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Comparative abundance and diversity of predatory coccinellids in Bhendi, brinjal, and cowpea in Coimbatore and Tiruppur districts in Tamil Nadu, India

MP Sruthi, S Raguraman, N Chitra and RK Balaji

Abstract
Field surveys were carried out in six village blocks three in Coimbatore and three in Tiruppur districts of Tamil Nadu *viz*., Karamadai, Kinathukadavu, Pollachi South, Udumalaipettai, Pongalur, and Tiruppur. The diversity study was conducted across two seasons in three vegetable crops: bhendi, brinjal, and cowpea, at the vegetative stage, reproductive stage, and harvesting stage. The roving survey was covered in a plot area of 10×5 m^2 and was conducted in five randomly selected plants from five different plots. The collected data was combined and the Species percent, relative abundance, diversity indices such as Shannon-Weiner Index, Simpson's Index, Margalef Index, and Species Evenness Index were calculated and represented graphically. *Cheilomenes sexmaculata* (39%) was the most abundant species in every location because of its diverse prey preferences, followed by *Coccinella transversalis* (22%), *Illeis indica* (21%), *Propylea* spp. (5%), and *Brumoides suturalis* (5%). *C. sexmaculata* was found to act as an aphidophagous and coccidophagous predator. The surrounding vegetation was found to influence the abundance of coccinellids. From this study, we analysed that diversity indices fluctuated according to the season, crop stages, and locations. In the second season, which extends from May to August 2021, we found a greater number of coccinellids than in the first (January-April, 2021). This study suggests that coccinellids are the reliable biological source to contain the soft bodies insects in vegetables such as bhendi, brinjal and cowpea.

Keywords: Abundance, coccinellids, diversity indices, season, vegetable crops

Introduction
Vegetables are having a key role in maintaining a healthy diet since they are rich in essential nutrients (Slavin *et al.*, 2012) [30]. Bhendi, brinjal, and cowpea are some of the vegetables grown in large quantities. India has a total production of 191769.11 MT vegetables in an area of 10352.88 ha (Horticultural Statistics, 2019-2020) [11]. Bhendi has a global area of 1148.0 million hectares and a production of 7896.3 million tonnes. India accounts for roughly 73 percent of the world's bhendi production. Bhendi is grown on 519 hectares in India, with a production of 6371 MT. With a production of 12777 MT and an area of 736 hectares, China is the leading producer of brinjal, followed by India. The majority of cowpeas are cultivated in Africa, mostly in Nigeria, which accounts for 66% of global production. According to a 2019 estimate, cowpeas are grown on 4303005 hectares of land in Nigeria, produce 3576361 tonnes, and are consumed by 200 million people daily (FAOSTAT 2019) [12].
Vegetable crops are susceptible to biotic stress from soft-bodied insects such as aphids, mealy bugs, and scales, and so harbor plenty of natural enemies. The coccinellids are one of several natural enemies that play a vital role in biological control (Mayadunnage *et al.*, 2007) [17]. Coccinellids, also known as ladybugs or ladybird beetles, are predatory beetles belongs to the Coleoptera order and family Coccinellidae. They have shining elytra with a variety of punctuations. The majority of coccinellids are polyphagous, although some of them are potential predators. Aphidophagous, which includes *Scymnus nubilis*, *Micraspis discolor*, *Menochilus sexmaculatus*, *Propylea dissecta and Coccinella transversalis*, *etc* and Coccidophagous *viz*., *Scymnus nubilis*, *Anegleis cardoni*, *Brumoides suturalis*, and *Hyperaspis maindroni* Coccinellids interact with a wide range of habitats, and hence it is amenable to conserve them. It is an effective predator since both adults and larval stages feed voraciously on soft-bodied insects. There are around 6000 species in the Coccinellidae family worldwide (Seago *et al*., 2011) [27].

Almost 400 Species were reported in India (Poorani, 2002) [22].

In this study, we investigated the abundance and diversity of predatory coccinellids in vegetable crops like bhendi, brinjal, and cowpea in different village blocks of Coimbatore and Tiruppur Districts. By analysing the obtained data, crop-wise and location-wise comparison studies are documented here.

Materials and methods

Field survey

Field surveys and diversity of predatory coccinellids were carried out in six different village blocks: three in Coimbatore District *viz.*, Karamadai, Kinathukadavu, Pollachi South, and three in Tiruppur District *viz.*, Udumalaipettai, Pongalur and Tiruppur of Tamil Nadu (Fig.1a, and Fig.1b) in three vegetable crops, which included bhendi, brinjal, and cowpea. The roving survey was undertaken once in every 30 days from January 2021 to August 2021, which includes two crop durations. For each crop, a crop duration of 120 days was taken, and a survey was conducted at each stage of the crop. First crop duration indicated as season I (January – April, 2021) and second crop as season II (May – August, 2021). For each crop, first 30 days were considered as vegetative stage, next 30 days considered as flowering and fruit setting for bhendi, flower initiation to first picking for brinjal and flowering stage for cowpea. The last 60 days were classified as podding and harvesting, alternate days from picking and harvesting stage for cowpea, bhendi, and brinjal, respectively, for each crop duration.

Five randomly selected plants were observed in a plot size of 10×5 m^2 and repeated in five plots in the field. Observations of each plant were taken by selecting three leaves from the top, middle, and bottom portions of the plants and the number of species, total number of individual species per plant and sum of species and individual species were calculated for each plot, crop and location. At last, the total numbers for each crop and location were pooled. The samples were handpicked in vials and polythene covers and killed by using ethyl acetate, then they were card mounted and labelled for identification. Live-grubs collected were reared and observed until adult emergence and then they were identified up to genus and species level with the type specimens available at Insect Museum, TNAU, Coimbatore, India according to the keys (Janakiraman *et al*., 2019) [24]. Species percent, relative abundance and diversity indices were calculated for each crop and each location and compared.

Fig 1a; Geographical location of the surveyed village blocks in Coimbatore Distict of Tamil Nadu

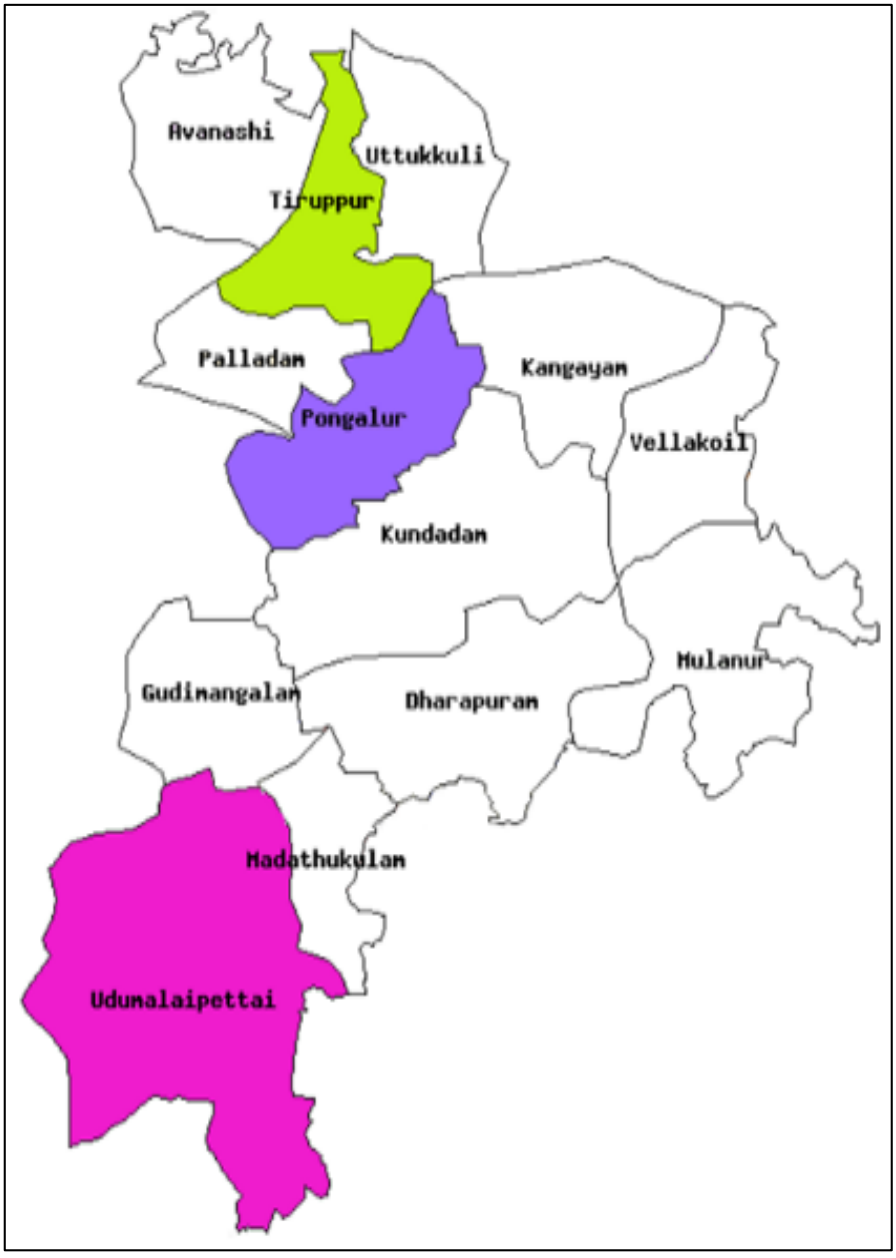


Fig 1b: Geographical location of the surveyed village blocks in Tiruppur Distict of Tamil Nadu

Species diversity assessment

Shannon-Wiener biodiversity index (H)

To study the proportion of each species within the local community, species diversity was computed based on Shannon-Wiener formula/ Shannon index/ Shannon-Wiener index (Humphries *et al*., 1996) [13].

$$H = -\sum_{i=0}^{S} Pi \, log_e \, Pi$$

H- Shannon-Weiner biodiversity index
Pi- Relative abundance of each species in the sample
S- Number of species in the community
$log_e \, Pi$- Natural log of Pi

Species evenness (J)

To know the measure of how similar the abundance of different species, species evenness was calculated to estimate the equitability component of diversity (Pielou, 1969) [20].

$$J = \frac{H}{log_e S}$$

H- Shannon-Wiener biodiversity index
S- Number of species in the community.

Species richness (Ma) (Pielou, 1969) [20]

To understand how a population's diversity is distributed or organised within a species.

$$Ma = S - \frac{1}{log_e} N$$

S- Total number of species sampled
N- Total number of individuals within each species.

Simpson's diversity index (Simpson, 1949) [29]

This takes into account both the species richness and the amount of each species in the local community (percentage). There are three alternative approaches to define the index.

Simpson's index (D)

Simpson's index was established to calculate the probability that two randomly selected individuals in the community belong to the same species.

$$D = \sum P_i^2$$

where, Pi is the proportion of each species in the sample (relative abundance)

Relative abundance (R) (Kedar *et al*., 2011) [15]
On the basis of population density of different coccinellids, their relative abundance was determined using the formula

$$R = \frac{a}{n} \times 100$$

where 'a' is the total number of individuals of a particular species 'n' is the total number of individuals in all species.

Results

Occurrence of coccinellids

The results of a survey conducted from January to August 2021 have been compiled and the abundance of coccinellids in percent was depicted in fig.2. It shows clearly that the *C. sexmaculata* (39%) was in greater abundance than the other species and followed by *C. transversalis* (22%), and *I. indica* (21%).

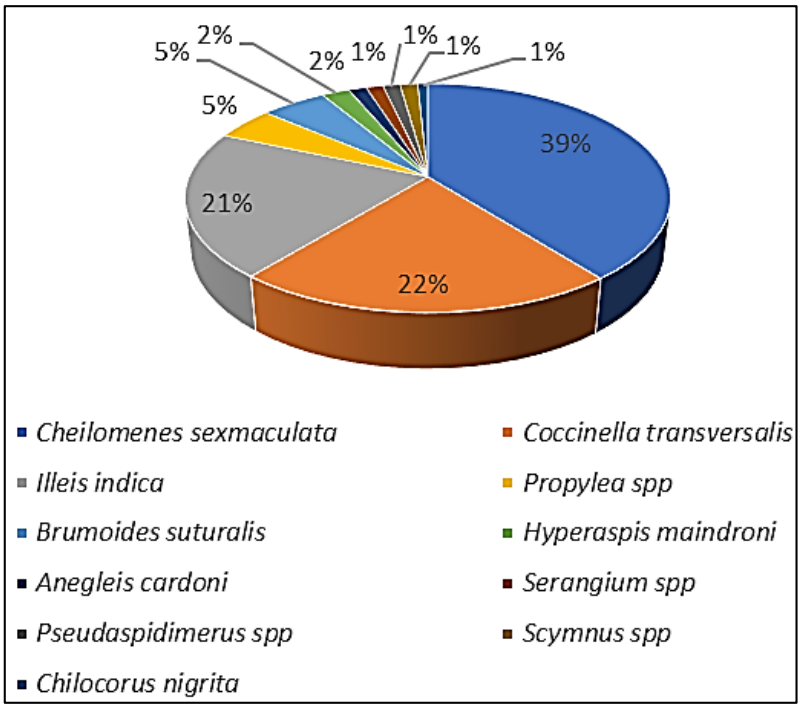


Fig 2: Percentage of total number of individuals coccinellid species collected from January-August 2021 from bhendi, brinjal and cow pea in two seasons

Relative abundance

The relative abundance (%) of coccinellid species in bhendi, brinjal, and cowpea in different village blocks for Season I (January-April 2021) and Season II (May-August, 2021) are presented in Table 1. For the Season I, *C. sexmaculata* was the most abundant species in all the 6 blocks surveyed, in which highest abundance was observed in Pongalur block (46.01%), followed by Tiruppur (40.35%), Pollachi South (39.73%), and Karamadai (36.1%). *Propylea* spp. was the most abundant in the Pongalur block (47.83%) compared to other locations. *C. nigrita* was the least abundant in every location which was 1.41% in Pongalur block. For the Season II, *C. sexmaculata* is abundant in Tiruppur (46.06%) followed by Pongalur (45.1%) and Karamadai (40.44%) blocks. *C. nigrita* was least abundant in the second season too. In both the seasons, *C. nigrita* was absent in the Udumalaipettai block.

Biodiversity indices

Diversity of coccinellids were calculated for bhendi, brinjal, and cowpea, which were labelled for vegetative stage (VS), reproductive stage (RS), and harvesting stage (HS) over two crop seasons. The diversity indices *viz.*, Shannon-Wiener Index (H), Simpson's diversity index, species richness (Ma), and species evenness (J) were represented in the graph, which was generated using an online freeware biodiversity calculator. While analysing the data in the case of bhendi, and brinjal Margalef Index was higher at the harvesting stage in almost every block but in the case of cowpea, it was observed to be high at the reproductive stage. At the vegetative stage compared to other indices Species evenness was high. Simpson's index is high at the harvesting stage in each crop in almost every location. Shannon Index was observed to be high at both harvesting and reproductive stages of all crops in each location.

Discussion

In this study, the relative abundance of *C. sexmaculata* is greater in each location compared to other species, followed by *C. transversalis, I. indica, Propylea* spp., and *B. suturalis. H. maindroni, A.cardoni, Serangium* spp., *Pseudaspidimerus* spp., *Scymnus* spp., and *C. nigrita* are less common in the vegetable ecosystem. *C. sexmaculata* were observed more in Pongalur block and less abundant in Udumalaipettai block. Since *C. sexmaculata* has a wide variety of prey preferences (Vinothkumar *et al*., 2013) [31] it was more prevalent in each location and each crop. In this study, we noticed the occurrence of aphid species like *Aphis craccivora, A. gossypii*, as well as mealybugs like *Phenococcus Solenopsis* and *Ferrisia virgata* abundant enough to support the survival of predatory species. Similar observations were also made by Rekha *et al*. (2009) [25] and Babasaheb *et al*. (2010) [3]. The

presence of higher numbers of coccinellids can be attributed to the presence of weeds as well which support the adult's microhabitat and food source from flowers as well. According to the study of (Vinothkumar *et al*., 2013) [31], weeds will boost the proliferation and enhance the abundance of coccinellids by serving as an alternate host.

I. indica was noticed to be prolific feeders of powdery mildew (Patil *et al*., 2019) [19]. Most of the brinjal and bhendi crops were affected by powdery mildew in its harvesting stage, hence *I. indica* was abundant. *P. solenopsis*, which is preferred by *B. suturalis*, was found to infest bhendi in the harvesting stage and hence it was more prevalent in mealy bug-affected areas. Coccinellid abundance was less at the vegetative stage compared to other stages and they are more abundant in the second season of the crop (May-August 2021). This is in accordance with the study by Honek *et al*. (2015) [10]. At the vegetative stage, only a narrow range of prey species were observed which may be the reason behind that the unavailability of plenty of predatory coccinellids at this stage. In the second season (May-August 2021) good number of weeds and a wide range of prey species were observed in almost every location so the number of natural enemies were high in this season compared to the previous season. Diversity indices were found fluctuating according to the season, crop stages, and locations.

The most commonly used diversity indices are Shannon-Wiener index and Simpson index (Buzas *et al.,* 1996, Gorelick, 2006) [6, 8]. However, richness and evenness are the components of diversity (Pielou, 1975 Ricotta, 2003, Liu *et al*., 2008) [21, 26, 16]. Simpson index is used to assess the dominance but fails to provide an idea about species richness. Shannon-Wiener index is expected to determine both diversity characteristics, that is, evenness and richness (Melo, 2008) [18] but does not provide any information on the rare species which, however, are very important in studies of biodiversity. This implies that diversity cannot be estimated just by one index (Hayek *et al*., 1997, Purvis *et al*., 2000) [9, 23]

The species richness and evenness of a locality are used to quantify its heterogeneity of taxa in comparison to other localities (Rekha *et al*., 2009) [25]. Species richness is the most widely used method for assessing species variation in a location and comparing habitats or species assemblages with those in other locations and different environmental conditions (Humphries *et al*., 1996) [13].

At the harvesting stage in both the seasons, bhendi has the highest Shannon, Margalef indices in each surveyed region, and Simpson's diversity index is nearly higher in the harvesting stage than in the reproductive stage. The Shannon diversity index ranges typically from 1.5 to 3.5 and rarely reaches 4.5 (Ifo *et al*., 2016) [14]. In this study, there was a high value of Shannon Index observed in cowpea at reproductive and harvesting stage, most probably due to the availability of specific prey, *Aphis crassivora*. In vegetative stage of cowpea, Shannon Index was low. Low biological diversity could be explained by the fact that it is dominated by a single species incidentally *C. sexmaculata* was dominating because of a good load of pray, *A. crassivora*. Simpson's index of diversity represents the probability that two individuals randomly selected from a sample belong to different species. The range of the value lies between 0 and 1. The bigger the value, the more diverse the sample. The most abundant species in the sample are significantly weighted in Simpson's index, which is less susceptible to species richness (Anbalagan *et al*., 2016) [1]. Here the Simpson's Index value lies between 0.222-1 which indicates that the sampled areas are more diversified (Bibi *et al*., 2013) [15] and having a stable community. Mature and stable communities have high diversity values (0.6 to 0.9), while the communities under stress conditions, exhibiting low diversity, usually show close to zero value (Dash, 2003) [7]. Species evenness is more prevalent in specific locations during the vegetative stage. It specifies the comparative occurrence of many species and was used to associate species abundance and relative richness amongst species (Whittaker, 1977, Barbour *et al*., 1998) [32, 4].

Shannon index for brinjal is higher during the reproductive stage in six locations during both seasons. In the first season, the Margalef index has a larger value during the reproductive stage, and in the second season, it has a higher value at the harvesting stage. The Margalef index is simple to calculate and is dependent on species richness. The more diverse, the higher the margalef index. The Margalef index is a good differentiating factor, but it is affected by sample size (Anbalagan *et al*., 2016) [1]. Margalef index has no limit value and it shows a variation depending upon the number of species. Based on the region, Simpson's index and species evenness have a larger value in the harvesting and reproductive stages.

In the case of cowpea, Shannon and Simpson's indices are high at the harvesting stage in the first season, but there are some changes in the values between the reproductive stage and harvesting stage in the second season. In two seasons, the Margalef index has higher values during the harvesting and reproductive stages. Here the value of Margalef index lies between 0.288-2.175. A slight increase was observed in Species evenness at the vegetative stage than other stages of cowpea in the first season. It may be due to the high occurrence of prey species during the vegetative phase. If the Evenness Index is found in between 0.47-0.59 indicating that the spread of coccinellids in the crop ecosystem is even ensuring good levels of natural control. (Anitha *et al*., 2020) [2]. Here Species evenness ranges between 0.3-1 which indicates a widespread of coccinellids which ensures effective biological control. According to the study of Shah *et al*. (2013) [28] whenever the Simpson's diversity index increases towards a higher value, the evenness index goes in opposite directions and vice versa. Therefore, there seems to be an inverse relationship between the two.

This study reals the occurrence of coccinellids is dependent on the prevalence of pray species and suitable microclimate in a given season and presence of weeds as well. The information on the relative abundance and diversity are very much needed to plan for biological control of soft bodies insects in vegetable crops especially in bhendi, brinjal and cowpea to avoid or reduce the insecticide usage. Also, it helps planning for coccinellid augmentation and conservation strategies for natural biological control as well.

Conclusion

The most abundant species observed in this study was *C. sexmaculata*. The survival of coccinellids was found to vary according to the season, crop stages and mainly associates with the prey distribution. As there was more prey availability in the second crop season (May-August, 2021) than in the first (January-April, 2021), predatory coccinellids were more abundant in the second crop season (May-August, 2021).

Table 1: Relative abundance (%) of coccinellid species in different block for two seasons Season I (January-April 2021) Season II (May-August, 2021) in bhendi, brinjal and cow pea. (Season I (S I) and Season II (S II)).

Predatory coccinellids Species	Relative abundance (%) of coccinellid species											
	Coimbatore District						Tiruppur District					
	Karamadai		Kinathukadavu		Pollachi South		Udumalaipettai		Pongalur		Tiruppur	
	S I	S II	S I	S II	S I	S II	S I	S II	S I	S II	S I	S II
Cheilomenes sexmaculata	36.1	40.44	31.53	35.42	39.73	38.76	34.81	38.73	46.01	45.1	40.35	46.06
Coccinella transversalis	21.89	19.66	28.63	26.04	16.56	17.41	23.7	18.3	25.35	19.56	22.22	14.6
Illeis indica	30.2	23.59	24.48	19.79	25.83	24.72	27.4	23.23	2.35	13.58	19.88	18.53
Propylea spp	1.18	4.49	4.97	4.17	10.59	8.42	2.22	4.93	47.83	3.8	1.17	5.05
Brumoides suturalis	4.14	5.05	0	4.17	3.97	5.05	3.7	4.93	11.27	9.78	4.68	5.61
Hyperaspis maindroni	3.55	2.8	1.65	1.56	1.98	1.68	2.22	2.11	2.82	2.17	1.75	2.24
Anegleis cardoni	1.77	0.56	3.73	1.56	0	0	0.74	1.41	0.94	1.63	1.75	1.68
Serangium spp	0	0.56	2.49	2.6	0	1.12	1.48	2.81	1.41	1.08	1.17	1.12
Pseudaspidimerus spp	0.59	1.12	0	1.56	0.66	1.12	0.74	0.7	3.29	1.08	2.92	2.24
Scymnus spp	0	0.56	2.48	2.08	0	0.56	2.96	2.81	0	1.08	2.92	1.68
Chilocorus nigritus	0.59	1.12	0	1.04	0.66	1.12	0	0	1.41	1.08	1.17	1.12

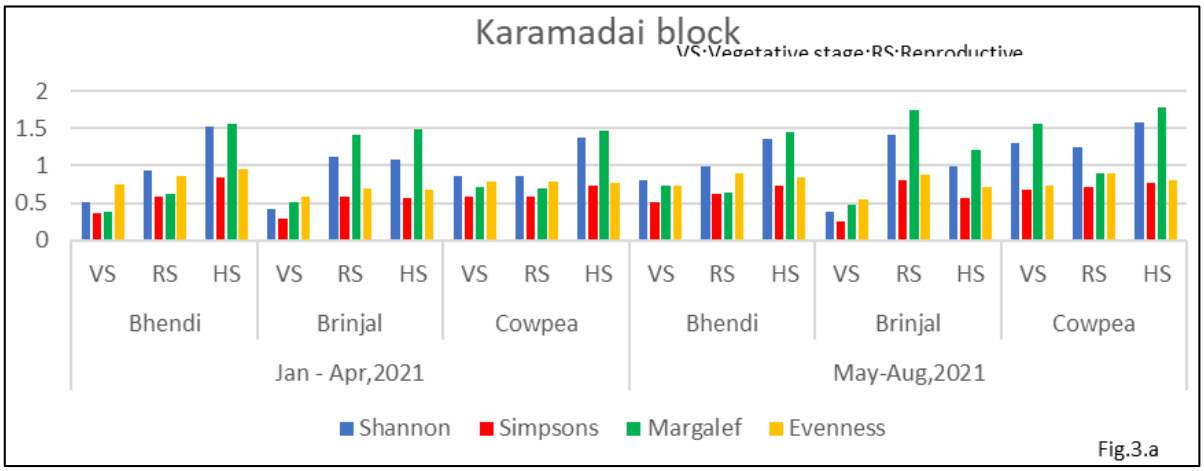


Fig.3.a

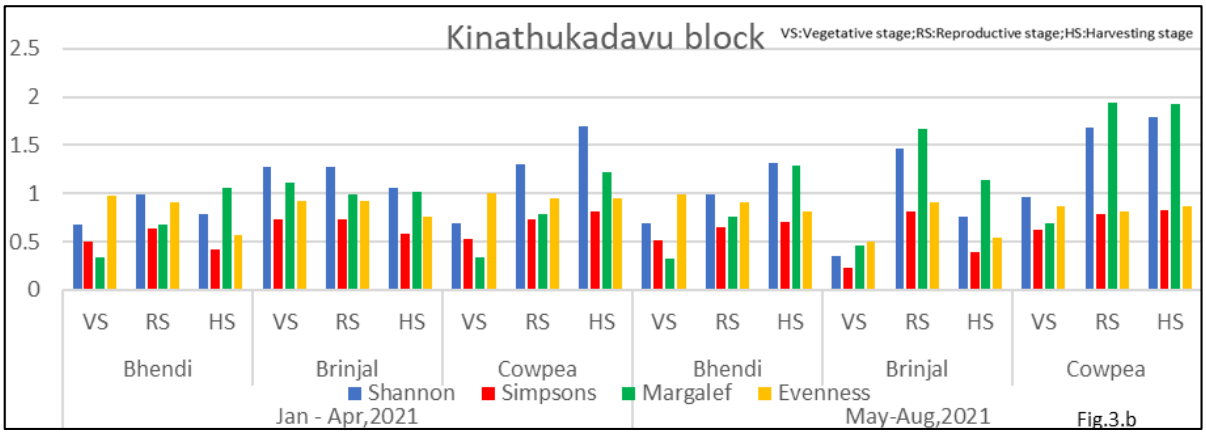


Fig.3.b

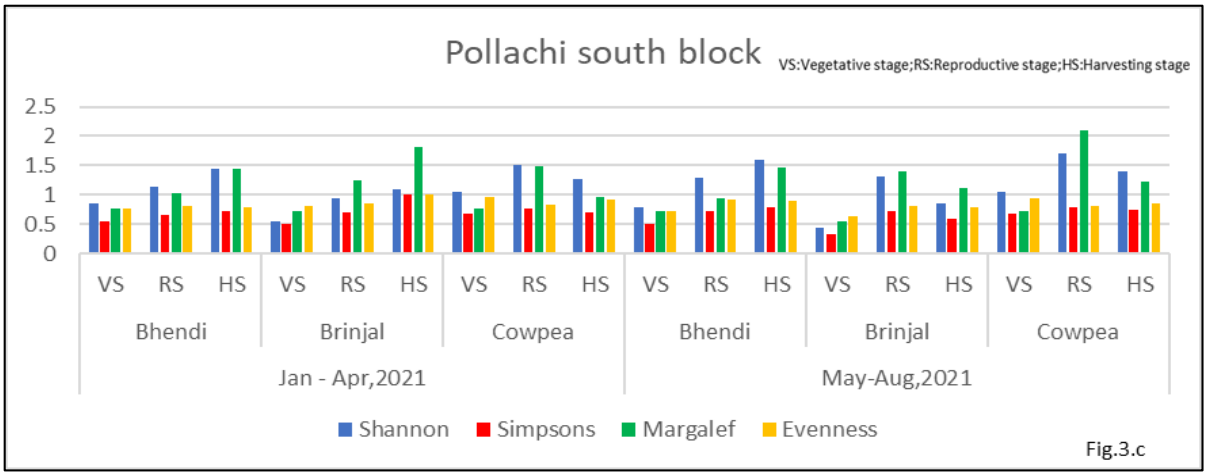
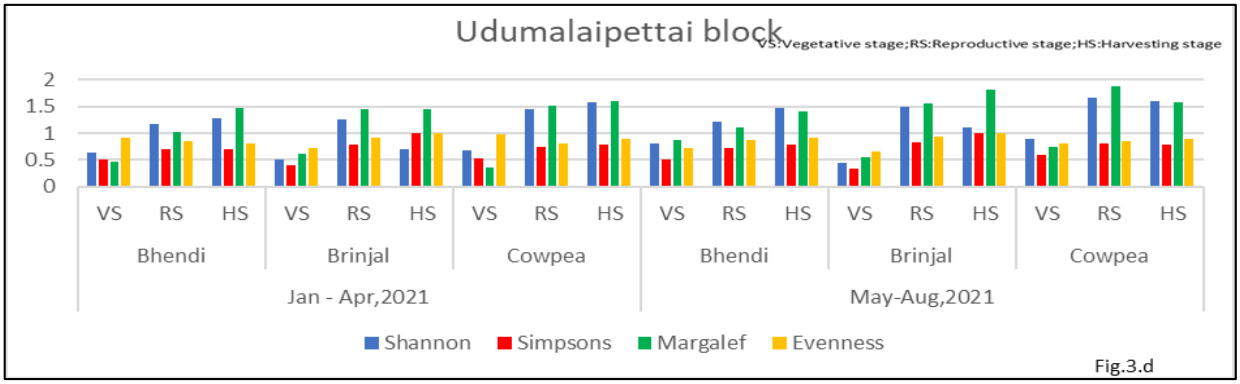
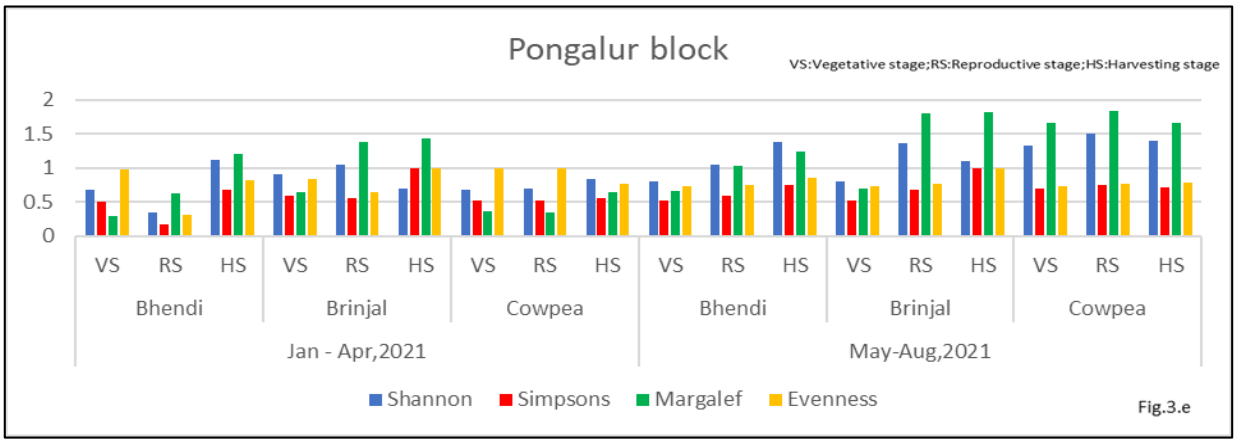


Fig.3.c





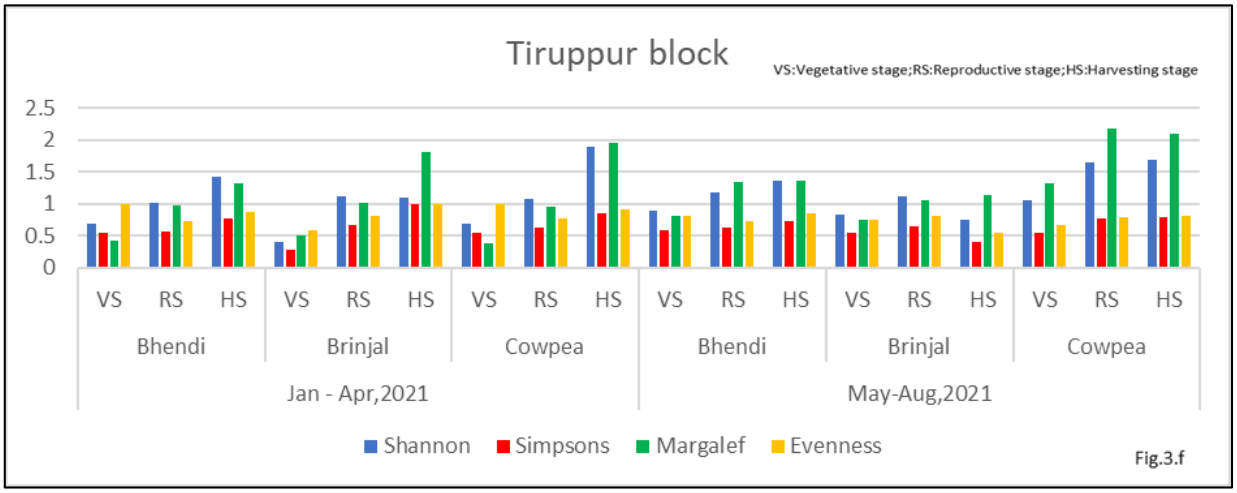


Fig 3: Comparative biodiversity indices of predatory coccinellids on bhendi, brinjal and cowpea at vegetative, reproductive and harvesting stages in two season (January-April 2021 and May-August 2021) in six village blocks: {Karamadai (Fig 3.a), Kinathukadavu (Fig 3.b), Pollachi South (Fig 3.c), Udumalaipettai (Fig 3.d), Pongalur (Fig 3.e) and Tiruppur (Fig 3.f)} in Coimbatore and Tiruppur Districts

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