2020) who propounded that the abiotic factors showed non-significant negative correlation of aphids with morning RH, evening RH and sunshine hours. The results were also in accordance with Sahito *et al*. (2012) who showed that leaf aphid had significant negative correlation with relative humidity.

The coccinellid and spider population was observed from 46th SMW to 8th SWM. The coccinellid population increased as the aphid population increased at 2nd SMW. The peak population of coccinellids and spiders was noticed at 2nd SMW with average population of 0.9/plant (Table 2 and Figure 2) when the maximum temperature, minimum temperature, morning RH, evening RH and rainfall were 29.21 , 19.35 , 86 per cent, 75.14 per cent and 59.2 mm, respectively. The usage of chemicals for the control of fall army worm in the 2nd SMW might have reduced the population of coccinellids in the 3rd SMW.

The coccinellid population showed significant negative correlation with maximum temperature (-0.568*), negatively correlated with minimum temperature (-0.191) and morning RH (-0.143). Whereas positive correlation was recorded with evening RH (0.112) and rainfall (0.183) (Table 3). Chakraborty and Korat, (2014) reported that coccinellids showed negative correlation with maximum temperature, minimum temperature and evening RH.

Spider population showed negative correlation with maximum temperature (-0.202), minimum temperature (-0.302), evening RH (-0.284), rainfall (-0.107) and significantly negative correlation with morning RH (-0.625*) (Table 3). The findings of Saranya *et al*. (2019) was similar with the present findings who observed that spider population showed negative correlation with maximum temperature, minimum temperature, morning RH, rainfall and positive correlation with evening RH.

In the bengal gram crop ecosystem, a total of 348 foliar arthropods were observed. Pod borer *Helicoverpa armigera* (Hubner) was the only pest found with 60 individuals accounting for 17.24 per cent of the total foliar arthropods recorded. Coleoptera (Coccinellidae) and Araneae were the major natural enemies found with 123 individuals (35.34%) and 146 individuals (41.95%), respectively. Neuroptera (Chrysopidae), Odonata (Damselflies), Hymenoptera and Hemiptera (Pentatomidae) were the other minor groups contributing less than 5 per cent of the total foliar arthropods. About 3 individuals of pentatomid bug were also noticed in the field (Table 1).

In bengal gram *H. armigera* larval population was observed from 47th SMW to 8th SMW. The peak population was noticed at 5th SMW which coincided with the pod development with an average population of 0.3 larvae/plant (Table 2 and Fig 3) with 29.91 maximum temperature, 17.64 minimum temperature, 85 per cent morning RH, 67.14 per cent evening RH and 0 mm rainfall, respectively. Similar findings were given by Singh *et al*. (2015) who reported that higher number of *H. armigera* larval population during 44th and 52nd SMW *i.e*., 21 DAS and 80DAS which coincided with podding stage in February, when temperatures rose abruptly by 5 °C.

The larval population of pod borer was positively correlated with maximum temperature (0.209), negatively correlated with evening RH (-0.412), rainfall (-0.324) and significantly negatively correlated with minimum temperature (-0.521*) and morning RH (-0.536*) (Table 3). The above findings were in line with Singh *et al*. (2015) who opined that maximum temperature and minimum temperature showed significant positive correlation and positive correlation with rainfall and morning RH (-0.143) and Evening RH (-0.223) showed negative correlation with abiotic factors during *rabi*.

The coccinellid and spider population was observed from 47th SMW to 8th SWM. The peak population of coccinellids was noticed at 49th SMW with 0.6 coccinellids/plant and the peak population of spiders was noticed at 5th SMW with 0.75 spiders/plant (Table 2 and Figure 3).

The coccinellid population had positive correlation with maximum temperature (0.193), negative correlation with minimum temperature (-0.287), morning RH (-0.221), evening RH (-0.235) and rainfall (-0.419). Spider population showed significant negative correlation with morning RH (-0.680**), negative correlation with maximum temperature (-0.090), minimum temperature (-0.356), evening RH (-0.386) and rainfall (-0.208) (Table 3.).

The lepidopteran pest population was more in the maize crop (0.28 larvae/plant) and it was 0.25 larvae/plant in sorghum and 0.09 larvae/plant in bengal gram. The coccinellids and the spider population was also more in the maize crop with 0.31 coccinellids/plant and 0.34 spiders/plant, respectively and in the sorghum crop it was 0.26 coccinellids/plant and 0.24 spiders/plant. In the bengal gram crop, 0.20 coccinellids/plant and 0.24 spiders/plant were found (Table 2).

Kruskal-Wallis test using the mean values of foliar arthropods across three crops (Asymptotic Sig.

0.752) indicated that there was no significant difference between the mean values of foliar arthropods in three crops and the distribution of foliar arthropods was same among the three crops.

Diversity of arthropods found in three crops were analysed by the Shannon-Wiener diversity index, Simpson's index, Relative abundance and Evenness. Shannon- Weiner diversity index indicates only the diversity and abundance. Thus, these indices were used to know the diversity in addition to richness and even distribution of the arthropods.

The Shannon-Weiner diversity index (1.616) and Simpson's index (0.774) were more in the maize crop (Table 4. and Figure 4.). This may be due to more number of pests, natural enemies and other arthropods. Low diversity indices in the bengal gram crop with less pest population, natural enemies and other arthropods in the field may be due to the direct exposure of pests and natural enemies to the pesticide applications in the bengal gram crop.

The area surrounding the maize crop study area was also occupied by maize. This might have contributed for the abundance of fall army worm which occupied the major share of the total foliar arthropods after aphids. The results were in partial agreement with Witmer *et al*. (2003) who reported that more pests were seen in the area where the same crop was grown consistently.

Of the total 1664 individuals, 525 individuals were found in the sorghum crop, 791 individuals in maize crop and 348 individuals in the bengal gram crop. The highest Shannon-Weiner diversity index (1.616) and Simpson's index (0.774) were found in the maize crop. In the maize crop, Aphididae dominated the total foliar arthropods with 201 individuals and Araneae also dominated with 200 individuals. In all the three crops Noctuidae, Coccinellidae and Araneae were recorded in highest number.

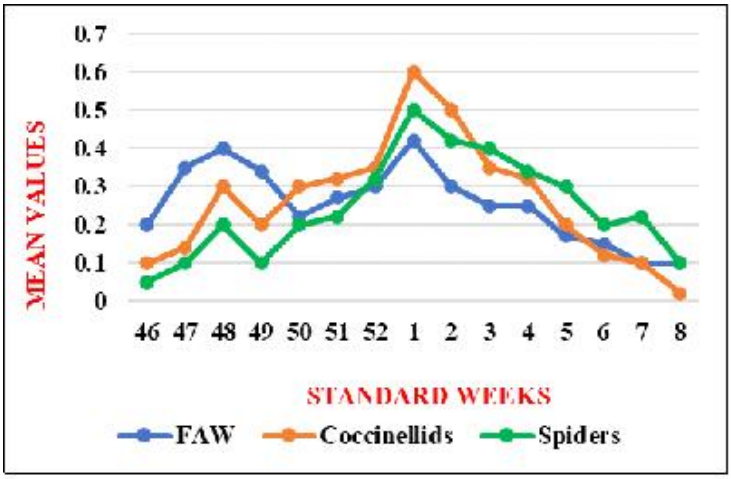

Fig 1. Major pests and natural Enemies in sorghum during November, 2021 to February, 2022

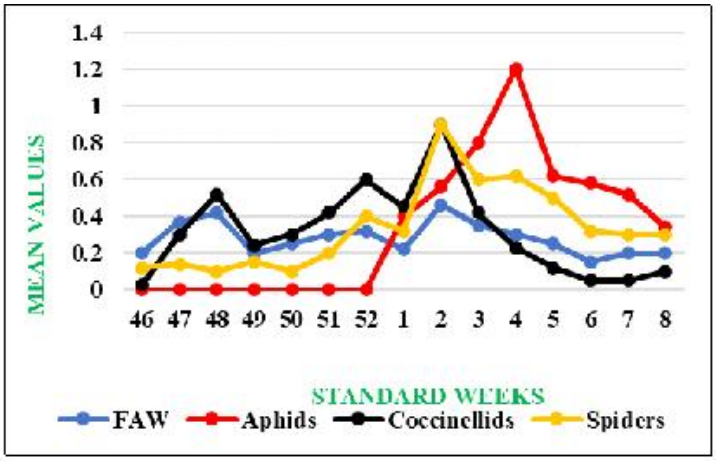

Fig 2. Major pests and natural Enemies in maize during November, 2021 to February, 2022

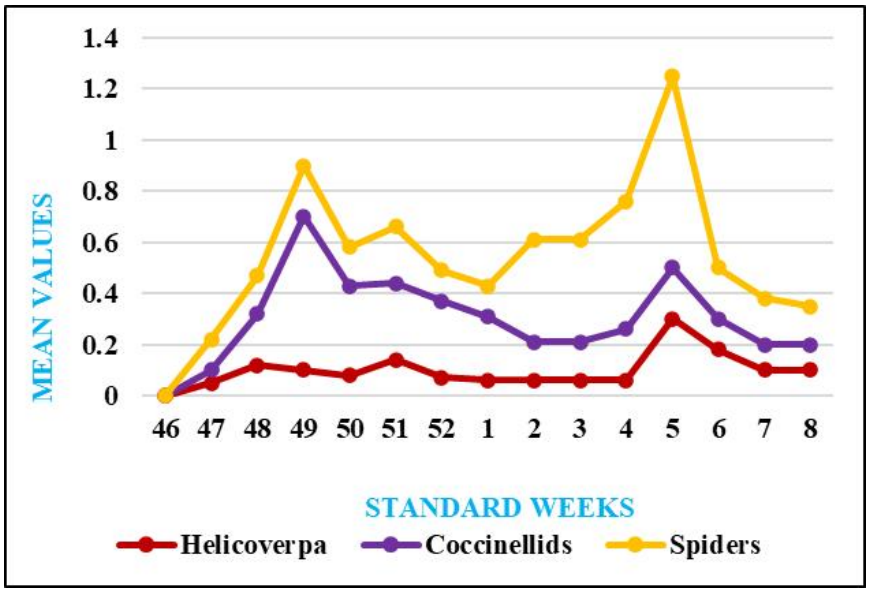

Fig 3. Major pests and natural Enemies in bengal gram during November, 2021 to February, 2022

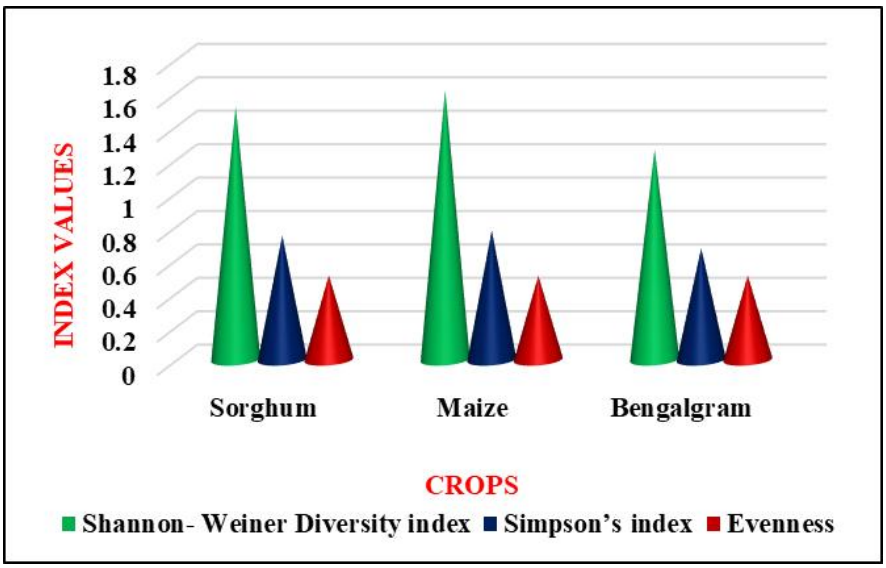

Fig 4. Diversity indices of foliar arthropods of three crops

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Table 1. Total abundance of foliar arthropods in sorghum, maize and bengal gram during November, 2021 to February, 2022

Class	Order	Family	Sorghum	RA (%)	Maize	RA (%)	Bengal gram	RA (%)	Total
Insecta	Lepidoptera	Noctuidae (Spodoptera frugiperda)	152	28.95	160	20.23	0	17.24	312
		Noctuidae (Helicoverpa armigera)	0		0		60		60
		Sub total	152		160		60		372
	Hemiptera	Aphididae (Rhophalosiphum maidis)	0	9.14	201	25.92	0	0.86	201
		Pyrrhocoreidae	48		0		0		48
		Pentatomidae	0		4		3		7
		Sub total	48		205		3		256
	Coleoptera	Coccinellidae	155	29.52	186	23.51	123	35.34	464
	Neuroptera	Chrysopidae	3	0.57	10	1.26	6	1.72	19
	Odonata	Dragonflies	7	2.09	12	2.27	0	0.57	19
		Damselflies	4		6		2		12
		Sub total	11		18		2		31
	Hymenoptera		4	0.76	6	0.76	8	2.29	18
	Diptera		8	1.52	6	0.76	0		14
Arachnida	Araneae		144	27.43	200	25.28	146	41.95	490
Total no. of individuals			525		791		348		1664

Table 2. Mean population (per plant) of major pest and natural enemies in three crops during November, 2021 to February, 2022

SMW	Sorghum			Maize				Bengal gram		
	Fall army worm	Coccinellids	Spiders	Fall army worm	Aphids	Coccinellids	Spiders	Pod borer	Coccinellids	Spiders
46	0.20	0.10	0.05	0.20	0.00	0.02	0.12	0.00	0.00	0.00
47	0.35	0.14	0.10	0.31	0.00	0.30	0.14	0.05	0.05	0.12
48	0.40	0.30	0.20	0.42	0.00	0.52	0.10	0.12	0.20	0.15
49	0.34	0.20	0.10	0.20	0.00	0.24	0.15	0.10	0.60	0.20
50	0.22	0.30	0.20	0.25	0.00	0.30	0.10	0.08	0.35	0.15
51	0.27	0.32	0.22	0.30	0.00	0.42	0.20	0.14	0.30	0.22
52	0.30	0.35	0.32	0.23	0.00	0.60	0.40	0.07	0.30	0.12
01	0.42	0.60	0.50	0.22	0.40	0.45	0.32	0.06	0.25	0.12
02	0.30	0.50	0.42	0.46	0.56	0.90	0.90	0.06	0.15	0.40
03	0.25	0.35	0.40	0.35	0.80	0.42	0.60	0.06	0.15	0.40
04	0.25	0.32	0.34	0.30	1.20	0.23	0.62	0.06	0.20	0.50
05	0.17	0.20	0.30	0.22	0.62	0.12	0.50	0.30	0.20	0.75
06	0.15	0.12	0.20	0.24	0.58	0.05	0.32	0.18	0.12	0.20
07	0.10	0.10	0.22	0.21	0.52	0.05	0.30	0.10	0.10	0.18
08	0.10	0.02	0.10	0.20	0.34	0.10	0.30	0.10	0.10	0.15
Average mean	**0.25**	**0.26**	**0.24**	**0.28**	**0.33**	**0.32**	**0.34**	**0.09**	**0.20**	**0.24**

Table 3. Correlation of weather parameters with pest and natural enemies in three crops

Crop		Maximum temperature	Minimum temperature	Morning RH	Evening RH	Rainfall
Sorghum	FAW	-0.473	0.138	0.175	0.358	0.337
	Coccinellids	-0.566*	-0.339	-0.301	-0.105	-0.112
	Spiders	-0.436	-0.501	-0.619*	-0.341	-0.279
Maize	FAW	-0.621*	0.055	-0.044	0.158	0.374
	Aphid	0.04	-0.238	-0.675**	-0.498	-0.286
	Coccinellids	-0.568*	-0.191	-0.143	0.112	0.183
	Spiders	-0.202	-0.302	-0.625*	-0.284	-0.107
Bengal gram	Pod borer	0.209	-0.521*	-0.536*	-0.412	-0.324
	Coccinellids	0.193	-0.287	-0.221	-0.235	-0.419
	Spiders	-0.09	-0.356	-0.680**	-0.386	-0.208

*Correlation is significant at p=5% level

**Correlation is significant at p=1% level

Table 4. Diversity indices of foliar arthropods of three crops

Diversity indices	Crop		
	Sorghum	Maize	Bengal gram
Shannon-Weiner diversity index	1.518	1.616	1.262
Simpson's index	0.744	0.774	0.668
Evenness	0.506	0.503	0.505

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