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Predatory Coccinellids or Ladybird Beetles (Coleoptera: Coccinellidae) of Bt and Non-Bt Cotton Fields

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A B S T R A C T

The study was carried out to investigate 'Seasonal diversity and abundance of Predatory coccinellids or ladybird beetles of Bt and non-Bt cotton fields of Nalgonda District, Telangana State, India'. Sample was collected by sweep net and hand-picking on Bt and non-Bt cotton fields. During study period (2018-2019 and 2019-2020) we observed three species of coccinellids in Bt cotton field, four species of coccinellids in non-Bt cotton field during 2018-2019 cotton cropping season. During 2019-2020 cotton cropping season, four species in Bt cotton field, four species in non-Bt cotton field were observed. The species *Brumoides suturalis* (Three-stripped lady birdbeetle), *Cheilomenes sexmaculata* (Six-spotted zigzag ladybird beetle), *Coccinella transverslis* (Transverse ladybird beetle) were recorded in both Bt and non-Bt cotton fields during 2018-2019 and 2019-2020 cotton cropping seasons. The species *Propylea dessecta* (Spotless ladybird beetle) was observed in non-Bt cotton fields only during 2018-2019 and 2019-2020 cotton cropping seasons. The species *Coccinella octomaculata* (Eight-spotted lady bird beetle) was observed in Bt cotton field only during 2019-2020 cotton cropping season. In September there were a large number of coccinellids in Bt and non-Bt cotton fields. However, coccinellids were observed from August to December during 2018-2019 cotton season and from August to January during 2019-2020 cotton season. Various ecological indexes were measured.

***Key words*:** Predatory coccinellids, Bt cotton, Non-Bt cotton, Seasonal diversity, Abundance

Coccinellids or ladybird beetles belonging to the family Coccinellidae, order Coleoptera of phylum Arthropoda. Majority of ladybird beetles are important group of biocontrol agents as they prey upon numerous phytophagous insect pests viz. aphids, mealy bugs, scale insects, whiteflies, thrips, and many more [1-4]. Biological control is a reliable and long-lasting solution to check the harmful insect of cotton and technique which is mature and nature friendly [5-6]. Predator control the prey population by eating and parasitizing them [7-8]. Predators like as *Coccinella* spp, *Chrysoperla* spp [9], *Cheilomenes sexmaculata*, *Geocoris* spp., and parasitoid *Apanteles* spp., *Trichogramma* spp., minimize the number of various cotton insect pests like as *S. exigua*, *H. armigera*, *Bemisia tabaci* and *Aphis* spp. [10-13]. Globally, more than 6000 ladybird beetle species are known; of which, 261 predaceous species are catalogued from India [14-15]. The predatory behavior of the Coccinellidae varies within the species as they have a positive impact by feeding on the insect pests and intraguild cannibalism included in their negative feeding behavior [16]. Most of the species are economically important predators, while some are also plant or being mycetophagous [17]. So, the predatory behavior of the Coccinellids includes different transitions throughout different trophic levels which covers primary carnivores to herbivorous insect. Similarly, the female Coccinellids are being proved stronger predators than the male beetles [18]. Many adult coccinellids are oval or convex, dome shaped, often shiny with short legs and antennae. Larvae are elongate, somewhat flattened and covered with minute tubercles or spines [19]. In size they range from the minutest (10.25 mm) to the largest (cerambycids 150 mm long) [20-21].

Indiscriminate use of synthetic pesticides in cotton crop to control the insect pests resulted in the pollution of environment in that way threatening the target and non- target organisms. Hence, instead of the pesticides, today biological agents are applied for the control of the insect pest in cotton cropping fields. Among these, Coccinellid beetles (Coleoptera) have great importance as biological controlling agent. The objective of this study was to investigate 'Seasonal diversity and abundance of Predatory coccinellids or ladybird beetles of Bt and non-Bt cotton fields of Nalgonda District, Telangana State, India'.

MATERIALS AND METHODS

The study was carried out at farmers' fields of Bt and non-Bt cotton fields in Palem village, Nakrekal Mandal,

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Nalgonda District, Telangana state, India. It is located around 17°13' 49''N and 79°28' 04'' E. This study was conducted during 2019-2020 and 2020-2021 cotton cropping seasons. For ladybird beetle observation five plots each having area 5m × 5m was selected in both Bt and non-Bt cotton fields. Sample was collected in the morning because insects become active when temperature is about 25°C to 30°C [22]. Sample was collected by sweep net and hand-picking on Bt and non-Bt cotton fields [23]. Whole plants were observed visually for the number of immature and mature population of insect pests and predators. The complete plant was observed from top to bottom and both sides (Upper and lower side) of the plant leaves. The insect pest population was carefully counted with help of 5x magnifier lens. Each preserved in 75% alcohol for identification. Predatory ladybird beetle species were identified with the help of Guide on cotton pests and predators [24] by RARS, PJTSAU Warangal and Literature.

We calculated Diversity indices of insect pest species i.e., Species diversity (Shannon-Wiener Index), Species richness (Margalefs Index) and Species evenness (Pielou Evenness Index).

1. Species diversity [Shannon-Wiener index (H)]

$$H = -\sum P_i \log P_i$$

Where;
H = Shannon-Weiner index,
∑ = Sum,
Pi = ni /N,
ni = Number of individuals of each species in the sample,
N = Total number of individuals of all species in the sample.

2. Species evenness [Pielou Evenness Index (J)]

$$J = H/H_{max}$$

Where;
J = Evenness index,
H= Shannon -Weiner index,
$H_{max} = \log S$,
S = number of species.

3. Species richness [Margalef's Index(D)]

$$D = \frac{S-1}{\log N}$$

Where;
D= Species richness,
S= total number of species,
N= total number of individuals

RESULTS AND DISCUSSION

During study period (2018-2019 and 2019-2020) we observed three species of coccinellids in Bt cotton field, four species of coccinellids in non-Bt cotton field during 2018-2019 cotton cropping season. During 2019-2020 cotton cropping season, four species in Bt cotton field, four species in non-Bt cotton field were observed (Table 1-2).

Table 1 List of coccinellids or ladybird beetles in Bt and non-Bt cotton fields 2018-2019

Order	Family	Species		Common name
		Bt cotton	Non-Bt cotton	
Coleoptera	Coccinellidae	*Brumoides suturalis* (Fabricius)	*Brumoides suturalis* (Fabricius)	Three-stripped lady bird beetle
		Cheilomenes sexmaculata (Fabricius)	*Cheilomenes sexmaculata* (Fabricius)	Six-spotted zigzag ladybird beetle
		Coccinella transverslis (Fabricius)	*Coccinella transverslis* (Fabricius)	Transverse ladybird beetle
		-	*Propylea dessecta* (Mulsant)	Spotless ladybird beetle

Table 2 List of coccinellids or ladybird beetles in Bt and non-Bt cotton fields 2019-2020

Orde	Family	Species		Common Name
		Bt cotton	Non-Bt cotton	
Coleoptera	Coccinellidae	*Brumoides suturalis* (Fabricius)	*Brumoides suturalis* (Fabricius)	Three-stripped ladybird beetle
		Cheilomenes sexmaculata (Fabricius)	*Cheilomenes sexmaculata* (Fabricius)	Six-spotted zigzag ladybird beetle
		Coccinella transversalis (Fabricius)	*Coccinella transversalis* (Fabricius)	Transverse ladybird beetle
		Coccinella octomaculata (Fabricius)	-	Eight-spotted ladybird beetle
		-	*Propylea dessecta* (Mulsant)	Spotless ladybird beetle

The species *Brumoides suturalis* (Three-stripped lady bird beetle) (Fig 1), *Cheilomenes sexmaculata* (Six-spotted zigzag ladybird beetle) (Fig 2), *Coccinella transverslis* (Transverse ladybird beetle) (Fig 3) were recorded in both Bt and non-Bt cotton fields during 2018-2019 and 2019-2020 cotton cropping seasons. The species *Coccinella octomaculata* (Eight-spotted lady bird beetle) (Fig 4) was observed in Bt cotton field only during 2019-2020 cotton cropping season. The species *Propylea dessecta* (Spotless ladybird beetle) (Fig 5) was observed in non-Bt cotton fields only during 2018-2019 and 2019-2020 cotton cropping seasons.

Seasonal diversity and abundance

Three-stripped ladybird beetle was noticed from 36th SMW (Standard Meteorological Week) to 39th SMW (September-2019) with 3.2 ± 0.374 in Bt, 3.6 ± 0.678 in non-Bt cotton fields during 2018-2019 cotton cropping season. during 2019-2020 cotton cropping season, the incidence of Three-stripped ladybird beetle was noticed from 36th SMW (September-2019) to 44th SMW (October-2019) in both Bt and non-Bt cotton fields and peak (5.4 ± 0.509 in Bt, 6.2 ± 1.067 in non-Bt) was noticed from 36th SMW to 40th SMW ((September) (Table 3).

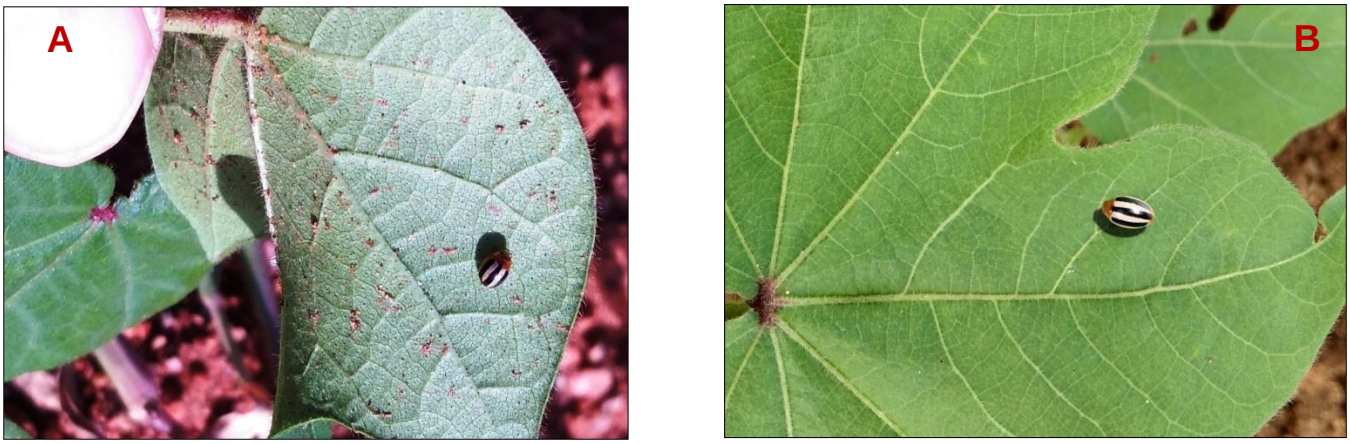

Fig 1 *Brumoides suturalis* (Fabricius) (Three-stripped ladybird beetle) in Bt cotton (A) and non-Bt cotton (B) fields

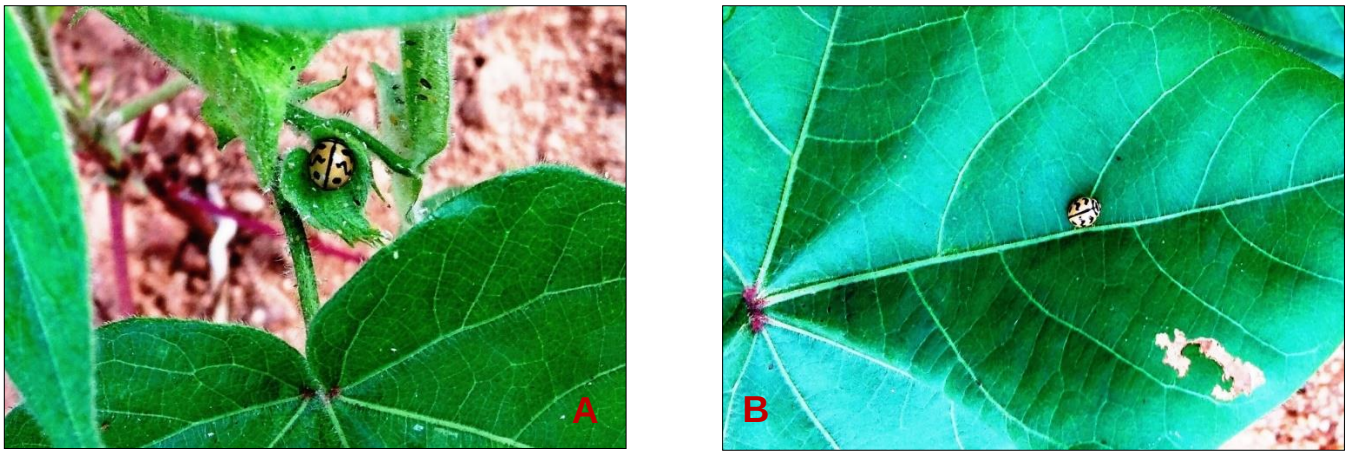

Fig 2 *Cheilomenes sexmaculata* (Fabricius) (Six-spotted zigzag ladybird beetle) in Bt cotton (A) and non-Bt cotton (B) fields

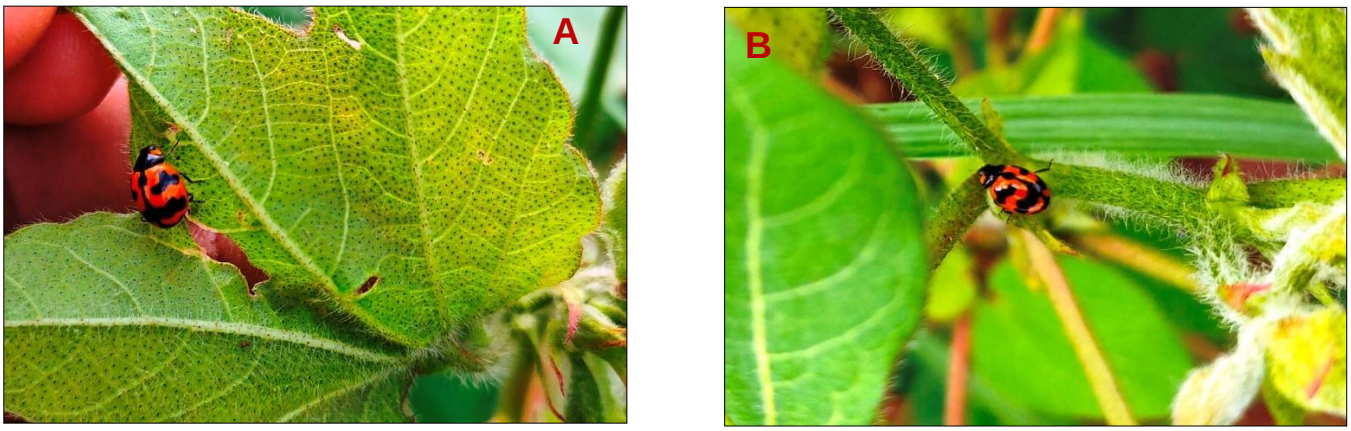

Fig 3 *Coccinella transversalis* (Fabricius) (Transverse ladybird beetle) in Bt cotton (A) and non-Bt cotton (B) fields

Fig 4 *Coccinella octomaculata* (Fabricius) (Eight-spotted ladybird beetle) in Bt cotton field

Fig 5 *Propylea dessecta* (Mulsant) (Spotless ladybird beetle) in non-Bt cotton field

Table 3 Seasonal diversity and mean abundance of three-stripped ladybird beetle (*Brumoides suturalis*) in Bt cotton and non-Bt cotton fields during 2018-2020

Month of observation	Mean ± SE of *Brumoides suturalis*			
	2018-2019		2019-2020	
	Bt cotton	Non-Bt cotton	Bt cotton	Non-Bt cotton
July	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
August	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
September	3.2 ± 0.374	3.6 ± 0.678	5.4 ± 0.509	6.2 ± 1.067
October	0.00 ± 0.00	0.00 ± 0.00	4.2 ± 0.583	5.2 ± 0.583
November	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
December	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
January	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Six-spotted zigzag ladybird beetle incidence was observed from 32nd SMW (August-2018) to 52nd SMW (December-2018) in both Bt and non-Bt cotton fields and the peak (7 ± 0.447 in Bt, 7.8 ± 1.2 in non-Bt) was observed from 45th SMW to 48th SMW (November) during 2018-2019 cotton season. during 2019-2020 cotton season, Six-spotted zigzag ladybird beetle incidence was observed from 32nd SMW (August-2019) to 52nd SMW (December-2019) in both Bt and non-Bt cotton fields and the peak with 7.6 ± 1.077 from 36th SMW 40th SMW (September) in Bt, 9 ± 0.707 from 49th SMW to 52nd SMW (December) in non-Bt cotton was noticed (Table 4).

Table 4 Seasonal diversity and Mean abundance of in Bt cotton and non-Bt cotton fields during 2018-2020

Month of observation	Mean ± SE of *Cheilomenes sexmaculata*			
	2018-2019		2019-2020	
	Bt cotton	Non-Bt cotton	Bt cotton	Non-Bt cotton
July	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
August	7 ± 0.707	6.6 ± 0.812	6.2 ± 0.860	2.8 ± 0.374
September	5 ± 0.447	5.6 ± 0.509	7.6 ± 1.077	4 ± 0.707
October	4.8 ± 0.374	5.6 ± 0.678	5.4 ± 0.509	6.2 ± 1.067
November	7 ± 0.447	7.8 ± 1.2	5 ± 0.707	7.2 ± 0.583
December	5.4 ± 0.812	6.6 ± 0.509	7 ± 1.581	9 ± 0.707
January	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Transverse ladybird beetle was initiated from 32nd SMW (August-2018) to 52nd SMW (December-2018) in both Bt and non-Bt cotton fields and the peak (3.8 ± 0.374 in Bt, 4.6 ± 0.509 in non-Bt) was observed from 45th SMW to 48th SMW (November) during 2018-2019 cotton season and during 2019-2020 cotton season, Transverse ladybird beetle was initiated from 32nd SMW (August-2019) to till end of the season in both Bt and non-Bt cotton fields and the peak (5 ± 0.707 in Bt, 5.6 ± 0.509 in non-Bt) was observed from 49th SMW to 52nd SMW (December) (Table 5).

Table 5 Seasonal diversity and mean abundance of Transverse ladybird beetle (*Coccinella transversalis*) in Bt cotton and non-Bt cotton fields during 2018-2020

Month of observation	Mean ± SE of *Coccinella transversalis*			
	2018-2019		2019-2020	
	Bt cotton	Non-Bt cotton	Bt cotton	Non-Bt cotton
July	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
August	1.8 ± 0.583	2.2 ± 0.734	2.2 ± 0.663	2 ± 0.707
September	2 ± 0.316	2.6 ± 0.4	3.8 ± 0.663	4.6 ± 0.509
October	1.8 ± 0.374	2.2 ± 0.583	1.4 ± 0.509	2 ± 0.316
November	3.8 ± 0.374	4.6 ± 0.509	3 ± 0.316	4.2 ± 0.583
December	1 ± 0.316	1.4 ± 0.509	5 ± 0.707	5.6 ± 0.509
January	0.00 ± 0.00	0.00 ± 0.00	4.2 ± 0.860	5.4 ± 0.509

Table 6 Seasonal diversity and mean abundance of Eight-spotted ladybird beetle (*Coccinella octomaculata*) in Bt cotton and non-Bt cotton fields during 2018-2020

Month of observation	Mean ± SE of *Coccinella octomaculata*			
	2018-2019		2019-2020	
	Bt cotton	Non-Bt cotton	Bt cotton	Non-Bt cotton
July	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
August	0.00 ± 0.00	0.00 ± 0.00	8.2 ± 0.860	0.00 ± 0.00
September	0.00 ± 0.00	0.00 ± 0.00	6.4 ± 0.927	0.00 ± 0.00
October	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
November	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
December	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
January	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Eight-spotted ladybird beetle incidence was recorded from 32nd SMW (August-2019) to 40th SMW (September-2019) on Bt cotton only and peak (8.2 ± 0.860) was recorded from 32nd SMW to 35th SMW (August) during 2019-2020 cotton cropping season only (Table 6).

Spotless ladybird beetle was observed 36th SMW (September-2018) to 44th SMW (October-2018) on non-Bt cotton field only and the peak (9 ± 0.316) was recorded from 40th SMW to 44th SMW (October) during 2018-2019 cotton cropping season and during 2019-2020 cotton cropping season, Spotless ladybird beetle was observed from 36th SMW (September-2019) to 44th SMW (October-2019) on non-Bt cotton field was observed and the peak (7 ± 0.707) was noticed from 41st SMW to 44th SMW (October) (Table 7).

Table 7 Seasonal diversity and mean abundance of spotless ladybird beetle (*Propylea dessecta*) in Bt cotton and non-Bt cotton fields during 2018-2020

Month of observation	Mean ± SE of *Propylea dessecta*			
	2018-2019		2019-2020	
	Bt cotton	Non-Bt cotton	Bt cotton	Non-Bt cotton
July	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
August	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
September	0.00 ± 0.00	7.4 ± 0.4	0.00 ± 0.00	5.2 ± 0.860
October	0.00 ± 0.00	9 ± 0.316	0.00 ± 0.00	7 ± 0.707
November	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
December	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
January	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00

Ecological indexes

Three characteristics were calculated for analysis of community structure of Coleopterans (Table 8-9). i.e., 1. Species diversity (Shannon –Wiener Index), 2. Species evenness (Pielou Evenness Index) and 3. Species richness (Margalef's Index).

Table 8 Ecological Indexes for Coleoptera in Bt & Non-Bt cotton fields during 2018-2019 cotton cropping season

	H-Values		Evenness		Richness	
	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt
July	-	-	-	-	-	-
August	0.53	0.53	0.764	0.764	0.455	0.455
September	1.03	1.335	0.937	0.963	0.869	1.001
October	0.598	0.956	0.863	0.87	0.514	0.706
November	0.655	0.666	0.946	0.961	0.417	0.39
December	0.451	0.377	0.65	0.544	0.558	0.481
January	-	-	-	-	-	-

Table 9 Ecological Indexes for Coleoptera in Bt & Non-Bt cotton fields during 2019-2020 cotton cropping season

	H-Values		Evenness		Richness	
	Bt	Non-Bt	Bt	Non-Bt	Bt	Non-Bt
July	-	-	-	-	-	-
August	0.974	0.673	0.887	0.971	0.721	0.621
September	1.354	1.376	0.977	0.993	0.957	1.001
October	0.943	1.305	0.859	0.942	0.869	1.001
November	0.662	0.655	0.954	0.946	0.481	0.417
December	0.679	0.673	0.98	0.971	0.402	0.369
January	0	0	-	-	0	0

Species diversity (Shannon-Weiner Index) values (H-Values) of Coleoptera ranged between 0.451 and 1.03 in Bt, 0.377 to 1.335 in non-Bt were calculated during 2018-2019 cotton cropping season and during 2019-2020 cotton cropping season, ranged between 0 and 1.354 in Bt, 0 to 1.376 in non-Bt were calculated. Over all H-Values of coleoptera ranged between 0 and 1.354 in Bt, 0 to 1.376 in non-Bt were calculated during 2018-2020 cotton seasons.

Species richness (Margalef´s Index) values (D-Values) of Coleoptera ranged between 0.417 and 0.869 in Bt, 0.39 to 1.001 in non-Bt were calculated during 2018-2019 cotton cropping season and during 2019-2020 cotton cropping season, ranged between 0 and 0.957 in Bt, 0 to 1.001 in non-Bt were calculated. Over all D-Values of coleoptera ranged between 0 and 0.957 in Bt, 0 to 1.001 in non-Bt were calculated during 2018-2020 cotton seasons.

Species evenness (Pielou Evenness Index) values (J-Values) of Coleoptera ranged between 0.65 and 0.946 in Bt, 0.544 to 0.963 in non-Bt were calculated during 2018-2019 cotton cropping season and during 2019-2020 cotton cropping season, ranged between 0.859 and 0.98 in Bt, 0.942 to 0.993 in non-Bt were calculated. Over all J-Values of coleoptera ranged between 0.65 and 0.98 in Bt, 0.544 to 0.993 in non-Bt were calculated during 2018-2020 cotton seasons.

The H-values of Coleoptera under 1.0 indicate that the habitat structure not suitable. In case H-values above 1.0 indicate that Bt and non-Bt cotton fields are stable for them. In case H-values are between 1.5 and 2.0 indicate that the structure of habitat is stable and suitable balanced for them. Evenness values are in Bt and non-Bt cotton are closer to 1.0 indicate that the individuals are distributed equally. Richness values are in Bt and non-Bt cotton are under 0.5 it indicates that the

individuals are low, closer to 1.0 indicate that the individuals are more.

The incidence of ladybird beetles was initiated from 32nd SMW (August-2018) to 52nd SMW (December-2018) in both Bt and non-Bt cotton fields and the peak was observed from August to November in both Bt and non-Bt cotton fields during 2018-2019 cotton season and during 2019-2020 cotton season the incidence of ladybird beetle was initiated from August to till end of the season in both Bt and non-Bt cotton fields and the peak was observed from August to December in both Bt and non-Bt cotton fields. The present results partially corroborate with those of Sharma *et al*. [25] who reported that the lady bird beetle predators of cotton pests were more active during August to October. The predatory Coccinellids appeared more or less same in Bt and Non Bt-cotton reported by [26-27]. The present investigation not agreement with Hegde *et al*. [28] who reported no difference in the population of coccinellidae between Bt and non Bt-cotton. Wadhawa and Gill [29] reported that the population of Coccinelled beetles were similar between the Bt and non Bt-cotton. The present findings were contrary to the Hagerty *et al*. [30] who reported that the activity of natural enemies (Coccinellids) was consistently higher in Bollgard and Bollgard-II, as compared to non Bt-cotton. The population density of natural enemies was significantly lower in transgenic cotton than in normal cotton [31-32], the present findings similar that of Head *et al*. [33] reported that the population of lady beetles while the number of *Helicoverpa* sp were significantly lower in the Bt cotton.

CONCLUSION

The study was carried out to investigate the seasonal diversity and abundance of coccinellids or ladybird beetles in Bt and non Bt-cotton during 2018-2019 and 2019-2020 cotton cropping seasons. In September there were a large number of coccinellids in Bt and non-Bt cotton fields. However, coccinellids were observed from August to December during 2018-2019 cotton season and from August to January during 2019-2020 cotton season. Bt-cotton (Transgenic cotton with CryIAC) genes to produce endotoxin has single mode of action against pest of Lepidopteran to be effective against *Helicoverpa armigera*, *Pectinophora gassypiella* and *Spodoptera litura* (bollworms) the introduced genes did not show any impact on sucking pests and also the activity of predatory coccinellids.

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