

Article

## Insect pest infestation on *Gmelina arborea* Roxb. in different agroclimatic zones of Jharkhand, India

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### Abstract

The fast growing and multipurpose timber species *G. arborea* has problem of multiple insect pest attack in India. To understand the diversity of insect pest infestation abundance on *Gmelina arborea*, the data was collected on insect pest infestation (%) in three agro-climatic zones (Zone IV, V and VI) of Jharkhand province of India over a period of 3 years. Results shows that the plants were infested with total twenty insect pests species, out of these ten insect pest were recorded as new for *G. arborea*. Various diversity and similarity indices were calculated to explore the relationship of insect pest infestation among zones. It was found that Zone V have the maximum species infestation diversity followed by the zones IV and VI, whereas, zones IV and V were most similar and zone VI was differ from others. Duncan's multiple range test determined that *Phyllocnistis amydropa* was the most abundant species for *G. arborea*. Additionally, ten insect pests viz. *Maladera* sp., *Hyperops coromandelensis*, *Lobotrachelus* sp., *Apion* sp., *Ectropis bhurmitra*, *Belippa lalean*, *Pagyda* sp., *Phromnia marginella*, and *Homeocerus inornatus*, *Megalurothrips peculiaris* were found to be as new insect pest records, infesting to *G. arborea* first time. The study may helpful to understand the expanding range of insect pest fauna of *G. arborea* in the country and framing insect pest management policy more effectively.

**Key words** abundance; alpha diversity; beta diversity; insect pest infestation; *Gmelina arborea*; new records.

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### 1 Introduction

India has diversified forest type including dry desert forest to moist rain forest (Champion and Seth, 1968) which covers about 21.23 % of total geographical area. The Jharkhand province has 29.45 % forest cover with 3.30 % forest cover of India (Anonymous, 2013). *Gmelina arborea* Roxb. (Family: Verbenaceae) is fast growing timber species and has additional importance due to its medicinal properties (Pathala et al., 2015) which widely occurs in deciduous and moist forest of India. It is naturally spread throughout the India and its

major plantation has also been raised outside the forest (Singh et al., 2002). Such a fast growing multipurpose timber species has encounter the problem of multiple insect pest infestation. Various worker has observed 101 insect pests infesting to *G. arborea* has been reported from India (Mathur and Singh, 1959; Nair and Mathew, 1988; Meshram et al., 2001; Beesen, 1941) reported. The heavy infestation of termite was noticed in natural forest of North- East India (Chaudhuri, 1925). Subsequently, Mathur and Singh (1959) recorded 21 defoliators and 13 shot borers infesting to *G. arborea*, but *Calopepla leayana* and *Tingis beesoni* was found to be the most destructive defoliator (Beesen, 1941; Aung-Zeya, 1981; 1983; Nair and Mathew, 1988; Meshram et al., 2001; Mathur, 1979; Ahmed, 1982; Burman, 2014). Additionally, *Xyleutes ceramicus* hole borer; *Alcidodes ludificator* were recorded as serious pest in India (Beesen, 1941), wood boring insect *Xyleborus fornicates* (Mathew, 1986); *Eupterote undata* leaf defoliator (Sheikh and Kalita, 1995) was reported as serious insect pest of *G. arborea* in India. Some other important pest were reported viz. *Alcides ludificator* and *Eupterote undata*, *C. leayana*, *Perioptera maculipennis* and *Aleuropapillatus gmelinae* (Kumar et al., 1995), *Parasa lepida*, *Trypanophora semihyalina* in *G. arborea* plantation (Meshram and Gerg, 2000). Though, there are many scattered studies have been done on *G. arborea* so far as India is concerned, but none of the study was done exclusively to the insect pest fauna and their infestation on *G. arborea* in Jharkhand. Hence, this study is aimed to observed the total insect pest fauna of *G. arborea* and their infestation abundance in all the three agro-climatic zones of Jharkhand along with their diversity.

## 2 Materials and Methods

### 2.1 Study site

The study was carried out in all three agro-climatic zones of the province Jharkhand, India which spread out from the latitude 22°00' to 24°37' N and longitude 83°15' to 87°01' E (Fig. 1). These agro-climatic zones are namely, Central and North eastern plateau (Zone IV), Western plateau sub zone (Zone V), South eastern Plateau sub zone (Zone VI), all having low water retentive capacity of the soil particularly that of uplands, uneven distribution of rainfall and lack of safe disposal of runoff water during monsoon and water storage. The details of zonal distribution of the districts cover, geographical area, annual rainfall and total forest area are shown the Table 1. The present study deals with Zone IV covered 8 districts (including two-third area of Ranchi district), Zone V covered 9 districts (including one-third area of Ranchi district) and zone VI covered 3 districts as detailed in Table 1.

**Table 1** Description about agro-climatic zones of Jharkhand.

Zone	Districts covers	Geographical area (m ha)	Annual rainfall (mm)	Forest Area (%)
Zone IV	Bokaro, Chatra, Dumka*, Deoghar, Dhanbad, Giridih, Hazaribage, Koderma, two-third of Ranchi, Godda*, Sahebganj*, Pakur*, Jamtara*	4.1	1,320	13
Zone V	Garhwa, Gumla, Khunti, Latehar, Lohardaga, Palamu, Ramgarh, Simdega and one-third of Ranchi	2.5	1,246	33
Zone VI	East Singhbhum, Saraikela Kharsawan, West Singhbhum	1.3	1400	24

Note: All the districts are covered in the study excepts those marked with asterisk.

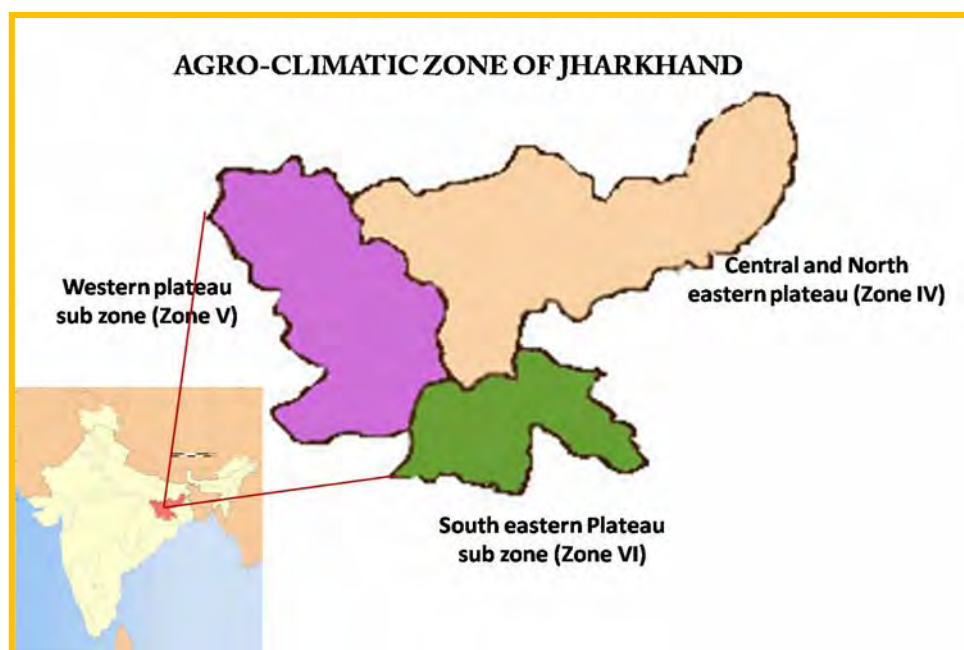


Fig. 1 Three agro-climatic zones of Jharkhand.

## 2.2 Sampling method for insect pest infestation

Based upon the priory information (list of forest areas of *G. arborea*), six forest areas, comprises natural and manmade forest, block plantation, road side plantation and bund plantation on farmer's field, in different directions of each district under study were randomly selected for insect pest data collection and their infestation. From each selected forest area, 25 trees of *G. arborea* were randomly selected and marked. The presence of the insect pest species in the selected trees from their root zone to the leaf were observed from 2011-2013 at monthly interval. We have taken different forest areas in all the three years to increase the precision of the result. The insects and their stages were collected and brought to the laboratory and reared for adult emergence. The adult insect pests were identified with the help of published literature. These identified insect were again confirmed from Zoological Survey of India (ZSI), Kolkata, India and Indian Agricultural Research Institute (IARI), New Delhi, India. The identified insect pests as new for the plant were indicated separately. Plant infestation data recorded at monthly interval during the three years was converted in percent plant infestation. On the basis of pooled data on plant infestation (%) observed was used for biodiversity indices calculation.

## 2.3 Biodiversity indices using infestation percentage

The biodiversity indices was calculated through the infestation (%) data using the method given by Whittaker (1967, 1972), who first discussed the diversity levels of natural communities in terms of alpha, beta and gamma diversity indices. Alpha represents the local diversity, beta represents the species similarity between sites and gamma shows the regional diversity (Li et al., 2014). In the present study, we have worked on various alpha and beta diversity indices to see the occurrence of insect pest infestation on *G. arborea* and their diversities within and between each agro-climatic zone. In alpha diversity, following four indices (Table 2) have been taken under consideration.

**Table 2** Formulae for within zone similarity indices.

Index Name	Formula
Shannon Index ( $H'$ )	$-\sum_{i=1}^S p_i \ln p_i$
Simpson Diversity Index ( $D_1$ )	$1 - \sum_{i=1}^S p_i^2$
Simpson Dominance Index ( $D_2$ )	$1 / \sum_{i=1}^S p_i^2$
Berger-Parker Dominance ( $BP_1$ )	$p_{\max}$
Berger-Parker Diversity ( $BP_2$ )	$\frac{1}{p_{\max}}$

$P_i$  is the proportion  $i^{\text{th}}$  species infestation in the zone, S is the total number of species responsible for infestation,  $p_{\max} = \max_{1 \leq i \leq S} (p_i)$  is the proportion value of the most abundant species.

Here,  $H'$  is an information statistic index, which means it assumes all species infestations are represented in a sample and that they are randomly sampled. It represents the probability of identifying an individual's infestation which is unknown to us. This means, in a highly diverse infestation population, an unknown infestation could belong to any species, leading to a low probability of right predictions about the identity while for the low diverse population (say dominated by only one or two species infestation), the same probability have higher value.  $D_1$  is the complement of Simpson's original index and represents the probability that two randomly chosen infesting belong to different species (McCune and Grace, 2002).  $D_2$  is closely related to  $D_1$ . Both these indices increase as diversity intuitively increases.  $BP_1$  is the dominance index. The inverse of this index is used as an index of diversity ( $BP_2$ ). The sample size does not affect BP's index.

**Table 3** Formulae for between zones similarity indices.

Index Name	Formula
Sorenson ( $\beta_s$ )	$\frac{2C}{S_1 + S_2}$
Bray-Curtis ( $\beta_{BC}$ )	$\frac{2C_{ij}}{I_1 + I_2}$
Jaccard ( $\beta_j$ )	$\frac{C}{C + S_1 + S_2}$

C represents the number of shared species responsible for infestation between two zones under comparison,  $C_{ij}$  is the sum of the lesser values for only those species in common between the both zones,  $S_1$  and  $S_2$  represents the total number of species counted at both sites and  $I_1$  and  $I_2$  are the sum of proportion of the insect pest infestation present in both zones.

Beta diversity is used in calculate zonal similarities (what the zones have in common in terms of species infestation) which helps us determine if we are comparing different zones each other or determine changes over time in a given region. Beta diversity is calculated by one of the important coefficient is called Sorenson's similarity index ( $\beta_s$ ) which gives a value between '0' and '1'. The value closer to '1' shows infestation similarity between the zone, while, the value enclined to 0 is shoes dissimilarity in the infestation. the more the zones have in common. Complete zone overlap is equal to '1'; complete zone dissimilarity is

equal to '0'. Other important beta diversity indices are calculated through Bray-Curtis index (Bray and Curtis, 1957) and Jaccard similarity index (Jaccard, 1912; Zhang, 2015). The formulae for these three indices are presented in the following Table 3.

#### 2.4 Duncan's multiple range test (DMRT) for species infestation

To compare the infestation of various insect species found across all the three agro-climatic zones, DMRT is used. procedure. DMRT involves the numerical boundaries that allow for the classification of the difference between any two species infestation as significant or non significant. In this method, we follow the following steps:

- (i) Rank all the species infestation either in increasing or decreasing order.
- (ii) Compute the standard error of the difference of means ( $SE_d$ ).

- (iii) Obtain the value of least significant range  $R_p = \frac{r_\alpha(p, edf)}{\sqrt{2}} SE_d$ ,

where,  $P=2,3,\dots$  is one more than the distance in rank between the pairs of the species infestation means to be compared,  $edf$  is the error degrees of freedom,  $\alpha$  is the desired level of significance (in our case, we have chosen  $\alpha=0.05$ ) and  $r_\alpha(p, edf)$  is the tabulated values obtained from Duncan's table of significant ranges.

- (iv) Finally, the observed differences between infestation by insect species are tested, beginning with largest versus smallest, then largest versus second smallest and so on until all means have been compared with the largest species infestation. Again, the second largest species infestation mean is compared with smallest, then second largest versus second smallest and so on. This process is continued until all the possible comparisons are calculated. If the observed difference is greater than the corresponding  $R_p$ , then we conclude that the pair of species infestation mean in the study is significantly differ with each other.

As the observed data contains the percent values, therefore, the data transformed into arcsine transformation before proceeding for the DMRT test. For the purpose of DMRT test using SPSS software version 21.

To understand the nature of data in terms of mean, median, inter-quartile range and possible outliers in the data, we further plotted box plots of species infestation for each agro-climatic zone and for each observed species. Means are shown by dots; boxes indicate median and inter-quartile range, with vertical lines depicting the range and '0' represents the presence of outliers (if any).

### 3 Results

#### 3.1 Insect pest of *G. arborea*

The result revealed that *G. arborea* was found to be infested with twenty insect pests belonging to five orders (Table 4). Out of these, ten insect pests viz. *Maladera* sp., *Hyperops coromandelensis*, *Lobotrachelus* sp., *Apion* sp., *Ectropis bhurmitra*, *Belippa lalean*, *Pagyda* sp., *Phromnia marginella*, and *Homeocerus inornatus*, *Megalurothrips peculiaris* were found to be as new insect pest records, infesting to *G. arborea* first time (Fig. 2).

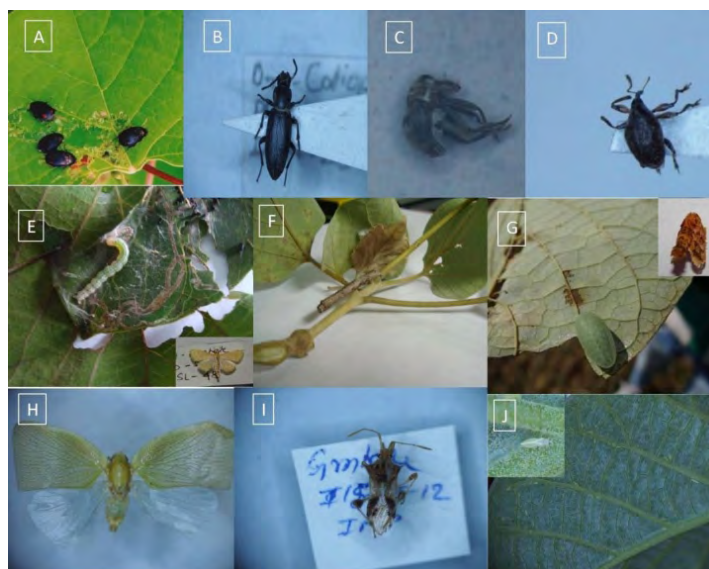
#### 3.2 Insect pest infestation

The observed infestation (%) for each zone has been presented in Table 5. A slight variation was found in infestation of the species across the zones. Maximum infestation was found for the species *Phyllocnistis amydropa* in Zone VI (94.39%). This species is also dominated in other two zones with their infestation 93.92 % and 93.25 % in the zones IV and V, respectively. DMRT test (Table 6) validated that, *Phyllocnistis amydropa* has the highest infestation over the Jharkhand Province and significantly differ with other species at 5% level of significance ( $p<0.05$ ). The relative percentages of insect infestation species are also considered to see the

contribution of infestation of a particular insect species among the total. For example, the relative percentage of the highly infested species *Phyllocnistis amydro*s have the relative percentage 17.58%, 16.87% and 16.7% for the zones VI, IV and V respectively. From Table 6, the species *Megalurothrips peculiaris*, *Pagyda* sp., *Indarbela quadrinotata*, and *Tingis beelsoni* are showing similar infestation in the province of Jharkhand ( $p \leq 0.05$ ) after the highly infested species *Phyllocnistis amydro*s. For the province of Jharkhand, it is to say that the species *Psylliodes bretteinghamii* have the least infestation percentage with non-significant difference with the species *Maladera* sp., *Phromnia marginella* and *Aspidomorpha miliaris*. The least infestation was found for the species *Psylliodes bretteinghamii* for each of the zones under study. The relative percentages of these species are 0.10, 0.20 and 0 for the zones IV, V and VI respectively.

**Table 4** Detail to insect pest infesting to the *G. arborea*.

SN	Species	Family	Common name	Nature of damage	Records
<b>Order: Coleoptera</b>					
1	<i>Alcides gmelinae</i> Marshall	Curculionidae	Shoot weevil	Leaf feeding	Beeson, 1941
2	<i>Dihammus cervinus</i> Gressitt	Cerambycidae	Trunk Borer	Trunk borer	Beeson, 1925
3	<i>Aspidomorpha miliaris</i> Fab.	Chrysomelidae	Tortoise beetle	Leaf feeder	Keshari, 2007
4	<i>Maladera</i> sp.	Scarabaeidae	Leaf beetle	Leaf defoliator	New record
5	<i>Hyperops coromandelensis</i> Sol	Tenebrionidae	Bark beetle	Bark feeder	New record
6	<i>Psylliodes bretteinghamii</i> Baly	Chrysomelidae	Leaf beetle	Leaf defoliator	Beeson, 1941
7	<i>Calopepla leayana</i> Latr.	Chrysomelidae	Defoliator	Leaf defoliator	Chaudhuri, 1925
8	<i>Lobotrachelus</i> sp.	Curculionidae	Leaf weevil	Leaf defoliator	New record
9	<i>Apion</i> sp.	Curculionidae	Leaf weevil	Leaf defoliator	New record
<b>Order: Lepidoptera</b>					
10	<i>Xyleutes ceramicus</i> Walker	Cossidae	Trunk borer	Trunk borer	Beeson, 1941
11	<i>Indarbela quadrinotata</i> Wal.	Cossidae	Bark caterpillar	Bark , trunk	Beeson, 1941
12	<i>Ectropis bhurmitra</i> Walker	Geometridae	Leaf caterpillar	Leaf defoliator	New record
13	<i>Phyllocnistis amydro</i> pa Mayr	Gracillariidae	Leaf miner	Leaf mining	Beeson, 1941
14	<i>Pagyda</i> sp.	Crambidae	Leaf folder	Leaf defoliator	New record
15	<i>Belippa laleana</i> Moore	Limacodidae	Gelatin grub	Leaf defoliator	New record
<b>Order: Hemiptera</b>					
16	<i>Tingis beelsoni</i> Drake	Tingidae	Tingid bug	Sap feeder	Beeson, 1941
17	<i>Phromnia marginella</i> (Oliv)	Flatidae	Flatid bug	Sap feeder	New record
18	<i>Homeocerus inornatus</i> Stål	Coeidae	Corid bug	Sap feeder	New record
<b>Order: Thysanoptera</b>					
19	<i>Megalurothrips peculiaris</i> Bagn.	Thripidae	Thrips	Sap feeder	New record
<b>Order: Isoptera</b>					
20	<i>Odontotermes obesus</i> Rambur	Termitidae	Termite	Bark, wood feeder	Akhtar et al., 1992



**Fig. 2** New recorded insect pest of *G. arborea* (A-J); A-*Maladera* sp.; B- *Hyperops coromandelensis* Sol; C- *Lobotrachelus* sp.; D- *Apion* sp.; E- *Pagyda* sp.; F- *Ectropis bhurmitra* Walker; G- *Belippalaleana* Moore; H- *Phromnia marginella* (Oliv); I- *Homeocerus inornatus* Stål and J- *Megalurothrips peculiaris* Bagnall.

**Table 5** Zone wise insect pest infestation (%) and their relative percentage.

Species	Zone IV		Zone V		Zone VI	
	Infestation %	Relative %	Infestation %	Relative %	Infestation %	Relative %
<i>Alcides gmelinae</i>	8.24	1.48	9.49	1.70	0.00	0.00
<i>Dihammus cervinus</i>	10.53	1.89	8.26	1.48	10.66	1.98
<i>Aspidomorpha miliaris</i>	2.46	0.44	2.28	0.41	0.00	0.00
<i>Maladera</i> sp.	1.39	0.25	1.34	0.24	0.00	0.00
<i>Hyperops coromandelensis</i>	4.48	0.80	11.15	2.00	14.00	2.61
<i>Psylliodes brettinghamii</i>	0.56	0.10	1.09	0.20	0.00	0.00
<i>Caloeppla leayana</i>	16.80	3.02	19.66	3.53	17.21	3.20
<i>Lobotrachelus</i> sp. Weevil	14.35	2.58	16.64	2.99	16.26	3.03
<i>Apion</i> sp.	25.68	4.61	27.16	4.87	28.38	5.29
<i>Xyleutes ceramicus</i>	19.55	3.51	14.50	2.60	14.24	2.65
<i>Indarbela quadrinotata</i>	75.64	13.59	69.52	12.47	67.29	12.53
<i>Ectropis bhurmitra</i> Walk	17.35	3.12	20.10	3.61	15.78	2.94
<i>Phyllocnistis amydropa</i>	93.92	16.87	93.25	16.73	94.39	17.58
<i>Pagyda</i> sp	72.93	13.10	71.50	12.83	69.53	12.95
<i>Belippa laleana</i>	16.51	2.97	16.48	2.96	12.36	2.30
<i>Tingis beelsoni</i>	67.68	12.16	63.53	11.40	63.08	11.75
<i>Phromnia marginella</i>	0.88	0.16	2.43	0.44	0.00	0.00
<i>Homeocerus inornatus</i>	13.70	2.46	14.46	2.59	14.76	2.75
<i>Megalurothrips peculiaris</i>	69.98	12.57	70.17	12.59	73.87	13.76
<i>Odontotermies</i> sp.	24.03	4.32	24.33	4.37	25.17	4.69

### 3.3 Diversity indices across zones

The calculated alpha and beta diversity indices presented in Table 7 and Table 8 respectively. In alpha diversity, the Shannon Index was found highest for the zone V ( $H^1=2.5340$ ) followed by zone IV ( $H^1=2.4856$ ) and VI ( $H^1=2.0429$ ). The order of increasing pattern for the zones V, IV and VI are found the same for Simpson diversity index ( $D_1=0.9002, 0.8954, 0.8930$ ) and for Berger-Parker diversity index ( $BP_2=5.9773, 5.9277, 5.6883$ ). Out of the two dominance indices Simpson Dominance Index ( $D_2$ ) and Berger-Parker

Dominance ( $BP_1$ ), the index  $D_2$  have the same order of magnitude ( $D_2=10.0250, 9.5586, 9.3495$ ) as found for all the three diversity indices; however, the index  $BP_1$  is found highest for the zone VI ( $BP_1=0.1758$ ) followed by the zones IV ( $BP_1=1687$ ) and V ( $BP_1=0.1673$ ). we can conclude from these indices that the zone V have the maximum number of species with more or less similar abundance whereas the zone VI has the poor species infestation richness. This may due to the species infestation not found by the species *Alcides gmelinae*, *Aspidomorpha miliaris*, *Maladera* sp., *Psylliodes brettehamii* and *Phromnia marginella* in zone VI.

**Table 6** Insect pest species infestation dominance homogeneous groups using DMRT test.

Insect Species	Homogeneous groups (Arc sine transformation based)							
	1	2	3	4	5	6	7	8
6	3.4302							
4	4.4738							
17	4.7780							
3	5.9000							
1		11.5417						
5			17.8980					
2			18.2292					
18			22.2223	22.2223				
15			22.8337	22.8337				
8			23.3688	23.3688				
10			23.5988	23.5988				
12				24.8871	24.8871			
7				25.0072	25.0072			
20					29.6726	29.6726		
9						31.3484		
16							53.5943	
11							57.3439	
14							57.6272	
19							57.6442	
13								75.6542
<i>p</i> value	0.393	1.000	0.059	0.354	0.088	0.521	0.161	1.000

Note: The names of the species corresponding to the S. No. shown above are given in Table 4.

**Table 7** Results of alpha diversity.

Index Name	Zone IV	Zone V	Zone VI
Shannon Index ( $H'$ )	2.4856	2.5340	2.0429
Simpson Diversity Index ( $D_1$ )	0.8954	0.9002	0.8930
Simpson Dominance Index ( $D_2$ )	9.5586	10.0250	9.3495
Berger-Parker Dominance ( $BP_1$ )	0.1687	0.1673	0.1758
Berger-Parker Diversity ( $BP_2$ )	5.9277	5.9773	5.6883

The result of beta diversity indices showed that the zones IV and V were most similar as the indices Sorenson ( $\beta_S$ ), Bray-Curtis ( $\beta_{BC}$ ) and Jaccard ( $\beta_J$ ) have the highest values between the zones IV and V ( $\beta_S=1.00$ ,  $\beta_{BC}=0.9636$ ,  $\beta_J=0.3333$ ). This means, for example, that there was 96.36% similarity between the

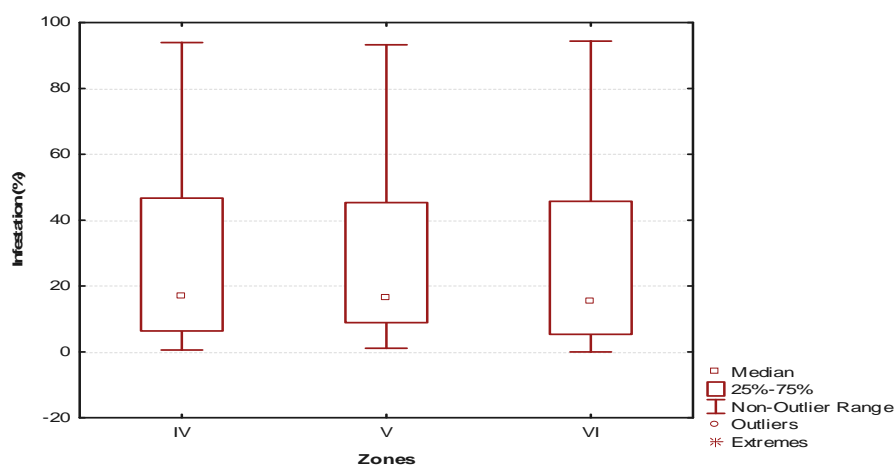


zone IV and V in terms of Bray-Curtis index. The zones IV and VI were found least similar in terms of all the beta diversity indices as shown in Table 8. This can be explained as; Sorenson index indicated that there was only 70.97% similarity between the zone IV and VI whereas Bray-Curtis and Jaccard indices respectively indicated that there was only 94.32% and 26.19% similarity between these two zones. The shared species statistics found in the *G. arborea* between the zones of Jharkhand species were also presented in Table 8.

**Table 8** Results of beta diversity.

Zone I*	Zone II*	$I_1$	$I_2$	C	Index Name		
					Sorenson ( $\beta_S$ ),	Bray-Curtis ( $\beta_{BC}$ )	Jaccard ( $\beta_J$ )
1	1	5.5663	5.5663	20	1.00	1.00	0.3333
1	2	5.5663	5.5734	20	1.00	0.9636	0.3333
1	3	5.5663	5.3696	11	0.7097	0.9432	0.2619
2	2	5.5734	5.5734	20	1.00	1.00	0.3333
2	3	5.5734	5.3696	11	0.7097	0.9586	0.2619
3	3	5.3696	5.3696	11	1.00	1.00	0.3333

Fig. 3 represents a box plot compiling data from three agro-climatic zones and shows that no species infestation are found in the outlier range. It means that the all insect infestation percentages were under the inter-quartile range. Similar results were obtained when the compiled data were taken from the all 20 species as depicted in Figure 4. Fig 4 revealed that amount of insect infestation was marginally higher for *Phyllocnistis amydropa* as compared to the other species.



**Fig. 3** Zone wise box plots depicting variation in infestation (%).

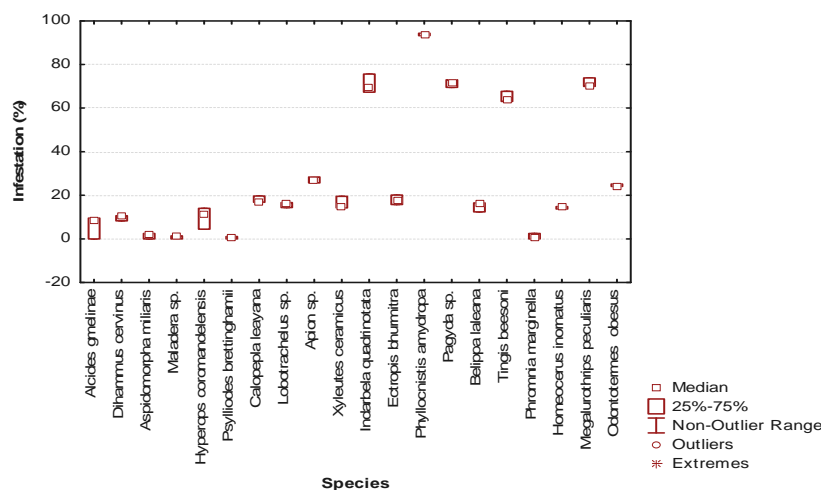


Fig. 4 Species wise box plots depicting variation in infestation (%).

#### 4 Discussion

The plant *G. arborea* was found to be infested with twenty insect pests from Jharkhand province. Out of these ten insect pests viz. *Alcides gmelinae*, *Dihammus cervinus*, *Aspidomorpha miliaris*, *Psylliodes bretteghamii*, *Calopepla leayana*, *Xyleutes ceramicus*, *Indarbela quadrinotata*, *Phyllocnistis amydroga*, *Tingis beelsoni*, *Odontotermes obsesus* were already reported from India (Stebbing, 1914; Beeson, 1941; Browne, 1968; Mathur and Singh, 1959; Mathew, 1986; Nayar and Sumardi, 2000; Meshram et al., 2001; Sharavati et al., 2012). Subsequently, ten insect pest viz. *Maladera sp.*, *Hyperops coromandelensis*, *Lobotrachelus sp.*, *Apion sp.*, *Pagyda sp.*, *Ectropis bhurmitra*, *Belippa lalleana*, *Phromnia marginella*, *Homeocerus inornatus*, *Megalurothrips peculiaris* were recorded first time on *G. arborea*.

In this study, infestation of *Phyllocnistis amydroga* was found to be maximum and it cause damage through mining in leaves, though, damage of this insect pest was not much damaging. After this species the *Indarbela quadrinotata*, *Tingis beelsoni*, *Pagyda sp.*, *Megalurothrips peculiaris* were found to be the next major infesting species. Amongst, *Indarbela quadrinotata* is a tree borer which cause a major damage to the developing timber, also (Varma, 1996) recorded as a major infesting species in India, *Tingis beelsoni* is a major sucking insect pest of *G. arborea* distributed all over the India (Burman, 2014; Beeson, 1941; Mathur, 1979), this insect suck the plant sap gregariously on growing plant parts resulted stunted growth and some time complete mortality of the plant (Meshram et al., 2001; Meshram and Tiwari, 2003). *Pagyda sp.* was reported first time from *G. arborea* and it larvae folds the leaves and feed internally and made the leaves skeletonised. *Megalurothrips peculiaris* were found to be new for the *G. arborea*.

*Calopepla leayana* was found as a major insect pest of *G. arborea* in this study, though the infestation (%) was less, but more destructive to the plant. Beeson (1941) has reported widely distribution of *T. beelsoni* throughout in India (Mathew, 1986; Kumar et al., 1995; Meshram et al., 2001), this beetle feeds on the leaf, cutting large circular holes and also cuts the young buds and shoots (Garthwaite, 1939; Ahmed and Sen-Sharma, 1983; 1990; Ahmed et al., 1983; Sen-Sharma et al., 1983; Sen-Sharma and Ahmed, 1984) and defoliate the plant (Singh et al., 2002; Singh et al., 2006).

*Indarbela quadrinotata* stem borer has recorded infesting to *G. arborea* and is widely distributed in India (Varma, 1996). *Pagyda* species was found to be majorly infested all over the Jharkhand, and they feed the leaf of *G. arborea* by folding the leaf.

*Tingis beesoni* was the major insect pest of *G. arborea* in Jharkhand. It is a small blackish brown tinged bug occurs in eastern India. The bug breeds gregariously in leaves and soft shoots of *Gmelina arborea*. Meshram and Tiwari (2003) has recorded plantation of *G. arborea* attacked by sap lace bug, *Tingis beesoni* deciduous forests of Madhya Pradesh, India. Beeson (1941) and Browne (1968) has reported as a pest and both nymphs and adult of the lace bug feed almost entirely at the base of leaf blade on the under surface or at the axils.

Thrips, *Megalurothrips peculiaris* was recorded first time majorly infesting pest species to *G. arborea*, this pest was feeding the leaf by scraping the lamina, though this pest was earlier reported on *Dolichos lablab* L., and the weed *Vicia tetrasperma* (L) Moench in India (Maisnam et al., 2012)

The analysis of the species diversity at the landscape of Jharkhand in terms of the infestation (%) can be seen by the two types of diversity indices i.e. alpha and beta for within zones and between zones respectively. Out of the various diversity indices discussed in this paper, we could not identify one ideal diversity index but the recommendation given by Morris et al. (2014). In these recommendations, it is said that Simpsons' indices performed best when differentiating sites, but simpler indices may be slightly preferable when detecting effects of land use intensity on diversity. If dominant species are expected to be more important, then  $D_1$ ,  $D_2$ ,  $BP_1$  and  $BP_2$  would be more appropriate. However,  $H'$  would be preferred when rare and abundant species are treated as equally important. The overall result of beta diversity indices shows that the insect species infestation in *G. arborea* are uniformly present in Jharkhand Province except for the zone VI. This may because of differences in cropping patterns, presence of much wildlife animals, and large area of mixed forest of *G. arborea* in zone VI.

## 5 Conclusion

This study and the result revealed that most dominant species found for insect pest infestation in all the three agro-climatic zones is *Phyllocnistis amydropa*. Ten new insect pests infesting to the *G. arborea* were recorded. This shows that changing environmental condition affecting the insect habitat and their food preference.

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