ABUNDANCE, DISTRIBUTION AND DIVERGENCE OF STEM BORER SPECIES AND PREDATORS IN RICE ECOSYSTEM OF KRISHNA DISTRICT, ANDHRA PRADESH

SUDHA RANI, D.[1] – CHIRANJEEVI, CH.[2] – MADHUMATHI, T.[2] – KRISHNAM RAJU, S.[3] – NAFEEZ UMAR, S.[4]

[1]*Agricultural Research Station, Garikapadu, Acharya N G Ranga Agricultural University, Guntur, Andhra Pradesh, India*

[2]*Department of Entomology, Agricultural College, Bapatla, Guntur District, Andhra Pradesh, India*

[3]*Department of Plant Pathology, Agricultural College, Rajamahendravarum, Andhra Pradesh, India*

[4]*Department of Statistics, Agricultural College, Bapatla, Guntur District, Andhra Pradesh, India*

**Corresponding author*
e-mail: d.sudharani@angrau.ac.in; phone: +91-944-105-8009

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Abstract. The relative abundance, distribution and divergence of various stem borer species and predators in the rice ecosystem of Krishna district, Andhra Pradesh, India were assessed by adapting stratified random sampling technique during a survey in selected ten mandals of Krishna district. The survey was executed for four consecutive seasons *viz*., *wet season* 2016, *dry season* 2016-17, *wet season* 2017 and *dry season* 2017-18 during early hours at three crop stages (tillering, panicle initiation and grain filling) of rice crop and the sampled species of stem borers and predators in the rice ecosystem were identified and categorized. The survey results confirmed the prevalence of four rice stem borer species *viz*., yellow stem borer, pink stem borer, white stem borer and dark headed stem borer and nearly ten predatory fauna *viz*., wolf spider, long jawed spider, lynx spider, dragonfly, damselfly, preying mantid, mirid bug, carabid beetle, tiger beetle and lady bird beetle as most abundant in the rice ecosystem of Krishna district. The various diversity indices for stem borer and predatory species in rice ecosystem were evaluated and the results inferred that stem borer species exhibited aggregated distribution pattern, while the predators exhibited random distribution patterns in ten mandals surveyed. The highest divergence was witnessed in Jaggayapeta mandal with 20.88 per cent contribution followed by Penuganchiprolu, G. Konduru, Ghantasala, Koduru, Machilipatnam, Ibrahimpatnam, Vatsavai and Mopidevi mandals with 17.58, 15.38, 15.38, 9.89, 8.79, 6.59, 3.30, 2.20 and 0.01 per cent contributions, respectively.
Keywords: *rice, stemborer, predators, variability*

Introduction

Rice is the dominant food crop cultivated all over the world and is the staple food for more than half of the world's population. In order to improve their socioeconomic status and reap higher profits by increasing rice productivity, cultivators had adopted intensive farming and thereby crop cultivation had become industrial agriculture i.e., commercialization. This intensive modern farming had led to enormous tribulations with respect to pest management, environment and human health, besides hampering ecological biodiversity. Implementation of sustainable agricultural strategies plays a pivotal role in conserving crop biodiversity for which ecology-based studies are

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essential. The studies pertaining to divergence of pest and natural enemy complex in a particular crop ecosystem will ensure ecological knowledge to check the severely aggravating pest menace. The ecological pest management simply relies on preventive rather than reactive management strategies (Heeb *et al*., 2019). The rice ecosystem is bestowed with a complex of pests and natural enemies and their correlation studies through periodical survey and surveillance aids in assembling the information on ecological dynamics of species abundance, evenness, density, distribution, dispersion and their relationship with changing climatic scenario. This information sustains to forecast the pest situation and to frame appropriate pest management strategies. Among various biotic stresses limiting the yield of rice crop, stem borers are the predominant devastators and responsible for economic crop losses under field conditions (Mahar and Hakro, 1979).

The studies on abundance of pest species, natural enemies and their interactions provide information on the homeostatic capacity of the ecosystem to the unforeseen environmental changes (Magurran, 1988) which are essential for formulating ecological based pest management strategies. The studies on relative abundance of various stem borer species infesting rice are important aspects in determining the stem borer species abundance in certain locations (Banwo, 2002).

The studies relating to dominance, relative abundance and distribution of various stem borer species infesting rice in India and in other countries; predator complex in rice fauna and the interactions between stem borers and predators in the rice ecosystem were studied by many researchers and accordingly framed ecological based pest management strategies. Hence, a study in Krishna district, Andhra Pradesh, India was undertaken to assess the relative abundance, evenness, richness, distribution and divergence among various stem borer species and predators in the rice ecosystem to evaluate the ecological diversity and also to outline an integrated pest management approach.

Materials and methods

A survey was conducted in ten rice growing mandals of Krishna district, Andhra Pradesh, India to determine the density, relative abundance and distribution of various stem borer species and predators in different rice ecosystems.

The experimental site, period of survey and sampling procedure

The survey was conducted in different rice ecosystems for various stem borer species and predators prevalent in ten mandals *viz*., G. Konduru, Ghantasala, Ibrahimpatnam, Jaggayapeta, Koduru, Machilipatnam, Mopidevi, Mylavarum, Penuganchiprolu and Vatsavai of Krishna district (*Fig. 1*) for a period of two years i.e., from 2016 to 2018 representing four successive seasons *viz*., *wet season* 2016, *dry season* 2016-17, *wet season*, 2017 and *dry season*, 2017-18. Among the rice growing areas in Andhra Pardesh, Krishna district is covered with large extend of rice growing area both in uplands and delta areas covering around 52000 ha. In Krishna district varied cropping sequences/patterns exists with different rice varieties and methods of cultivation and hence, the Krishna district was chosen for survey. The survey was made during early morning hours at three growth stages of the rice crop i.e., tillering stage, panicle initiation stage and grain filling stage. A stratified random sampling procedure was adopted for survey where in a total of three farmer fields (1.0 ha area) were selected in

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each mandal. The selected field was divided in to four strata and in every stratum four quadrates of 10 × 10 m area was sampled and there by a total of 16 quadrates in each field were sampled (*Fig. 2*).

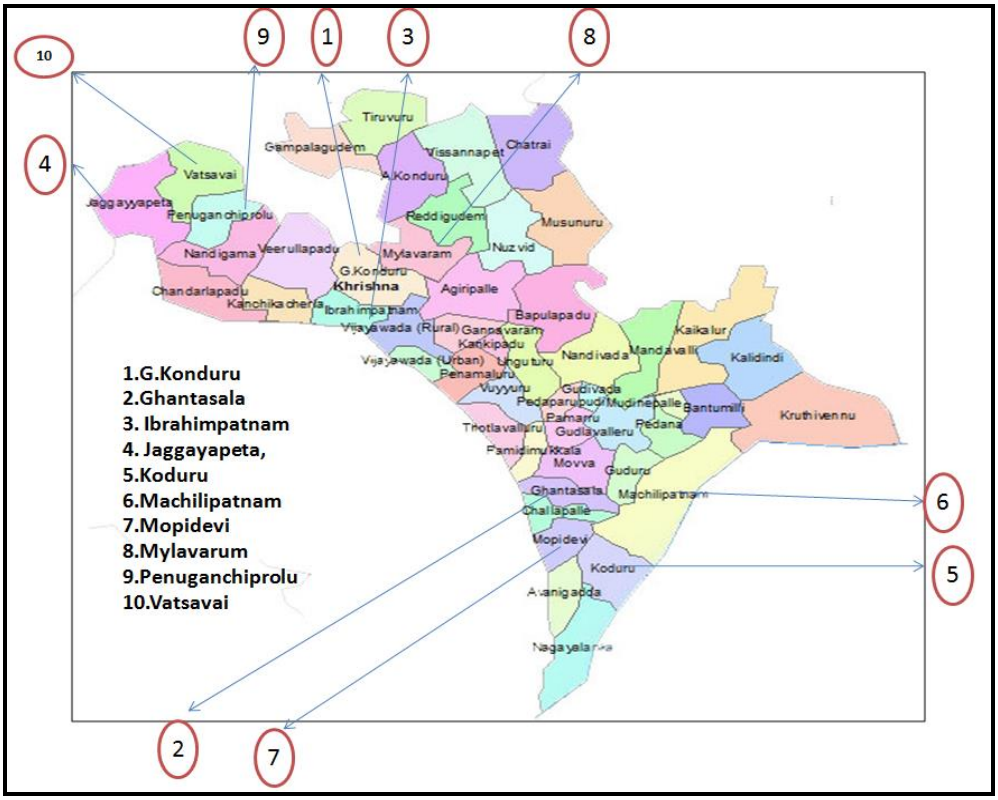

Figure 1. *Survey conducted in various rice ecosystems of Krishna district (ten mandals)*

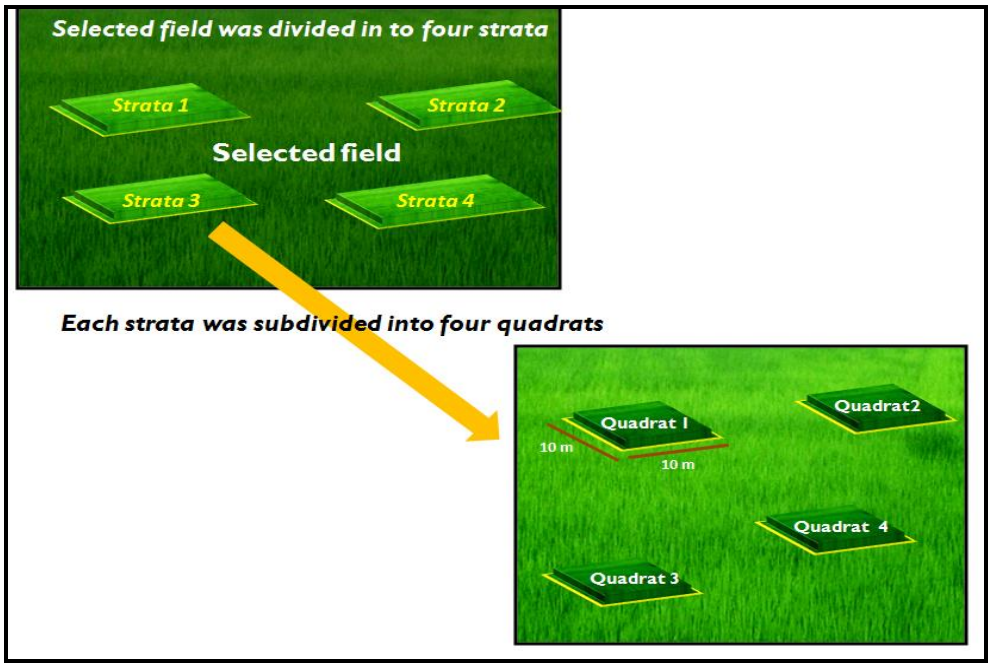

Figure 2. *Methodology depicting stratified random sampling technique*

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A split plot experimental design was applied where the mandals were regarded as main plot factor and the selected farmers' fields as sub plot factor. In each quadrate 20 sweeps were made using fine nylon cloth sweep net from the plant canopy including the interspaces between plants and basal region of the rice crop. The various stem borer moths and predators were collected, identified and preserved.

Relative abundance and distribution of stem borer species and predators

The identified stem borer species and predators in different rice ecosystems of Krishna district at three growth stages of the rice crop were tabulated and the relative abundance of various stem borer species and predators in rice fields were calculated mandal wise according to Thomas (2005) as follows:

$$\text{Relative abundance (\%)} = \frac{\text{Total number of individuals of each species}}{\text{Total number of individuals of all species}} \times 100$$

The data on mean relative abundance of various stem borer species and predators in the rice ecosystem at three growth stages were subjected to split plot two factorial analysis to judge the variations in populations of stem borers and predators at different growth stages of rice.

Interaction effects of stem borer species and predators

To determine the relationship between rice stem borer species and the predators in different rice ecosystems of Krishna district the correlation coefficients were worked out by adopting multiple correlation analysis.

The diversity indices for stem borer and predatory species in rice ecosystem

The studies relating to diversity among stem borers and predators will enlighten about the rarity and commonness of species in a particular community. The ability to quantify diversity aids in perceiving the community structure by cluster analysis.
Hence, Margalef Richness index (R) for species richness, the Shannon-Wiener index and Simpson index (λ) for diversity in community, Pilou species evenness (J) to compares the actual diversity value to the maximum possible diversity were used to measure the diversity of stem borer species and predators from the original data recorded from different rice ecosystems in Krishna district. The Morisita index of dispersion was also used to determine the spatial distribution pattern for rice stem borer species and predators in various mandals of Krishna district.
The species richness of various stem borers and predators of rice ecosystem were determined by Margalef Richness index (R) as per the formulae described below.

$$R = \frac{n-1}{\ln N}$$

where n = number of species, ln = natural logarithm; N = total number of individuals.

The diversity of various stem borer species and predatory community in different rice ecosystems surveyed were analyzed by widely used indices *viz.*, the Shannon-Wiener index (H'), which is sensitive to changes in the abundance of rare species in a community and the Simpson index (λ), which is sensitive to changes in the most

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abundant species in a community and is usually expressed as the reciprocal ($D^S = 1-\lambda$) so that as a measure of diversity, higher values represent higher diversity.

Shannon-Wiener index (H'):

$$H' = -\sum(\frac{n1}{n2} \text{ X } ln\ \frac{n1}{N})$$

where n_i is the number of individuals of amount (biomass) of each of the I species and N is the total number of individuals (or biomass) for the site.

Simpson index (λ):

$$\lambda = \sum \frac{ni(ni-1)}{N(N-1)}$$

$$D^s = 1 - \sum \frac{ni(ni-1)}{N(N-1)}$$

Pilou species evenness (J) compares the actual diversity value (such as the Shannon-Wiener Index, H') to the maximum possible diversity value (when all species are equally common) for the various stem borer species and predators surveyed in rice ecosystem also calculated.

For the Shannon-Wiener Index, the Pilou evenness (J):

$$\frac{H'}{H_{\max}}$$

Hmax = ln$S$, where S is the total number of species.

The spatial distribution pattern for rice stem borer species and predators was determined by Morisita's index of dispersion described by Morisita (1959) given below.

Morisita's index ($I\delta$):

$$I\delta = \frac{\Sigma i = 1\ ni(ni-1)N}{n(n-1)}$$

where $I\delta$ = index or coefficient of dispersion; N = Number of samples; n_i = number of individuals in the samples; n = total number of individuals in the sample; if $I\delta < 1$ and $I\delta > 1$ indicates random and aggregated distribution patterns, respectively.

Cluster analysis of stem borer species and predators in the rice ecosystem

Cluster analysis is a common technique for statistical data analysis and is the process of grouping similar objects into different groups, or more precisely, the partitioning of a data set into subsets, so that the data in each subset according to some defined distance measure can be studied. The Euclidean distance function was employed for cluster analysis of stem borer species and predatory guild in rice ecosystem of Krishna district. The Euclidean distance was computed by finding the square of the distance between each variable, summing the squares and finding the square root of that sum. In the two-variable case, the distance was analogous to finding the length of the hypotenuse in a triangle; that is, it is the distance "as the crow flies." The Euclidean distance function

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measures the "as the-crow-flies distance". The formula for this distance between a point X (X1, X2, *etc*.) and a point Y (Y1, Y2, *etc*.) is:

$$d = \sqrt{\sum_{j=1}^{n} (x_j - y_j)^2}$$

The average inter and intra cluster Euclidean[2] distances of prevalence of various rice stem borer species and predators in ten mandals of Krishna district was estimated based on ward's minimum variance and grouped the species in to different clusters in each mandal. This method builds the hierarchy from the individual elements by progressively merging clusters resulting a tree diagram or dendrogram. The per cent composition of divergence among the various mandals surveyed was also determined by utilizing clustering pattern in identifying the variability with respect to various mandals under study.

Data analysis

The recorded data were tested normally using Indo stat package (www.indostat.org) upon which conformity to the normal distribution no transformations made. Data for abundance were subjected to the one way (ANOVA) in split plot design, mean separation was tested and the critical difference among means was established at 5% and 1% level of significance

Results and discussion

Abundance of rice stem borer species with respect to crop growth stages

The summative survey in ten mandals of Krishna district, Andhra Pradesh, India for a period of four successive seasons indicated the prevalence of four species of stem borer's *viz*., yellow stem borer -YSB (*Scirpophgaga incertuals*, Walker), pink stem borer-PSB (*Sesamia inferens*, Walker), white stem borer-WSB (*Scirpophaga* spp.) and dark headed stem borer-DHSB (*Chilo polychrysus*, Meyers) in rice ecosystem. The survey results inferred that there was a significant difference among the stem borer species prevalence in rice ecosystem with respect to various crop growth stages. There was a variance in relative abundance of same stem borer species at three different crop growth stages (tillering, panicle initiation. and grain filling) of rice crop and was found more or less similar (on par) representing their evenness or uniformity in presence throughout the crop season. However, among all the stem borer species prevalent in the rice ecosystem of Krishna district, yellow stem borer was predominant at all the growth stages of rice crop. It was witnessed from the cumulative mean data of survey results (*Table 1*) that YSB was the predominant stem borer species in the rice ecosystem of Krishna district in all the growth stages of rice crop with 82.0 and 78.88 per cent abundance during *wet* and *dry* seasons, respectively. During *wet* season next to YSB, PSB (7.412) was more abundant than WSB (5.235) and DHSB (3.053), whereas WSB (9.087) was more dominant compared to PSB (7.839) and DHSB (2.53) in *dry* season.

Abundance of predators in the rice ecosystem with respect to crop growth stages

From the present appraisal through sampling in various surveyed sites (ten mandals of Krishna district) it was revealed that nearly ten predatory species were dominant in

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Krishna district *viz.*, wolf spider (*Lycosa pseudoannulata*), long jawed spider (*Tetragnatha* spp.), lynx spider (*Peucetia viridians)*, dragonfly (*Anisoptera* spp.), damselfly (*Zygoptera* spp.), preying mantid (*Mantis religiosa)*, mirid bug (*Cyrtorhinus lividipennis)*, carabid beetle (*Pheropsohus* spp.), tiger beetle (*Cicindela* spp.) and lady bird beetle (*Coccinella* spp.). It was inferred from results that there was a significant difference in abundance of various predatory species at different crop growth stages. However, most of the species among predatory guild were statistically at par with each other in all the three growth stages (tillering, panicle initiation and grain filling) of rice crop.

Table 1. *Relative abundance of stem borer species in the rice ecosystem of Krishna district (cumulative mean)*

Stem borer species	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
YSB	80.273[a]	83.746[a]	82.010[a]	75.130[a]	82.626[a]	78.878[a]
PSB	7.683[b]	7.140[b]	7.412[b]	8.715[b]	6.963[b]	7.839[b]
WSB	6.931[b]	3.538[bc]	5.235[bc]	10.628[b]	7.545[b]	9.087[b]
DHSB	4.210[c]	1.896[c]	3.053[c]	3.651[c]	1.409[c]	2.530[c]
Mean	24.770	24.080	24.430	24.530	24.640	24.580
Significance	*	*	*	*	*	*
CD (P = 0.05)	2.58	3.56	2.92	4.53	1.99	3.26
CV (%)	21.85	11.98	16.92	35.41	19.58	27.45
SEM	2.81	1.57	2.19	1.14	2.02	1.58

Significance levels * = < 0.05
Mean with same letter are not significantly different by Duncan's Multiple Range test

The cumulative mean per cent abundance of various predators in the rice ecosystem inferred that there was no significant difference in the mean abundances of predatory species during *wet* season. During *dry* season there was a significant difference among various predators in the guild and majority of them are statistically on par with each other in relation to per cent abundance. The mean per cent abundance of wolf spider, long jawed spider and lynx spider were 9.77 & 10.35, 10.35 & 9.91 and 10.36 & 10.53 per cent during *wet* and *dry* seasons, respectively.

The corresponding percentages for dragonfly, damselfly, preying mantid and mirid bug during *wet season*, 2017 and *dry* season 2017-18 were 10.44 & 10.11, 9.37 & 9.83, 9.94 & 10.36 and 10.05 & 9.68 per cent respectively. The predatory beetles' fauna in rice ecosystem during *wet* and *dry* seasons were composed of carabid beetle (9.83 & 9.70%), tiger beetles (9.91 & 9.25%) and lady bird beetles (9.48 & 9.58%) (*Table 2*).

Relative abundance of stem borer species infesting rice at various mandals of Krishna district

In various mandals of Krishna district the survey was made by following stratified random sampling technique and the per cent relative abundance of the stem borers in rice ecosystem were deliberated. The survey reports indicated that there was a significant difference among stem borer species prevalence in various mandals of Krishna district in all the four seasons *viz.*, *wet season* 2016, *dry season* 2016-17, *wet season* 2017 and *dry season* 2017-18 (*Table 3*).

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Table 2. *Relative abundance of predators in the rice ecosystem of Krishna district (cumulative mean)*

Predators	*Wet season,* 2016	*Wet season,* 2017	Mean	*Dry season,* 2016-17	*Dry season,* 2017-18	Mean
Wolf spider	9.35[a]	10.18	9.77	10.67[b]	10.04[ab]	10.35[ab]
Long jawed spider	10.28[ab]	10.41	10.35	10.38[b]	9.44[a]	9.91[ab]
Lynx spider	10.53[b]	10.20	10.37	10.33[b]	10.74[b]	10.53[b]
Dragonfly	10.77[b]	10.11	10.44	9.13[a]	11.10[b]	10.11[ab]
Damselfly	9.14[a]	9.60	9.37	9.81[ab]	9.85[ab]	9.83[ab]
Preying mantid	9.94[ab]	9.95	9.94	9.93[ab]	10.80[b]	10.36[ab]
Mirid bug	10.02[ab]	10.10	10.05	10.26	9.09[a]	9.68[ab]
Carabid beetle	10.20[ab]	9.46	9.83	9.95[ab]	9.44[a]	9.70[ab]
Tiger beetle	9.54[ab]	10.29	9.91	9.16[a]	9.34[a]	9.25[a]
Lady bird beetle	9.41[a]	9.56	9.48	9.62[ab]	9.54[a]	9.58[ab]
CD (P = 0.05)	1.270	NS	NS	1.120	1.135	1.167
CV	14.25	15.36	15.42	14.02	18.32	15.73
SEM	0.765	0.695	0.615	0.145	0.958	0.715

Significance Levels * = < 0.05
Mean with same letter are not significantly different by Duncan's Multiple Range test

Table 3. *Relative abundance (Mean ± SD) of stem borer species in rice ecosystem of various mandals of Krishna district (pooled mean of four seasons)*

	G. Koduru	Ghantasala	Ibrahimpatnam	Jaggayapeta	Koduru
Yellow stem borer	77.39±24.9	76.68±24.9	71.18±29.3	83.25±21.8	80.64±22.7
Pink stem borer	10.11±16.9[a]	11.20±17.3	10.57±17.9[a]	6.46±12.4[a]	6.70±13.3ab
White stem borer	8.03±14.7[a]	7.88±12.8	10.85±14.4	5.92±12.3ab	8.36±12.2b
Dark headed stem borer	3.78±10.5	2.68±6.5	4.85±11.4[a]	2.28±6.1b	1.86±7.12b
Mean	24.83	24.61	24.52	24.48	24.39
Level of significance	***	***	***	***	***
CD 5%	3.195	2.585	3.682	2.853	4.543
CD 1%	4.212	3.054	4.351	3.984	5.938
CV (%)	7.255	6.953	7.095	6.358	7.456
SEM	2.091	1.954	1.265	1.652	1.985

	Machilipatnam	Mopidevi	Mylavarum	Penuganchriprolu	Vatsavai
Yellow stem borer	83.40±21.4	79.71±25.1	85.17±21.7	86.11±18.5	80.90±24.8
Pink stem borer	5.51±11.9[a]	8.35±15.3[b]	5.53±11.3[a]	4.91±9.1[a]	6.90±13.3[a]
White stem borer	5.53±10.3[a]	5.97±10.5[ab]	4.51±11.2[a]	6.32±13.0[a]	7.82±14.8[a]
Dark headed stem borer	4.97±7.30[a]	3.52±7.5[a]	2.30±7.0[a]	1.62±5.5[a]	2.30±7.9
Mean	24.85	24.39	24.38	24.74	97.92
Level of significance	***	***	***	***	***
CD 5%	2.673	2.495	3.183	4.361	2.92
CD 1%	3.155	4.021	4.009	5.682	3.58
CV(%)	8.165	6.954	5.842	7.451	8.009
SEM	1.547	3.120	1.584	1.556	1.275

NS = non significant; Significance Levels * = < 0.05, ** = < 0.01 & *** = < 0.001
Mean with same letter are not significantly different by Duncan's Multiple Range test

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The present investigations inferred that yellow stem borer was predominant species among all the borers and attained peak infestation at grain filling stage followed by tillering and panicle initiation stage with a mean infestation of 82.010 and 78.878 per cent abundance at both *wet* and *dry* seasons, respectively. Among the various mandals surveyed, the YSB abundance had ranged from 71.18 to 86.11 per cent. The next dominant stem borer species was pink stem borer (7.412) and white stem borer (9.087) as against lowest per cent abundance observed in dark headed stem borer with 3.053 and 2.530 per cent during *wet* and *dry* seasons, respectively.

The present results were in close conformity with the survey reports in various agro climatic regions by many researchers *viz*., Chakravorty (1979), Dutt and Kundu (1983), Catling et al. (1984), Husain and Begum (1985), Rai et al. (1989), Damayanti et al. (1991), Rahim et al. (1992) Pathak and Khan (1994), Islam (1996), Sharma et al. (1996), Ragini et al. (2000), Salim et al. (2001), Jian Wei et al. (2002), Rahaman et al. (2014), Balleras et al. (2016) and Pallavi et al. (2018) who strongly admitted the predominance of yellow stem borer in rice ecosystem with a range from 57.5 to 98.0 per cent among various stem borer species.

The yellow stem borer exhibited peak activity during grain filling stage in the present survey but contradictory results by Qadeer et al. (1990) indicated slight increase in the population of YSB (53.8%) at tillering to flowering stage (68.8%) followed by a decline during dough stage (7.5%). The PSB incidence was comparatively more than WSB in *wet season*, while it was reverse in case with *dry season* where WSB was more abundant. The shift in the species abundance may be due to change in cropping pattern or climatic conditions. The statement finds support with the declaration by Litsinger et al. (2006) who confirmed the climate change as major factor contributing the shift and subsequent outbreaks of pests. Similar studies by Rahaman et al. (2014) studied the relative abundance of various stem borers in rice at Madhupur, Tangail, Bangladesh and confirmed the rank order of relative abundance of rice stem borers as YSB (69.90%) > DHSB (14.36%) > PB (8.08%) > WB (4.91%) > SSB (2.75%).

The investigations by Balleras et al. (2016) on dominance and composition of rice stem borers revealed that SSB was the most dominant species throughout the cropping season, followed by WSB and PSB. The presence of WSB + SSB and WSB + PSB in a single tiller were prevalent during the vegetative and reproductive phases, respectively. Murali et al. (2017) inferred that *S. incertulas* dominated (92.3%; 159 female adults) among all the species of stem borers, while *C. Suppressalis* (7.7%; 15 adults) and *S. spp.* (>1%) ranked 2nd and 3rd in relation to relative abundance.

Bonaventure (2018) assessed the rice stem borer species abundance and indicated that two species were abundant *viz*., *Chilo spp* (79.24-92.05%) and *S. calamistis* (7.97-20.77%) and their damage significantly varied with respect to planting dates and varieties. Analogous investigations by Pallavi et al. (2018) exposed that YSB was the predominant species (61 no) followed by PSB (51 no) in terms of larvae per 100 plants expressing white ear damage in rice crop.

Relative abundance of various predators prevalent in rice ecosystem at various mandals of Krishna district

In various mandals of Krishna district the survey was made by employing stratified random sampling technique and determined the per cent relative abundance of the predators prevalent in different rice ecosystem. The pooled mean of four seasons data pertaining to relative abundance of predatory inhabitants prevalent in the rice ecosystem

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of Krishna district in various mandals were summarized in *Table 4*. In Ghantasala, Mopidevi and Penuganchiprolu mandals there was no significant difference among the predatory fauna in rice ecosystem.

Table 4. *Relative abundance (Mean±SD) of predators in the rice ecosystem of various mandals of Krishna district (pooled mean of four seasons)*

	G. Konduru	Ghanta sala	Ibrahim patnam	Jaggaya peta	Koduru	Machili patnam	Mopi devi	Mylava rum	Penugan chriprolu	Vatsavai
Wolf spider	11.57 ±1.17[b]	9.58 ±1.510	10.28 ±1.390	11.53 ±1.486	11.23 ±1.464	8.49 ±1.398	9.76 ±1.319	10.87 ±1.319	11.07 ±1.269	9.52 ±1.098
Long jawed	13.75 ±1.408[b]	11.02 ±1.627	9.20 ±1.312	6.95 ±1.078	9.72 ±1.358	11.02 ±1.535	11.01 ±1.493	8.100 ±1.226	8.24 ±1.163	10.16 ±1.168
Lynx spider	6.39 ±1.025[a]	9.08 ±1.486	11.59 ±1.459	11.56 ±1.414	8.11 ±1.360	10.29 ±1.463	9.26 ±1.470	10.88 ±1.378	10.31 ±1.276	9.80 ±1.158
Dragonfly	7.29 ±1.336[a]	10.25 ±1.405	8.53 ±1.184	8.33 ±1.231	9.61 ±1.342	11.79 ±1.548	9.18 ±1.297	8.95 ±1.200	9.37 ±1.323	9.79 ±3.497
Damselfly	8.82 ±1.676[a]	9.80 ±1.480	10.44 ±1.422	11.20 ±1.508	10.30 ±1.468	7.95 ±1.176	9.85 ±1.296	11.94 ±1.404	11.40 ±1.454	10.40 ±1.220
Preying mantid	12.16 ±1.744	9.54 ±1.388	8.20 ±1.245	9.20 ±1.337	11.77 ±1.524	11.15 ±1.47	10.71 ±1.302	8.85 ±1.221	9.36 ±1.256	10.83 ±1.238
Mirid bug	8.96 ±1.544[a]	8.80 ±1.337	12.11 ±1.437	11.58 ±1.583	8.51 ±1.266	8.77 ±1.254	9.28 ±1.266	9.71 ±1.261	10.44 ±1.329	10.69 ±1.422
Carabid beetle	11.69 ±1.647	9.87 ±1.322	8.42 ±1.337	9.23 ±1.345	9.37 ±1.236	10.93 ±1.366	7.57 ±1.372	8.86 ±1.272	10.09 ±1.338	16.03 ±1.951
Tiger beetle	8.38 ±1.401[a]	11.68 ±1.596	12.00 ±6.302	9.61 ±1.271	8.34 ±1.368	9.55 ±1.37	12.47 ±1.453	11.53 ±1.499	10.13 ±1.146	4.78 ±1.114
Lady bird beetle	9.94 ± 1.14ab	9.32 ±1.47	8.70 ±1.302	9.95 ±1.414	12.34 ±1.545	9.85 ±1.29	8.51 ±1.226	9.17 ±1.258	9.58 ±3.688	7.46 ±1.393
Mean	9.89	9.89	9.95	9.91	9.93	9.98	9.76	9.89	9.10	18.51
Significance	***	NS	*	*	*	***	NS	*	NS	*
CD 5%	3.921	-	3.587	3.182	2.965	2.558	-	2.141	-	3.054
CD 1%	4.352	-	5.01	4.953	3.547	3.154	-	3.581	-	4.951
CV (%)	16.456	17.017	14.258	16.954	16.5214	14.065	13.482	14.528	14.011	15.041
SEM	1.745	1.531	1.030	1.820	1.965	1.662	1.284	1.051	1.321	1.359

NS = non significant; Significance Levels * = < 0.05, ** = < 0.01 & *** = < 0.001;
Mean with same letter are not significantly different by Duncan's Multiple Range test

In G. Konduru the rank order pertaining to the abundance of predatory fauna were long jawed spiders (13.75) > preying mantid (12.16) > carabid beetle (11.69) > wolf spider (11.57) > lady bird beetle (9.94) > mirid bug (8.96) > damselfly (8.82) > tiger beetle (8.32) > dragonfly (7.29) > lynx spider (6.39). In Ibrahimpatnam and Jaggayapeta mandals the per cent abundance order were mirid bug (12.11) > tiger beetle (12.00) > lynx spider (11.59) > damselfly (10.44) > wolf spider (10.28) > long jawed spider (9.20) > lady bird beetle (8.70) > dragonfly (8.53) > carabid beetle (8.42) > preying mantid (8.20). In Koduru mandal the highest per cent relative abundance was noticed with lady bird beetle (12.34) followed by preying mantid, wolf spider, damselfly, long jawed spider, dragonfly, carabid beetle, mirid bug, tiger beetle and lynx spider with 11.77, 11.23, 10.30, 9.72, 9.61, 9.37, 8.51, 8.34, 8.11 per cent, respectively.

The predators abundance rank order in case with Machilipatnam mandal was dragonfly (11.79) > preying mantid (11.15) > long jawed spider (11.02) > carabid beetle (10.93) > lynx spider (10.29) > lady bird beetle (9.85) > tiger beetle (9.55) > mirid bug (8.77) > wolf spider (8.49) > damselfly (7.95). In Mylavarum mandals the highest per cent abundance with 11.94, 11.53, 10.88, 10.87, 9.71, 9.17, 8.95, 8.86, 8.85 and 8.10

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per cent were recorded with damselfly, tiger beetle, lynx spider, wolf spider, mirid bug, lady bird beetle, dragonfly, carabid beetle, preying mantid and long jawed spider, respectively.

The per cent abundance of predators rank in descending order at Vatsavai mandal encompass carabid beetle, preying mantid, mirid bug, damselfly, long jawed spider, lynx spider, dragonfly, wolf spider, lady bird beetle and tiger beetle with 16.03, 10.83, 10.69, 10.40, 10.16, 9.80, 9.79, 9.52, 7.46 and 4.78 per cent, respectively.

From the present investigation and analysis of the surveyed data relating to abundance of predators in the rice ecosystem at various growth stages and different mandals of Krishna district, it was inferred that all the predatory fauna had exhibited uniform distribution throughout the crop season. The major predatory fauna included wolf spider, long jawed spider, lynx spider, dragonfly, damselfly, preying mantid, mirid bug, carabid beetle, tiger beetle and lady bird beetles.

The per cent abundance of predatory spiders, Odonata species, mantid, bug and beetles in various mandals were found statistically on par with each other in many cases. Non-significant abundance was noticed in Ghantasala, Mopidevi and Penuganchiprolu mandals. The present findings gain agreement with the monitoring studies by Khan (1983) who inferred that in rice ecosystem 21 predaceous and 8 parasitic insect species were prevalent and among them carabids, cicindellids of coleoptera and reduviids in hemiptera were abundant.

Gupta *et al*. (1986) admitted the relative abundance of spiders in rice ecosystem of Andhra Pradesh comprised of *Tetragnathidae* (47%), *Araneidae* (20%), *Lycosidae* (16%), *Thomisidae* (10%), *Clubionidae* (4%) and *Oxyopidae* (2%) as dominant spiders. Wang et al. (1989), Battu (1990), Rubia and Almazan (1990) Baitha (1991), Gupta and Pawar (1992), Geethavishwanathan *et al*. (1996), Venkateshalu (1996), Anbalagan and Narayanasamy (1999), Mohan (2000), Jayakumar and Sankari (2010) and many more scientists declared through their monitoring studies that the spider population accounts for 55-80 per cent of the total predatory community in rice ecosystem resulting in reduced host (stem borer) population.

Tiwari *et al*. (2001) reported the occurrence of spider, dragonfly (*Crocothemis* spp.), damselfly (*Agriocnemis* spp.), cricket, rove beetle (*Paederus fuscipes*), ground beetle (*Ophionea indica*), predatory grass hopper (*Conocephalus* spp.) and brown bug (*Andrallus spinidens*) as dominant predators of rice pests. Ameilia *et al*. (2008) found 617 individuals from sub order Zygopteran, 575 individuals from sub order Anisopteran and 19 species of adult's odonata as dominant predators in the rice ecosystem. Kasyanov (2010) stated that there are 13 coccinellid species in rice based ecosystem at Krasnodar Krai which act as dominant predators suppressing the wheat aphid. Noorhosseini et al. (2010) inferred that dragonflies, earwigs and spiders act as predators feeding on larvae and adults of stem borers.

Similar relative abundance studies by Rahaman *et al*. (2014) indicated the predators in chronological order of abundance as lady bird beetle (49.95%) > long jawed spider (17.82%) > wolf spider (7.87%) > damselfly (6.26%) > carabid beetle (5.81%) > mirid bugs (4.94%) > lynx spider (2.83%) > dragonfly (2.30%) > earwigs (2.21%) in rice ecosystem. Chakraborthy et al. (2016) stressed that among predatory guild in rice crop, spiders were dominant group occupied over 41 per cent followed by Coleoptera (29%), Hemiptera (8%), Odonata (8%), Diptera (5%), Hymenoptera (6%) and Neuroptera (2%).

Israrul and Chakraborthy (2017) studied the relative abundance of natural enemies and the rank for order of abundance were lady bird beetles (51.06%) > long jawed

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spider (18.91%) > carabid beetle (7.47%) > damselfly (6.54%) > wolf spider (6.32%) > lynx spider (3.86%) > dragonfly (2.96%) > wasps (2.85%). Yadav et al. (2018) considered nearly more than ten insect species as the potential predators regulating the population of YSB *viz., Micraspis hirrashimai* and *Harmonia octomaculata* (Coleoptera: coccinelidae) feeding on eggs of YSB, dragonflies and damselflies on adults of YSB and leaf folders, respectively.

The correlation between stem borer species and predators in the rice ecosystem

To assess the association between predatory fauna and stem borer species abundant in rice ecosystem in various mandals of Krishna district the correlation studies were made for all the four seasons under the study period.

From the summative mean correlation matrix of *wet* and *dry* seasons (*Tables 5* and *6*) it was revealed that YSB had negative correlation only with preying mantid (-0.0167) during *wet season* and both with preying mantid (-0.0002) and carabid beetle (-0.004) in *dry season*. YSB had exhibited significant positive correlations with spider guild during both the seasons. The results were in concurrence with the affirmation by Arif et al. (2005) who indicated that maximum infestations of YSB (7.8%WE/5 hills) and maximum spider populations (13.3 no per m^2) were observed during the crop growth representing positive correlation between the spider abundance and white ears infestation. Jayakumar and Sankari (2005) also expressed that spiders had a positive maximum correlation with stem borer ($r = 0.738$; $n = 6$; $P < 0.05$).

The PSB had exhibited negative correlation with all the predators in rice crop except damselfly (0.0460 & 0.008) during *wet season* and *dry season*. PSB also exhibited positive association with long jawed spider (0.0094) during *dry season*. With long jawed spider (-0.0010), lynx spider (-0.0060) and preying mantid (-0.0344) WSB had negative correlation during *wet season*, whereas in *dry season* negative correlations were seen with wolf spider (-0.0120) and carabid beetle (-0.0185) and positive correlations with all other predatory guilds of rice ecosystem. During *wet season*, DHSB had exhibited negative correlation with wolf spider (-0.0185), long jawed spider (-0.0156) and mirid bug (-0.009) while, positive correlation with others. But during *dry season*, DHSB had exerted positive correlations only with damselfly, mantid and tiger beetle with 0.0317, 0.0069 & 0.0301 correlation coefficients, respectively.

Table 5. *Correlation matrix among stem borer species and predators in rice ecosystem of Krishna district during wet season (pooled mean)*

	Yellow stem borer	**Pink stem borer**	**White stem borer**	**Dark headed stem borer**
Wolf spider	0.0398*	-0.0060	0.0486	-0.0185
Long jawed spider	0.0209	-0.0359*	-0.0010	-0.0156
Lynx spider	0.0299**	-0.0310	-0.0060	0.0072
Dragonfly	0.2704	-0.0107	0.0185	0.0378
Damselfly	0.0499	0.0460*	0.0544	0.007
Preying mantid	-0.0167	-0.0080	-0.0344	0.020
Mirid bug	0.0534	-0.0287	0.0134	-0.009
Carabid beetle	0.0548	-0.3580**	0.0512	0.002
Tiger beetle	0.0094	-0.0004	0.0352	0.0361
Lady bird beetle	0.0737	-0.0050	-0.0008	0.0377

Significance levels * = < 0.05, ** = < 0.01 & *** = < 0.001

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Table 6. *Correlation matrix among stem borer species and predators in the rice ecosystem of Krishna district during dry season (pooled mean)*

	Yellow stem borer	**Pink stem borer**	**White stem borer**	**Dark headed stem borer**
Wolf spider	0.283*	-0.0415**	-0.0120	-0.0054
Long jawed spider	0.0003***	0.0094	0.0130	-0.0021
Lynx spider	0.01698*	-0.0257	0.048	-0.0260
Dragonfly	0.004	-0.0055*	0.0082	-0.0149
Damselfly	0.002	0.008	0.0374	0.0317
Preying mantid	-0.0002	-0.244	0.0298	0.0069
Mirid bug	0.0140	-0.002*	0.0263	-0.004
Carabid beetle	-0.004	-0.005	-0.0185	-0.0001
Tiger beetle	0.0325	0.0073	0.0078	0.0301
Lady bird beetle	0.0052	-0.0104	0.0086	-0.0298

Significance levels * = < 0.05, ** = < 0.01 & *** = < 0.001

From the present correlation matrix it can be inferred that there is a variation in association between stem borers and the predator's prevalence in the rice ecosystem of Krishna district. There was a dissimilarly in the correlations between stem borers and predators among the seasons under study as the abundance of predatory fauna may vary in different seasons as influenced by various cultivation or management aspects, abiotic and biotic stresses.

Analogous correlation studies by Rahaman *et al*. (2014) determined the relationship between rice stem borer species and natural enemies and stated that populations of PSB, DHSB, YSB, SSB and WSB were positively correlated with ladybird beetle (0.988, 0.929, 0.995, 0.945 & 0.945), wolf spider (0.710, 0.799, 0.849, 0.669 & 0.823), long jawed spider (0.979, 0.949, 0.935, 0.989, 0.937 & 0.937), lynx spider (0.184, 0.316, 0.397, 0.128 & 0.355), damselfly (0.999, 0.983, 0.963, 0.999 & 0.974), dragonfly (0.771, 0.678, 0.611, 0.806 & 0.647), green mirid bug (0.871, 0.796, 0.741, 0.898, 0.771) and negatively correlated with carabid beetle (-0.338,-0.207, -0.121,-0.391 & -0.166) and earwig (-0.544,-0.425,-0.345,-0.591 & -0.387) populations, respectively.

Israrul and Chakravorthy (2017) revealed that the incidence of natural enemies varied in relation to the YSB incidence exhibiting a positive correlation in their abundance. Parasappa et al. (2017a) stated that the YSB population in different rice ecosystem had exhibited positive and significant relationship with spider per hill (r = + 0.898*), staphylinidae per sq m (r = + 0.922*), carabidae per sq m (r = + 0.910*) and Odonata per sq m (r = + 0.833*).

The diversity indices for stem borer and predatory species in rice ecosystem

The diversity among stem borers and predators in the rice ecosystem of Krishna district regarding the rarity and commonness of species in a particular community was determined used various indices and their spatial distribution patterns were determined.

Margalef Richness index (R) for species richness

It was clearly evidenced from the analyzed data that species richness varied at various mandals of Krishna district both for stem borer species and predators in rice habitats. The index also varied among the four seasons under study period and hence the

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mean index for both *wet* and *dry* seasons was evaluated to assess the species richness. However, in all the mandals for both the seasons the number of species was found more or less constant. With respect to stem borer species, the mean richness index for *wet season* was highest in Vatsavai (0.379) mandal followed by Koduru, Mopidevi and Mylavarum mandals with 0.378 index. The other mandals in descending order of richness index were Ghantasala (0.377) ≥ Ibrahimpatnam (0.377) > G. Konduru (0.376) ≥ Jaggayapeta (0.376) > Penuganchiprolu (0.375) > Machilipatnam (0.372).

The pooled mean Margalef richness index rank order for rice stem borers during *dry season* were Vatsavai (0.377) ≥ Mylavarum (0.377) > Penuganchiprolu (0.375) > G. Konduru (0.374) ≥ Koduru (0.374) > Jaggayapeta (0.373) ≥ Ibrahimpatnam (0.373) > Machilipatnam (0.372) > Mopidevi (0.371) > Ghantasala (0.370) (*Table 7*). The pooled mean Margalef richness index for predators in various mandals of rice ecosystem during *wet season* were highest in G. Konduru (1.189), followed by Vatsavai and Ghantasala (1.180) Mandals. The other mandals in order of highest richness index included Mopidevi (1.177) > Mylavarum (1.168) > Koduru (1.167) > Machilipatnam (1.166) ≥ Ibrahimpatnam (1.166) > Jaggayapeta (1.165) > Penuganchiprolu (1.162) and for *dry season* the highest index were recorded in G. Konduru (1.211) > Vatsavai (1.209) > Ghantasala (1.200) > Mopidevi (1.199) > Mylavarum (1.198) > Machilipatnam (1.195) > Koduru (1.192) > Ibrahimpatnam (1.191) > Jaggayapeta (1.189) > Penuganchiprolu (1.186) (*Table 8*).

Table 7. *Margalef Richness index for rice stem borer species of Krishna district*

Mandal	Wet season, 2016	Wet season, 2017	Mean	Dry season, 2016-17	Dry season, 2017-18	Mean
G. Konduru	0.374	0.378	0.376	0.373	0.376	0.374
Ghantasala	0.376	0.377	0.377	0.371	0.369	0.370
Ibrahimpatnam	0.374	0.381	0.377	0.375	0.371	0.373
Jaggayapeta	0.375	0.377	0.376	0.375	0.371	0.373
Koduru	0.375	0.381	0.378	0.374	0.374	0.374
Machilipatnam	0.376	0.388	0.382	0.375	0.370	0.372
Mopidevi	0.373	0.383	0.378	0.370	0.372	0.371
Mylavarum	0.375	0.381	0.378	0.370	0.385	0.377
Penuganchiprolu	0.373	0.377	0.375	0.372	0.379	0.375
Vatsavai	0.374	0.384	0.379	0.373	0.381	0.377

Table 8. *Margalef Richness index for predators in the rice ecosystem of Krishna district*

Mandal	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
G. Konduru	1.220	1.159	1.189	1.219	1.203	1.211
Ghantasala	1.208	1.152	1.180	1.219	1.182	1.200
Ibrahimpatnam	1.189	1.143	1.166	1.215	1.168	1.191
Jaggayapeta	1.187	1.143	1.165	1.204	1.174	1.189
Koduru	1.195	1.139	1.167	1.204	1.181	1.192
Machilipatnam	1.190	1.143	1.166	1.208	1.182	1.195
Mopidevi	1.197	1.157	1.177	1.211	1.187	1.199
Mylavarum	1.190	1.147	1.168	1.217	1.180	1.198
Penuganchiprolu	1.186	1.139	1.162	1.201	1.172	1.186
Vatsavai	1.197	1.163	1.180	1.222	1.197	1.209

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From the above results, it was inferred that among all the mandals of Krishna district the species richness (number of species prevalent in that community) was more or less constant. However, richness index was highest in Vatsavi and G. Konduru mandals for stem species and predatory guild in rice ecosystem for both *wet* and *dry* seasons, respectively.

Shannon-Wiener index (H')

The Shannon Wiener diversity index for rice stem borers were highest in Ibrahimpatnam (0.544) during *wet season* and was followed by Penuganchiprolu, Mylavarum, Jaggayapeta, Koduru, Ghantasala, Machilipatnam, Vatsavai, G. Konduru with 0.524, 0.517, 0.516, 0.510, 0.510, 0.509, 0.488 and 0.407 index values and lowest being recorded in Mopidevi (0.344). The same for *dry season* were found highest in Koduru and Penuganchiprolu mandals with 0.669 index value. The next highest index was noticed in Mylavarum (0.649), Machilipatnam (0.628), Vatsavai (0.622), Mopidevi (0.617), Jagayyapeta (0.608), Ibrahimpatnam (0.592), G. Konduru (0.535) and Ghantasala (0.530) mandals (*Table 9*).

Table 9. *Shannon Wiener indices for rice stem borer species of Krishna district*

Mandal	***Wet season*, 2016**	***Wet season*, 2017**	**Mean**	***Dry season*, 2016-17**	***Dry season*, 2017-18**	**Mean**
G. Konduru	0.488	0.325	0.407	0.635	0.436	0.535
Ghantasala	0.617	0.402	0.510	0.730	0.331	0.530
Ibrahimpatnam	0.652	0.436	0.544	0.762	0.422	0.592
Jaggayapeta	0.608	0.424	0.516	0.795	0.422	0.608
Koduru	0.631	0.389	0.510	0.809	0.529	0.669
Machilipatnam	0.597	0.421	0.509	0.757	0.500	0.628
Mopidevi	0.552	0.136	0.344	0.721	0.514	0.617
Mylavarum	0.551	0.484	0.517	0.689	0.609	0.649
Penuganchiprolu	0.538	0.511	0.524	0.685	0.654	0.669
Vatsavai	0.552	0.424	0.488	0.678	0.566	0.622

During *wet season* the Shannon Wiener indices for predators (*Table 10*) were highest in Penuganchiprolu (2.059) mandal followed by Mylavarum (2.051), Mopidevi (2.042), Machilipatnam (2.014), Koduru (1.984), Jaggayapeta (1.977), Ibrahimpatnam (1.962), G. Konduru (1.947) and Ghantasala (1.937). The rank order for indices during *dry season* were Mylavarum (2.140) > Penuganchiprolu (2.129) > Mopidevi (2.114) > Machilipatnam (2.104) > Koduru (2.089) > Ibrahimpatnam (2.076) > Jaggayapeta (2.067) > Ghantasala (2.060) > G. Konduru (2.051). Relatively the index values were higher for stem borer species in *dry season* compared to *wet season* the reason might be during *dry season* the white stem borer incidence found higher than *wet season*. The highest index value of stem borers and predators for both the seasons were comparatively high in Penuganchiprolu mandal.

Simpson index (λ)

The Simpson index values for stem borers and predators in the rice ecosystem were presented in *Tables 11* and *12*, respectively. For the stem borers the Simpson index were highest (0.357) in Vatsavai mandal and lowest in G. Konduru (0.177) mandal during

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wet season while the value in other mandals ranged in between 0.224 to 0.258 representing less diversity. In *dry season*, the order of index values in descending manner were noticed in Koduru (0.332) > Penuganchiprolu (0.330) > Mylavarum (0.317) > Machilipatnam (0.306) > Vatsavai (0.303) > Mopidevi (0.299) > Jagayyapeta (0.295) > Ibrahimpatnam (0.284) > Ghantasala (0.252) > G. Konduru (0.249).

Table 10. *Shannon Wiener indices for predators in the rice ecosystem of Krishna district*

Mandal	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
G. Konduru	1.964	1.930	1.947	2.048	2.055	2.051
Ghantasala	1.943	1.932	1.937	2.063	2.057	2.060
Ibrahimpatnam	1.960	1.965	1.962	2.085	2.068	2.076
Jaggayapeta	1.955	2.000	1.977	2.079	2.056	2.067
Koduru	1.955	2.013	1.984	2.081	2.098	2.089
Machilipatnam	2.031	1.997	2.014	2.106	2.103	2.104
Mopidevi	2.008	2.077	2.042	2.118	2.111	2.114
Mylavarum	2.045	2.058	2.051	2.154	2.126	2.140
Penuganchiprolu	2.060	2.059	2.059	2.140	2.118	2.129
Vatsavai	2.061	2.091	2.076	2.154	2.154	2.154

Table 11. *Simpson index for rice stem borer species of Krishna district*

Mandal	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
G. Konduru	0.218	0.135	0.177	0.307	0.190	0.249
Ghantasala	0.294	0.183	0.239	0.364	0.139	0.252
Ibrahimpatnam	0.316	0.199	0.258	0.379	0.189	0.284
Jaggayapeta	0.287	0.188	0.238	0.399	0.190	0.295
Koduru	0.300	0.167	0.234	0.412	0.252	0.332
Machilipatnam	0.281	0.183	0.232	0.376	0.236	0.306
Mopidevi	0.254	0.194	0.224	0.356	0.241	0.299
Mylavarum	0.254	0.224	0.239	0.337	0.296	0.317
Penuganchiprolu	0.243	0.232	0.238	0.334	0.326	0.330
Vatsavai	0.253	0.461	0.357	0.331	0.274	0.303

Table 12. *Simpson index for predators in the rice ecosystem of Krishna district*

Mandal	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
G. Konduru	0.831	0.827	0.829	0.844	0.855	0.849
Ghantasala	0.830	0.835	0.833	0.852	0.859	0.855
Ibrahimpatnam	0.836	0.839	0.838	0.858	0.858	0.858
Jaggayapeta	0.834	0.847	0.841	0.859	0.855	0.857
Koduru	0.833	0.847	0.840	0.859	0.863	0.861
Machilipatnam	0.850	0.845	0.848	0.864	0.864	0.864
Mopidevi	0.842	0.859	0.851	0.866	0.867	0.866
Mylavarum	0.849	0.853	0.851	0.872	0.869	0.870
Penuganchiprolu	0.852	0.854	0.853	0.870	0.866	0.868
Vatsavai	0.852	0.862	0.857	0.871	0.872	0.871

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The Simpson index during *wet season* for predators were assessed and revealed highest values in Vatsavai (0.857) > Penuganchiprolu (0.853) > Mylavarum (0.851) ≥ Mopidevi (0.851) > Machilipatnam (0.848) > Jagayyapeta (0.841) > Koduru (0.840) > Ibrahimpatnam (0.838) > Ghantasala (0.833) > G. Konduru (0.829). The mean index values during *dry season* were highest in Vatsavai (0.871) > Mylavarum (0.870) > Penuganchiprolu (0.868) > Mopidevi (0.866) > Machilipatnam (0.864) > Koduru (0.861) > Ibrahimpatnam (0.858) > Jagayyapeta (0.857) > Ghantasala (0.855) > G. Konduru (0.849).

The Simpson index revealed high diversity among stem borer species and predators in the rice ecosystem among various mandals surveyed. Comparative assessments inferred that at Vatsavai mandal highest Simpson index was observed for both borers and predatory fauna of rice ecosystem.

Pilou species evenness (J)

The mean per cent Pilou species evenness of stem borer species ranged from 29.351 to 37.820 during *wet season* and from 38.267 to 48.283 during *dry* seasons, respectively. The highest per cent evenness among stem borer species fauna were observed in Penuganchiprolu mandal with 37.820 and 48.283 per cent evenness at *wet* and *dry* seasons, respectively. It was quite interesting to note that G. Konduru mandal had exhibited least per cent evenness among rice stem borers at both *wet* (29.351) and *dry* (38.267) seasons. The stem borer species per cent evenness at other mandals of Ghantasala, Ibrahimpatnam, Jaggayapeta, Koduru, Machilipatnam, Mopidevi, Mylavarum and Vatsavai had recorded 36.755, 39.240, 37.207, 36.715, 35.643, 37.333 & 35.202 per cent and 38.267, 38.628, 42.698, 43.918, 48.281, 45.344, 44.537, 46.825 & 44.885 per cent during *wet* and *dry season*s, respectively (*Table 13*).

Table 13. *Pilou species evenness for rice stem borer species of Krishna district*

Mandal	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
G. Konduru	35.231	23.471	29.351	52.635	23.898	38.267
Ghantasala	44.473	29.038	36.755	45.839	31.416	38.628
Ibrahimpatnam	47.020	31.460	39.240	54.956	30.440	42.698
Jaggayapeta	43.867	30.547	37.207	57.359	30.476	43.918
Koduru	45.492	28.050	36.771	58.383	38.179	48.281
Machilipatnam	43.044	30.386	36.715	54.623	36.065	45.344
Mopidevi	39.816	31.470	35.643	52.017	37.056	44.537
Mylavarum	39.766	34.900	37.333	49.692	43.958	46.825
Penuganchiprolu	38.799	36.841	37.820	49.423	47.142	48.283
Vatsavai	39.807	30.597	35.202	48.920	40.850	44.885

Similarly, the mean per cent Pilou species evenness for predatory inhabitants in the rice ecosystem of Krishna district (*Table 14*) inferred highest per cent evenness in Vatsavai mandal and lowest per cent eveness in G. Konduru mandal with 90.164 & 93.534 and 84.153 & 89.096 per cent during *wet* and *dry* seasons, respectively. The other mandals *viz*., Ghantasala, Ibrahimpatnam, Jaggayapeta, Koduru, Machilipatnam, Mopidevi, Mylavarum and Penuganchiprolu had registered per cent evenness of 84.576,

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85.220, 85.866, 86.147, 87.466, 88.718, 89.092 & 89.459 during *wet season* and 89.461, 90.165, 89.788, 90.744, 91.391, 91.840, 92.940 & 92.463 per cent during *dry season*, respectively.

Table 14. *Pilou species evenness for predators in the rice ecosystem of Krishna district*

Mandal	*Wet season,* 2016	*Wet season,* 2017	Mean	*Dry season,* 2016-17	*Dry season,* 2017-18	Mean
G. Konduru	84.387	83.918	84.153	88.955	89.236	89.096
Ghantasala	85.313	83.839	84.576	89.593	89.330	89.461
Ibrahimpatnam	85.120	85.324	85.220	90.538	89.792	90.165
Jaggayapeta	84.884	86.847	85.866	90.295	89.282	89.788
Koduru	84.889	87.404	86.147	90.367	91.121	90.744
Machilipatnam	88.187	86.744	87.466	91.462	91.319	91.391
Mopidevi	87.222	90.213	88.718	92.005	91.674	91.840
Mylavarum	88.809	89.375	89.092	93.532	92.348	92.940
Penuganchiprolu	89.479	89.438	89.459	92.959	91.967	92.463
Vatsavai	89.523	90.804	90.164	93.527	93.542	93.534

It was witnessed from the above results that in G. Konduru mandal the least per cent evenness of stem borer species and predators in rice ecology were recognized during both *wet* and dry seasons. The highest per cent evenness of stem borer species was recognized in Penuganchiprolu mandal, while in case with predators the highest evenness was perceived in Vatsavai mandal.

Morisita index of dispersion

The spatial distribution of stem borers and predators in the rice ecosystem of various mandals in Krishna district were determined by Morisita index of dispersion. The dispersion indices for stem borers in all the mandals were greater than one at both *wet* and *dry* seasons hence representing aggregate distribution pattern (*Table 15*).

Table 15. *Morisita's dispersion indices for rice stem borer species of Krishna district*

Mandal	*Wet season,* 2016	*Wet season,* 2017	Mean	*Dry season,* 2016-17	*Dry season,* 2017-18	Mean
G. Konduru	1.162	1.113	1.138	1.093	1.203	1.148
Ghantasala	1.144	1.206	1.175	1.105	1.076	1.091
Ibrahimpatnam	1.246	1.222	1.234	1.202	1.136	1.169
Jaggayapeta	1.072	1.230	1.151	1.037	1.227	1.132
Koduru	0.997	1.554	1.276	1.143	1.166	1.155
Machilipatnam	0.998	1.369	1.184	1.111	1.207	1.159
Mopidevi	1.080	1.150	1.115	1.234	1.199	1.217
Mylavarum	1.079	1.102	1.091	1.094	1.208	1.151
Penuganchiprolu	1.014	1.019	1.017	1.121	1.175	1.148
Vatsavai	1.132	1.128	1.130	1.217	1.223	1.220

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The mean Morisita index for predatory fauna during *wet season* were less than one at G. Konduru (0.991) and Ghantasala (0.966) mandals representing random distribution pattern, while the indices were greater than one for Ibrahimpatnam (10.19), Jaggayapeta (1.036), Koduru (1.067), Machilipatnam (1.075), Mopidevi (1.134), Mylavarum (1.093), Penuganchiprolu (1.083) and Vatsavai (1.138) mandals where aggregate distribution patterns were noticed. The mean index values during *dry season* were 0.855, 0.940, 0.947, 0.988 & 0.964 at G. Konduru, Ghantasala, Jaggayapeta, Penuganchiprolu and Vatsavai mandals representing random distribution of the predatory population while, indices were aggregate distribution pattern for Ibrahimpatnam, Koduru, Machilipatnam, mopidevi and Mylavarum with 1.004, 1.036, 1.020, 1.027 & 1.030 index values, respectively (*Table 16*).

Table 16. *Morisita's dispersion indices for predators in the rice ecosystem of Krishna district*

Mandal	*Wet season*, 2016	*Wet season*, 2017	Mean	*Dry season*, 2016-17	*Dry season*, 2017-18	Mean
G. Konduru	0.843	1.138	0.991	0.804	0.906	0.855
Ghantasala	0.867	1.065	0.966	0.864	1.016	0.940
Ibrahimpatnam	0.98	1.117	1.049	0.956	1.052	1.004
Jaggayapeta	0.961	1.11	1.036	0.835	1.059	0.947
Koduru	1.047	1.087	1.067	1.058	1.014	1.036
Machilipatnam	1.055	1.095	1.075	0.985	1.054	1.020
Mopidevi	1.111	1.157	1.134	1.04	1.014	1.027
Mylavarum	1.071	1.114	1.093	1.021	1.038	1.030
Penuganchiprolu	1.072	1.094	1.083	0.993	0.982	0.988
Vatsavai	1.109	1.166	1.138	0.845	1.082	0.964

The present findings were in concurrence with studies relating to abundance and spatial dispersion of rice stem borer species by Gounou and Schulthess (2004) who declared that aggregation of stem borer larvae along the field margins were abundant and might have been caused by migration of stem borers from alternative host plants around the rice fields.

Analogous studies in Kahama, Tanzania on rice stem borer species abundance and spatial distributions were carried out by Lenonard and Gration (2015) and admitted that stem borer had exhibited both uniform and aggregate type of distributions. Bonaventure *et al*. (2018) also conducted similar investigation in irrigated lowland rice ecosystem in Kilombero, Tanzania and confirmed an aggregated dispersion pattern for stem borers infesting rice and the parasitoids prevailing in rice ecosystem. Widyaningrum (2015) also studied the arthropods biodiversity by employing many diversity indexes in Indonesia.

Cluster analysis and per cent divergence

Cluster analysis by employing Euclidean distance function resulted in clustering the stem borer species and predators fauna of the rice ecosystem at Krishna district in to four different clusters (*Table 17*). The cluster I was represented with five cluster members *viz*., PSB, WSB, wolf spider, damselfly and mirid bug species whereas, the cluster II denotes only the yellow stem borer species. The cluster III was composed with

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three members *viz*., long jawed spider, dragonfly and lady bird beetle and the cluster IV was clustered with five cluster members *viz*., DHSB, lynx spider, preying mantid, carabid beetle and tiger beetle.

Table 17. *Cluster groups of stem borer species and predatory fauna in the rice ecosystem of Krishna district*

Cluster	Group	Within SS	Cluster members
1	5	2.9398	PSB, WSB, wolf spider, damselfly, mirid bug
2	1	0.0000	YSB
3	3	1.8990	Long jawed spider, dragonfly, lady bird beetle
4	5	0.1039	DHSB, lynx spider, preying mantid, carabid beetle, tiger beetle

There was a difference in cluster means of four clusters in various mandals of Krishna district (*Table 18*) and comparatively the means of abundance were recorded highest in cluster IV ranging from 2.007 to 2.405 per cent. Among all the clusters, cluster I recorded lowest mean abundance of species ranging between 1.018 to 1.352 per cent. The mandals minimum variance dendrogram (*Fig. 3*) revealed that spiders and beetles population depends on stem borer's abundance. Cluster analysis also indicated that there was a relationship between the stem borer abundance and the predatory fauna prevalence in the rice ecosystem of Krishna district. The clustering pattern was utilized in identifying the per cent divergence composition with respect to various mandals of Krishna district.

Table 18. *Cluster means of stemborer species and predatory fauna in the rice ecosystem of Krishna district*

Clusters	G. Konduru	Ghanta sala	Ibrahim patnam	Jaggaya peta	Koduru	Machili patnam	Mopidevi	Mylava ram	Penugan chiprolu	Vatsavai
1 Cluster	1.018	1.303	1.378	1.347	1.452	1.319	1.352	1.351	1.374	1.239
2 Cluster	0.910	1.389	1.481	1.559	1.517	1.516	1.550	1.594	1.589	1.500
3 Cluster	1.758	2.003	2.103	2.175	2.093	2.115	1.943	1.968	2.133	1.766
4 Cluster	2.007	2.229	2.252	2.405	2.304	2.264	2.108	2.233	2.368	2.026
Mean	2.370	2.510	2.522	2.542	2.482	2.452	2.471	2.424	2.535	2.337
F Ratio	29875.044	47896.822	16232.744	8367.192	6251.494	39114.135	8863.166	4790.852	4041.252	5321.029

The per cent contribution towards species divergence in various mandals of Krishna district was depicted in *Figure 4*. The highest divergence was witnessed in Jaggayapeta mandal with 20.88 per cent contribution followed by Penuganchiprolu, G. Konduru, Ghantasala, Koduru, Machilipatnam, Ibrahimpatnam, Vatsavai and Mopidevi mandals with 17.58, 15.38, 15.38, 9.89, 8.79, 6.59, 3.30, 2.20 and 0.01 per cent contributions, respectively. Similar studies by Ashrith et al. (2017) described insect diversity in direct seeded and transplanted rice growing area and admitted a strong relation between insect pests and natural enemies in rice ecosystem.

The results inferred that yellow stem borer was the predominant stem borer species in the rice ecosystem of Krishna district with 82.0 and 78.88 per cent abundance during *wet* and *dry* seasons, respectively. Next to yellow stem borer, pink stem borer was more abundant than white stem borer and dark headed stem borer during *wet* season, whereas white stem borer was more dominant compared to pink stem borer and dark headed stem

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borer in *dry* season. The predatory fauna prevalent in the rice ecosystem of Krishna district exhibited uniform distribution throughout the crop season. The cluster analysis indicated a relationship between stem borer species abundance and predatory guild prevalence in the rice ecosystem of Krishna district and the highest species divergence was witnessed in Jaggayapeta mandal (20.88%) followed by Penuganchiprolu mandal (17.58%) whereas, in Mopidevi mandal the least divergence (0.01%) was noticed.

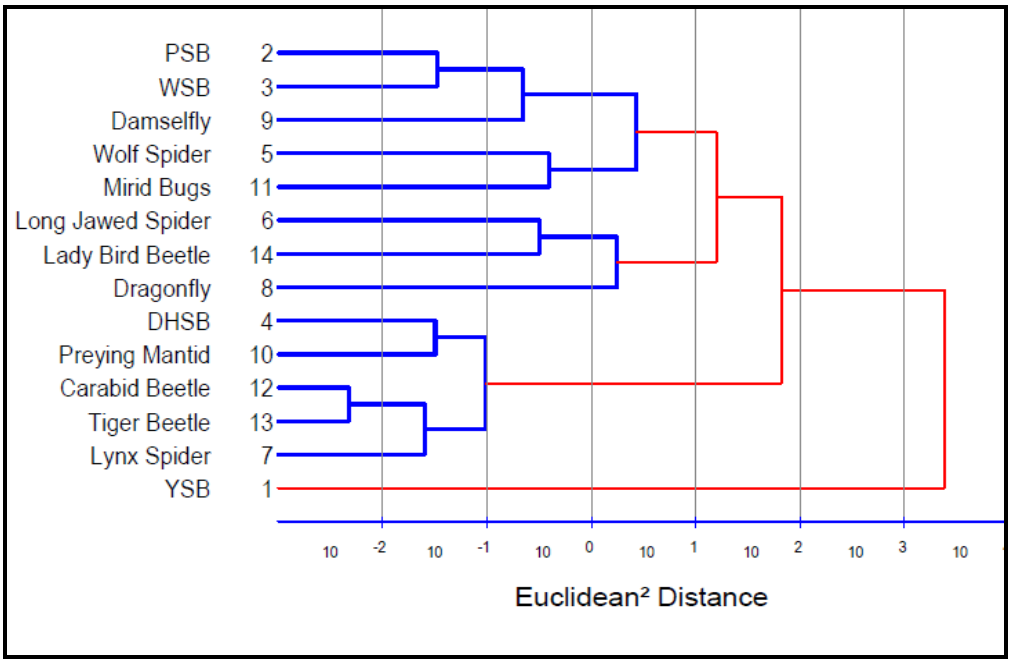

Figure 3. *Cluster analysis of stem borer species and predators in the rice ecosystem of Krishna district (Mandals minimum variance dendrogram)*

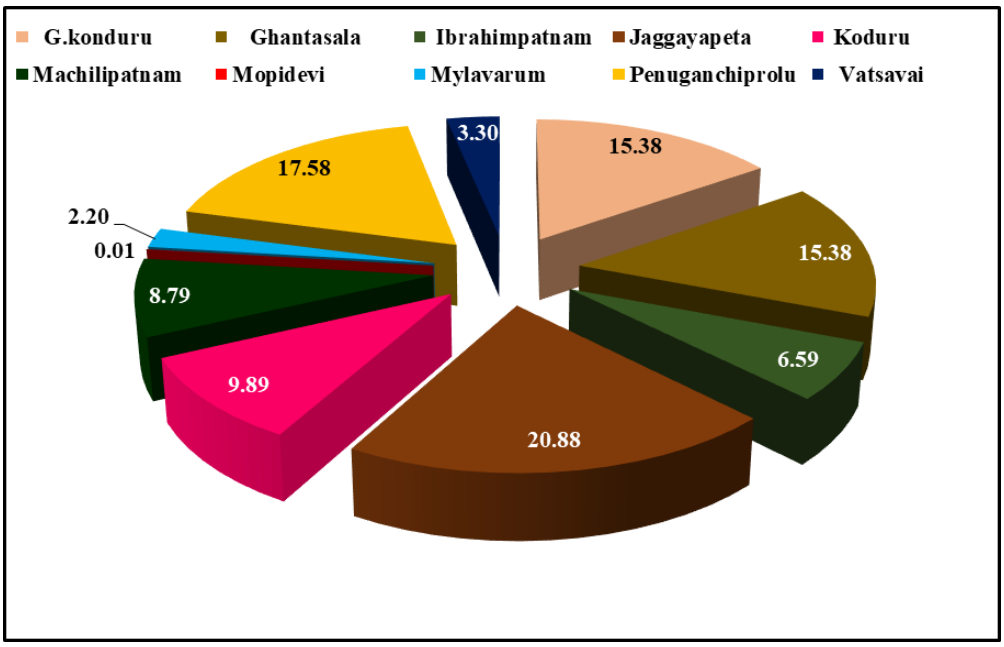

Figure 4. *The contribution (%) towards species divergence in various mandals of Krishna district*

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REFERENCES

[1] Ameilia, Z. S., Salmah, C., Rawi, M., Zulkifli, N. (2008): Abundance and diversity of Odonata in upland rice Field at Manik Rambung, North of Sumatera. – In: Proceedings of the 7th IMT-GT UNINET and the 3rd International PSU-UNS Conferences on Bioscience, Sumatera, Indonesia, pp 55-61.

[2] Anbalagan, G., Narayanasamy, P. (1999): Population fluctuation of spiders in the rice ecosystem of Tamil Nadu. – Entomon 24: 91-95.

[3] Arif, P., Misra, A. K., Mandal, S. K., Abdus, S. (2005): Activity of *Scirpophaga incertulas* and *Lycosa pseudoannulata* in boro rice as influenced by meteorological parameters. – J Appl 15(2): 55-59.

[4] Ashrith, K. N., Sreenivas, A. G., Guruprasad, G. S., Hanchinal, S. G., Chavan, I. (2017): Insect diversity: a comparative study in direct seed and transplanted rice ecosystem. – J Entomol 5(6): 762-765.

[5] Baitha, A. (1991): Management of important insect pests of rice with neem *(Azadirachta indica* A. Juss.). – MSc Dissertation. Rajendra Agricultural University, Pusa, Bihar, India.

[6] Balleras, G. D., Marjie, S., Doverte1, Leah, E., Endonela (2016): Alarming presence of three rice stem borer species in irrigated lowland rice agroecosystem in Midsayap, North Cotabato, Philippines. – JBES 9(5): 105-109.

[7] Banwo, O. O. (2002): Management of major insect pests of rice in Tanzania. – Plant Protect Sci. 38: 108-113.

[8] Battu, G. S. (1990): On the predatory activity of certain arthropods against insect pests of crop. – J Entomol. 52(2): 255-257.

[9] Bonaventure, J., Gration Rwegasira, M., Tadele, T. (2018): Distribution of rice stem borers and their parasitoid in irrigated low land rice ecosystem in Kilombero valley, Morogoro, Tanzania. – J Entomol 6(2): 237-242.

[10] Catling, H. D., Islam, Z., Pattrasudhi, R. (1984): Seasonal occurrence of the yellow stem borer, *Scirpophaga incertulas* (Walker) on deep water rice in Bangladesh and Thailand. – Agri Ecosyst Environ 2: 71.

[11] Chakraborty, K., Moitra, M. N., Sanyal, A., Rath, P. C. (2016): Important natural enemies of paddy insect pests in the upper Gangetic plains of West Bengal, India. – IJPAES 6(1): 35-40.

[12] Chakravorty, S. (1979): Damage of rice grains by stem borer attack. – IRRN 4: 17.

[13] Damayanti, D., Siwin, S. S., Soejitno, J. (1991): Distribution and composition of rice stem borer species in central Java. Balai Penelitian Tanaman Pangan Bogor (Indonesia). – In: Proceeding of the Seminar Hasil Penelitian Tanaman Pangan Balittan Bogor Tahun. Balittan 2, pp. 378-387.

[14] Dutt, N., Kundu, D. K. (1983): Stem borer complex of paddy on West Bengal. – Indian J Entomol 45: 229-236.

[15] Geethavishwanathan, Keerhi, M. G., Sreeram, S. (1996): Feeding behaviour of Linyphia (Sheet web weaver). – Insect Entomol 2(1): 29-30.

[16] Gounou, S., Schulthess, F. (2004): Spatial distribution of lepidopterous stem borers on indigenous host plants in West Africa and its implications for sampling schemes. – Journal of African Entomology.12: 171-178.

[17] Gupta, M., Pawar, A. D. (1992): Biological wealth in rice ecosystem. – Plant Prot Bull 44(3): 11.

[18] Gupta, M., Rao, P., Pawar, A. D. (1986): Survey of the predatory spider fauna from rice agro-ecosystems. – Indian J of Plant Prot 14(2): 19-21.

[19] Heed, L., Jenner, E., Matthew, J. W. C. (2019): Climate-smart pest management: building resilience of farms and landscapes to changing pest threats. – J Pest Sci 92: 951-969.

[20] Husain, M., Begum, N. (1985): Seasonal stem borer (SB) population fluctuations in Mymensingh, Bangladesh. – IRRN 10: 22.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2101_133156

[21] Islam, Z. (1996): Yellow stem borer, a threat to boro rice in coastal belt of Bangladesh. – J Entomol 6(1&2): 45-52.
[22] Israrul, H. M., Chakraborty, K. (2017): Observation on the impact of environmental parameters on rice yellow stem borer, *Scirpophaga incertulas* (Walker) and its natural enemies at Murshidabad, West Bengal, India. – J Entomol 5(6): 1656-1663.
[23] Jayakumar, S., Sankari, A. (2005): Spider population and their predatory efficiency in different rice establishment techniques in Aduthurai, Tamil Nadu. – J Biopest 3(1): 20-27.
[24] JianWei, S., Cheng Fa, S. (2002): Trapping effect of synthetic pheromone blends on two stem borers, *Chilo suppressalis* and *Scirpophaga incertulas*. – CRRN 10(2): 8-9.
[25] Kasyanov, A. I. (2010): Coccinellids in rice systems of the Krasnodar Krai. – Zashchita-i-Karantin-Rastenii. 7: 23-24.
[26] Khan, R. M. (1983): Studies on the common predatory and parasitic species of insects collected on light trap at Jabalpur. – M.Sc. (Ag.) Thesis submitted to Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India.
[27] Leonard, A., Gration, M. R. (2015): Abundance and spatial dispersion of rice stem borer species in Kahama, Tanzania. – J Insect Sci 15(1): 132.
[28] Litsinger, J. A., Alviola, A. L., Cruz, G. D., Canapi, B. L., Batay-An, E. H., Barrion, A. T. (2006): Rice white stem borer *Scirpophaga innotata* (Walker) in southern Mindanao, Philippines. I. Supplantation of yellow stem borer *S. incertulas* (Walker) and pest status. – Int J Pest Manage 52(1): 11-21.
[29] Magurran, A. E. (1988): Ecological Diversity and Measurement. – Princeton University Press, Princeton
[30] Mahar, M. M., Hakro, M. R. (1979): The prospects and possibilities of yellow rice stem borer eradication under Sindh condition. – Paper presented at the Rice Research and Production Seminar, Islamabad.
[31] Mohan, R. L. (2000): Possibilities of utilization of spiders as bioagents in rice ecosystem. – MSc thesis dissertation. University of Agricultural Sciences, Bangalore, Karnataka, India.
[32] Murali, B. R. K., Sharma, K. C., Kumar, J. (2017): Seasonal and relative abundance of stem-borer and leaf folder in wet land rice eco-system. – J Entomol 5(2): 879-884.
[33] Noorhosseini, S. A., Allahyari, M. S., Sabouri, M. S. (2010): Factors Influencing the Adoption of Biological Control of Rice stem borer (*Chilo suppressalis*) in Talesh Region, Iran. – International Journal of Agricultural Science and Research 1: 1.
[34] Pallavi, D., Sharanabasappa, Megaladevi, P. (2018): Relative abundance of yellow stem borer and pink stem borer on paddy. – J Entomol 6(4): 668-671.
[35] Parasappa, H. H., Narasa Reddy, G., Neelakanth (2017): Rice insect pests and their natural enemies complex in different rice ecosystem of Cauvery command areas of Karnataka. – J Entomol 5(5): 335-338.
[36] Pathak, M. D., Khan, Z. R. (1994): Insect Pests of Rice. – International Rice Research Institute, Manila, Philipines, pp 5-17.
[37] Qadeer, G. A., Sinha, S. N., Tomar, R. S. (1990): Light trap catches of major insect pests of rice in Karnal district (Haryana) and its relation with climatic factors. – Plant Prot Bull, Faridhabad 42: 1-6.
[38] Ragini, J. C., Thangaraju, D., David, P. P. M. (2000): Stem borer species composition in Tamil Nadu, India. – IRRN 25: 15.
[39] Rahaman, M. M., Islam, K. S., Jahan, M., Mamun, M. A. A. (2014): Relative abundance of stem borer species and natural enemies in rice ecosystem at Madhupur, Tangail, Bangladesh. – J Bangladesh Agric Univ 12(2): 267-272.
[40] Rahim, A., Jabbar, A., Hashmi, A. A., Khan, N. A. (1992): Chemical control of yellow stem borer in Sindh. – Pak J Agric Sci 13(4): 380-389.
[41] Rai, A. K., Singh, A. K., Hameed, S. F., Metho, D. N. (1989): Relative abundance of different spp. of stem borer in deep water rice in North Bihar. – Oryza 26: 282-284.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2101_133156

[42] Rubia, E. G., Almazon, L. P. (1990): Predation of yellow stem borer moth by wolf spider. – IRRN 15(5): 22.
[43] Salim, M. S., Masud, A., Ramzan, M. (2001): Integrated Pest Management of Basmati Rice in Pakistan. – In: Chaudhry, R. C. Tran, D. V. (tech. eds.) Duffy, R. (ed.) Speciality Rice of the World: Breeding, Production and Marketing. FAO, Rome, Italy, pp 149-162.
[44] Sharma, D. R., Gill, P. S., Dhaliwal, G. S. (1996): Extent of damage and pattern of emergence of over wintering larvae of rice stem borer in Punjab. – Indian J Entomol 23(2): 104-108.
[45] Thomas, J. A. (2005): Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. – Philos T R Soc B 360(1454): 339-57.
[46] Tiwari, V. K., Dubey, O. P., Tiwari, S. K. (2001): Predatory status of paddy pests in Jabalpur region. – Res Crop 2(3): 375-377.
[47] Venkateshalu (1996): Ecological studies on spiders in rice ecosystems with special reference to their role as biocontrol agents. – MSc thesis dissertation, University of Agricultural Sciences, Bangalore, Karnataka, India.
[48] Wang, D. D., Ye, Z. (1989): Composition and dynamics of the spider fauna in paddy of lianxi, Province. – Chinese J Biol Control 3(1): 11-14.
[49] Widyaningrum, I. (2015): Pest and weed suppressive mechanisms in complex rice system at Malang, East Java, Indonesia. – MSc thesis dissertation, Organic Agriculture Wageningen University, The Netherlands.
[50] Yadav, M., Prasad, R., Priyanka, K., Monisha, M., Kumari, A., Chitrangda, P., Saurabh, A., Krishna, P., Singh, A. K., Prasad, D., Singh, D. N., Kumar, R., Kumar, J. P. (2018): Potential and prospects of natural enemies in rice ecosystem in Jharkhand. – IJCMAS 7: 3389-3396.

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