*Article*

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

**Arvind Kumar**[1], **Girish Chandra**[2]

[1]Forest Entomology Division, Forest Research Institute, Dehradun-248006, India

[2]Division of Forestry Statistics, Indian Council of Forestry Research and Education, Dehradun-248006, India

E-mail: arvind.ento@gmail.com

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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 expending 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 $22^0 00'$ to $24^0 37'$ N and longitude $83^0 15'$ to $87^0 01$ 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.

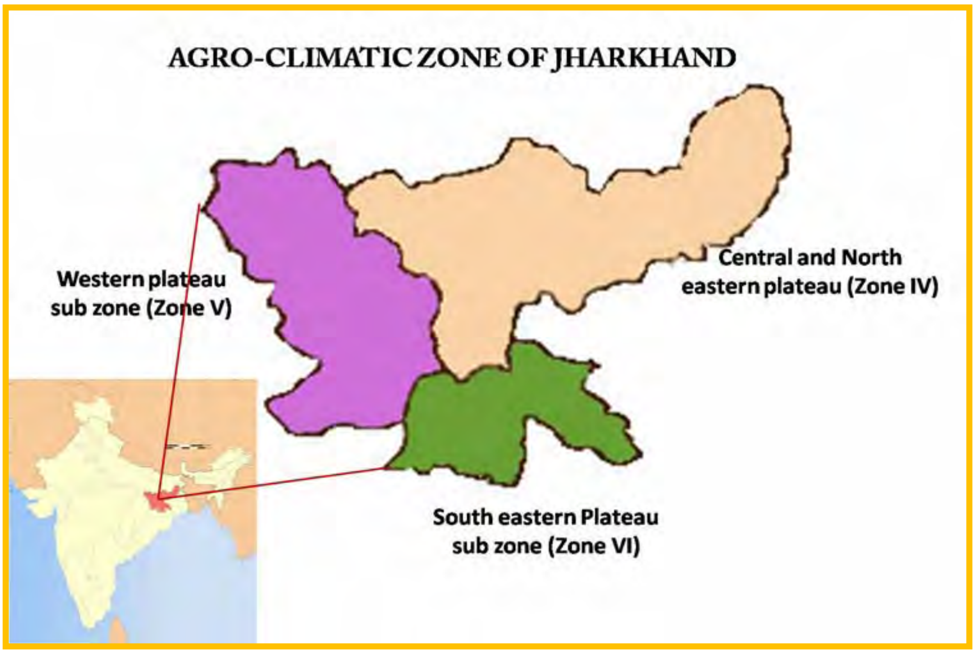


**Fig. 1** Three agro-climatic zones of Jharkhand.

**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 ($H^1$) | $-\sum_{i=1}^{S} p_i \ln p_i$ |
| 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[th] species infestation in the zone, S is the total number of species responsible for infestation, $p_{\max} = \max_{1 \le i \le S}(p_i)$ is the proportion value of the most abundant species.

Here, $H^1$ 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 $R_p = \frac{r_\alpha\left(p, edf\right)}{\sqrt{2}} SE_d$ ,

where, $P$=2,3…… 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 amydros* 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 beesoni* are showing similar infestation in the province of Jharkhand ($p \leq 0.05$) after the highly infested species *Phyllocnistis amydros*. For the province of Jharkhand, it is to say that the species *Psylliodes brettinghamii* 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 brettinghamii* 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 |
|---|---|---|---|---|---|
| | | | **Order: Coleoptera** | | |
| 1 | *Alcides gmelinae* Marshall | Curculionidae | Shoot weevil | Leaf feeding | Beeson, 1941 |
| 2 | *Dihammus cervinus* Gressitt | Cerambycidae | Trunk Borer | Trunk borer | Beeson, 1925 |
| 3 | *Aspidomorpha miliaris* Fab. | Chrysomelidae | Tortoise beetle | Leaf feeder | Keshari, 2007 |
| 4 | *Maladera* sp. | Scarabaeidae | Leaf beetle | Leaf defoliator | New record |
| 5 | *Hyperops coromandelensis* Sol | Tenebrionidae | Bark beetle | Bark feeder | New record |
| 6 | *Psylliodes brettinghamii* Baly | Chrysomelidae | Leaf beetle | Leaf defoliator | Beeson, 1941 |
| 7 | *Calopepla leayana* Latr. | Chrysomelidae | Defoliator | Leaf defoliator | Chaudhuri, 1925 |
| 8 | *Lobotrachelus* sp. | Curculionidae | Leaf weevil | Leaf defoliator | New record |
| 9 | *Apion* sp. | Curculionidae | Leaf weevil | Leaf defoliator | New record |
| | | | **Order: Lepidoptera** | | |
| 10 | *Xyleutes ceramicus* Walker | Cossidae | Trunk borer | Trunk borer | Beeson, 1941 |
| 11 | *Indarbela quadrinotata* Wal. | Cossidae | Bark caterpillar | Bark , trunk | Beeson, 1941 |
| 12 | *Ectropis bhurmitra* Walker | Geometridae | Leaf caterpillar | Leaf defoliator | New record |
| 13 | *Phyllocnistis amydropa* Mayr | Gracillaridae | Leaf miner | Leaf mining | Beeson, 1941 |
| 14 | *Pagyda* sp. | Crambidae | Leaf folder | Leaf defoliator | New record |
| 15 | *Belippa laleana* Moore | Limacodidae | Gelatin grub | Leaf defoliator | New record |
| | | | **Order: Hemiptera** | | |
| 16 | *Tingis beesoni* Drake | Tingidae | Tingid bug | Sap feeder | Beeson, 1941 |
| 17 | *Phromnia marginella* (Oliv) | Flatidae | Flatid bug | Sap feeder | New record |
| 18 | *Homeocerus inornatus* Stål | Coeidae | Corid bug | Sap feeder | New record |
| | | | **Order: Thysamoptera** | | |
| 19 | *Megalurothrips peculiaris* Bagn. | Thripidae | Thrips | Sap feeder | New record |
| | | | **Order: Isoptera** | | |
| 20 | *Odontotermes obesus* Rambur | Termitidae | Termite | Bark, wood feeder | Akhtar et al., 1992 |

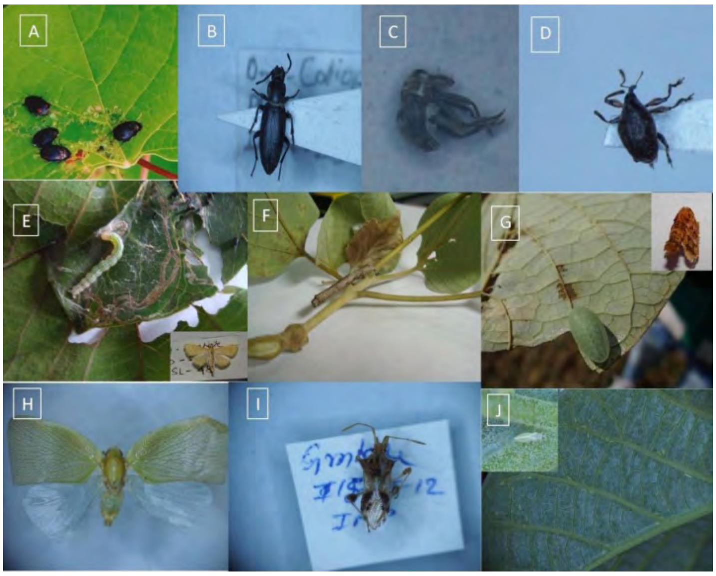

**Fig. 2** New recorded insect pest of *G. arborea* (A-J); A-*Maladera* sp.; B- *Hyperops coromandelensis* Sol; C- *Lobotrachelus* sp.; D- *Apion* sp.; E- *Pagyda* sp.; F- *Ectropis bhurmitra* Walker; G- *Belippalaleana* Moore; H- *Phromnia marginella* (Oliv); I- *Homeocerus inornatus* Stål and J- *Megalurothrips 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 % |
| *Alcides gmelinae* | 8.24 | 1.48 | 9.49 | 1.70 | 0.00 | 0.00 |
| *Dihammus cervinus* | 10.53 | 1.89 | 8.26 | 1.48 | 10.66 | 1.98 |
| *Aspidomorpha miliaris* | 2.46 | 0.44 | 2.28 | 0.41 | 0.00 | 0.00 |
| *Maladera* sp. | 1.39 | 0.25 | 1.34 | 0.24 | 0.00 | 0.00 |
| *Hyperops coromandelensis* | 4.48 | 0.80 | 11.15 | 2.00 | 14.00 | 2.61 |
| *Psylliodes brettinghamii* | 0.56 | 0.10 | 1.09 | 0.20 | 0.00 | 0.00 |
| *Calopepla leayana* | 16.80 | 3.02 | 19.66 | 3.53 | 17.21 | 3.20 |
| *Lobotrachelus* sp. Weevil | 14.35 | 2.58 | 16.64 | 2.99 | 16.26 | 3.03 |
| *Apion* sp. | 25.68 | 4.61 | 27.16 | 4.87 | 28.38 | 5.29 |
| *Xyleutes ceramicus* | 19.55 | 3.51 | 14.50 | 2.60 | 14.24 | 2.65 |
| *Indarbela quadrinotata* | 75.64 | 13.59 | 69.52 | 12.47 | 67.29 | 12.53 |
| *Ectropis bhurmitra* Walk | 17.35 | 3.12 | 20.10 | 3.61 | 15.78 | 2.94 |
| *Phyllocnistis amydropa* | 93.92 | 16.87 | 93.25 | 16.73 | 94.39 | 17.58 |
| *Pagyda sp* | 72.93 | 13.10 | 71.50 | 12.83 | 69.53 | 12.95 |
| *Belippa laleana* | 16.51 | 2.97 | 16.48 | 2.96 | 12.36 | 2.30 |
| *Tingis beesoni* | 67.68 | 12.16 | 63.53 | 11.40 | 63.08 | 11.75 |
| *Phromnia marginella* | 0.88 | 0.16 | 2.43 | 0.44 | 0.00 | 0.00 |
| *Homeocerus inornatus* | 13.70 | 2.46 | 14.46 | 2.59 | 14.76 | 2.75 |
| *Megalurothrips peculiaris* | 69.98 | 12.57 | 70.17 | 12.59 | 73.87 | 13.76 |
| *Odentotermies* 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 brettinghamii* and *Phromnia marginella* in zone VI.

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

| | **Homogeneous groups (Arc sine transformation based)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Insect Species** | 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 |
| *p* 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 ($H^1$) | 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.

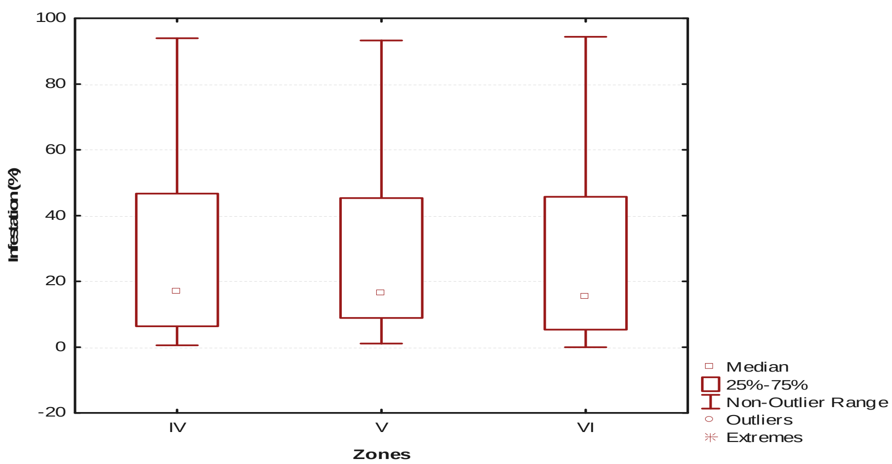


**Fig. 3** Zone wise box plots depicting variation in infestation (%).

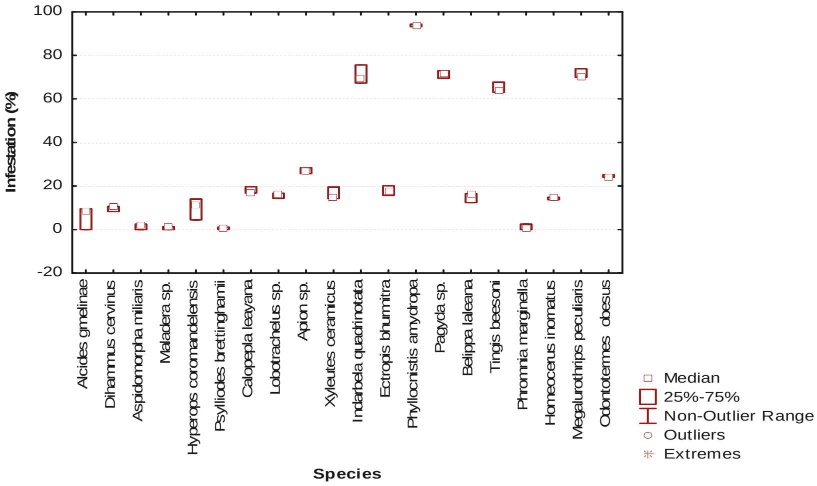


**Fig. 4** Species wise box plots depicting variation in infestation (%).

## 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 brettinghamii, Calopepla leayana, Xyleutes ceramicus, Indarbela quadrinotata, Phyllocnistis amydropa, Tingis beesoni, Odontotermes obesus* 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 lalean; Phromnia marginella, Homeocerus inornatus, Megalurothrips peculiaris* were recorded first time on *G. arborea*.

In this study, infestation of *Phyllocnistis amydropa* 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 beesoni, 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 beesoni* 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. beesoni* 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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## References

Ahmed SI, Sen-Sharma PK, Goil SC. 1983. On seasonal variation in population of *Calopapla leayana* Latr (Coleoptera: Chrysomelidae). Insect Ecology Resource Management, 93-98

Ahmed SI, Sen-Sharma PK. 1983. On seasonal variation in population of *Calopapla leayana* Latr (Coleoptera: Chrysomelidae). In: Insect Ecology and management (Goel SC, ed). Sanatan Dhram College, Muzaffarnagar, India. pp93-98.

Ahmed SI, Sen-Sharma PK. 1990. Bionomics of *Calopapla leayana* Latr (Coleoptera: Chrysomelidae) a serious defoliator of *Gmelina arborea* Roxb. Plantation in India. Indian Forester, 116: 71-82

Ahmed SI. 1982. Studies on the Morphology, bionomics, ecology, and digestive physiology of *Calopapla leayana* Lat (Chrysomelidae: Coleoptera), PhD Thesis, India

Akhtar MS, Awan S, Shakoor A. 1992. Altitudinal distribution of termites species in Azad Kashmir. *Pakistan* Journal of Zoology, 24(2): 91-94

Anonymous. 2000. Forest Health Bulletin, Forestry Tasmania, No. 4.

Anonymous. 2013. India state of forest report. Forest survey of India. http://fsi.nic.in/cover_2013/sfr_forest_cover.pdf

Aung-Zeya. 1981. Two insect species doing derious damage to planted Yamane (*Gmelina arborea*) in Yazin and Moswe areas. Burma Forest Research Institute. Yazin Leaflet, 7: 80-81

Aung-Zeya., 1983. Further observation on *Tingis beesoni* (Hemiptera: Tingidae) incidence on Yamane (*Gmelina arborea*). Burma Forest Research Institute. Yazin Leaflet, 7: 82-83

Barman A. 2014. A brief perspective on *Gmelina* tree insect pest *Craspedonta leayana*. Journal of Entomology and Zoology Studies, 2(4): 276-278

Beeson CFC. 1941. The Ecology and Control of Forest Insects of India and Neighboring Countries. New Delhi, India

Bray JR, Curtis JT. 1957. An ordination of the upland forest communities of Southern Wisconsin. Ecological Monographs, 27: 325-349

Browne. 1968. Pest and Diseases of Forest Plantation Trees. Clarendon Press, Oxford, UK

Champion HG, Seth SK. 1968. A Revised Survey of Forest Types of India. Govt. of India Press, New Delhi, India

Choudhuri MC. 1925. The defoliation of Gamhar in Chittagong Hills tracts, Bengal. Indian Forester, 51: 57-60

Garthwaite PF. 1939. Biology of *Calopepla leayana* and the possibilities of control. Indian Forest Records, 5(2): 237-275

Jaccard P. 1912. The distribution of the flora of the alpine zone. New Phytologist, 11: 37-50

Keshari S. 2007. Insect Pests of *Gmelina arborea* (Gamhar) from Chotanagpur. 63-71. In: Bio-informatics (Pandey BN, Sadhana Deshpande, Tripathi AK, et al., eds). SB Nangia, APH Publishing Corporation, New Delhi, India

Kumar M, Shylesha AN, Thakur NSA. 1995. Occurrence of *Craspedonta leayana* (Latr.) (Chrysomelidae: Coleoptera) on *Gmelina arborea* in Meghalaya. Insect Environment, 1(3): 17-18

Li R, Chen DT, Liang GW, et al., 2014. Diversity and aggregation patterns of plant species in a grass community. Selforganizology, 1(2): 78-88

Maisnam S, Singh OD, Varatharajan R. 2012. Diversity and diagnostics of Thysanoptera inhabiting leguminous plants with a note on life cycle of *Megalurothrips peculiaris* Bagnall. Indian Journal of Entomology, 74(3): 274-280

Mathew G. 1986. Insects associated with forest plantations of *Gmelina arborea* Roxb. in Kerala, India. Indian Journal of Forestry, 9(4): 308-312

Mathur RN, Singh B. 1959. A list of insect pest of forest plants in India and the adjacent country. Indian Forest Bulletin, 171(4): 1-165

Mathur RN. 1979. Biology of *Tingis beesoni* Dark (Heteroptera: Tingidae) pest of *Gmelina arborea*, in India. Indian Forest Bulletin, 276: 6

McCune B, Grace JB. 2002. Analysis of Ecological Community. MM Software Design, Gleneden Beach, Oregon, USA

Meshram PB, Pande PK. Banerjee SK. 2001. Impact of pest problems in *Gmelina arborea* Linn. plantations in Western Maharashtra. Indian Forester, 127(12): 1377-1386

Meshram PB, Gerg VV. 2000. A new report of *Parasa lepida* Craner (Lepidoptera: Limacodidae) and *Trypanophora semihyalina* Kallar (Lepidoptera: Zygaenidae) as a pest of *Gmelina arborea*. Indian Forester, 126: 690-691

Meshram PB, Tewari CK. 2003. Lace bug *Tingis beesoni* (Drake) causing top dying of *Gmelina arborea* (Linn.) Hi Tech plantation and evaluation of certain pesticide against the bug. Journal of Applied Zoological Research, 14(2): 200-252

Morris EK, Caruso T, Buscot F, Fischer M, Hancock C, et al. 2014. Choosing and using diversity indices: insights for ecological applications from the German Biodiversity Exploratories. Ecology and Evolution, 3514-3524

Nair KSS, Mathew. 1988. Biology and control of fast growing hardwood species: I *Albezia falcataria* and *Gmelina arborea*. KFRI Reseach Report No. 51. Kerala Forest Resaerch Institute, Peechi, India

Nayar KKS, Sumardi. 2000. Insect pest and diseases on major plantation species. In: Insect Pests and Diseases In Indonesian Forest: An Assessment of The Major Threats, Research Efforts and Literature (Nayar, KSS, ed). Center for International Forestry Research, Bogor, Indonesia

Pathala D, Harini A, Hegde PL. 2015. A review on Gambhari (*Gmelina arborea* Roxb.) Journal of Pharmacognosy and Phytochemistry, 4(2): 127-132

Sekha MS, Kalita J. 1995. A preliminary work on *Eupterote undata* (Lepidoptera: Eupterotidae) defoliator of *Gmelina arborea* Roxb in Assam. Insect Environment, 1: 12-13

Sen-Sharma PK, Ahmed SI, Ahuja SS. 1983. Influence of temperature and relative humidity on the survival period of starved adult and larvae of *Calopapla leayana* Latr. In: Insect Interrelation in Forestry and Agro-Ecosystem (Sen-Shara PK, Kulshrestha SK, Sahgal SK, eds). 59-77, Jugal Kishor, Dehradun, India

Sen-Sharma PK, Ahmed SI. 1984. Studies on digestive physiology of *Calopapla leayana* Latr (Coleoptera: Chrysomelidae). Digestibility and chemical composition of food and fecal matters. Annals of Entomology, 2: 11-15

Sharavati T, Chakraborti S, Modak M. 2012. Isolation and characterization of gut bacteria from *Aspidomorpha miliaris.* World Journal of Environmental Biosciences, 2(1): 13-20

Singh S, Barman HK, Barthakur ND. 2002. Pathogenicity of entomogenous fungi ion *Calopepla leayana* (Coleoptera: Chrysomelidae), A major insect pest of Gamhar, *Gmelina arborea*. Annals of Forestry, 10(2): 351-355

Singh S, Barman HK, Deka B, Rajak B. 2006. Bio-ecology of *Brachymeria excarinata* Gahan (Hymenoptera: Chalcididae), A pupal parasitoid of *Crspedonata leayana* (Coleoptera: Chrysomelidae) A major defoliator of *Gmelina arborea* in Northeast India. Annals of Forestry, 14(2): 306-3016

Stabbing EP. 1914. Indian forest insect of importance, Coleoptera. New Delhi, India

Varma RV. 1996. Major insect pests of forest trees in north Bihar. In: Impact Of Diseases and Insect Pests In Tropical Forests (Ali MS., Chaturvedi OP, Nair KSS, Sharma JK, eds). Proceedings of the IUFRO Symposium. 464-467, Peechi, India

Whittaker RH. 1967. Gradient analysis of vegetation. Biological reviews of the Cambridge Philosophical Society, 42: 207-264

Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon, 21: 213-251

Zhang WJ. 2015. Calculation and statistic test of partial correlation of general correlation measures. Selforganizology, 2(4): 65-77