The Clarion Volume 9 Number 2 (2020) PP 12-24

The Clarion

International Multidisciplinary Journal

ISSN : 2277-1697

Impact of season on leaf beetles diversity in garbhanga reserve forest (coleoptera, chrysomelidae) and its feeding pattern.

Lipika Tamuli

Department of Zoology, Cotton University, Guwahati, India

Abstract

The paper aims to study the impact of season on the diversity of leaf beetle population in Garbhanga Reserve Forest and how it inflicts damage to the vegetation through its different feeding habits in a wide variety of host plants. A total of 1673 individuals belonging to 24 species under 14 genera and 5 subfamilies were recorded from the five chosen plots. The diversity of Chrysomelids beetle in the five chosen plot were compared by using different parameters– species composition, total abundance, species richness and diversity.

Keywords: Chrysomelidae beetle, Garbhanga Reserve forest, Diversity.

1. Introduction

The Chrysomelidae, commonly referred to as leaf beetles (Jolivet and Petitpierra, 1981), constitute one of the most abundant and diverse families of living organisms (Santiago-Blay, 1994) exhibiting phytophagous feeding habit, which it shares with Curculionidae, Cerambycidae and Bruchidae (Hsiao, 1994). The family Chrysomelidae placed under the order Coleoptera consists of 25% of the known life forms (Powell, 2009; Rosenzweig, 1995; Hunt *et al*., 2007). The order Coleoptera consists of 179 families, of which 103 families are known from India (Biswas, 1995). Among the 103 coleopteran families found in India, the family Chrysomelidae consists of diverse group of phytophagous insects with over 38,000 species all over the world and is classified into 19 subfamilies (Seeno & Wilcox, 1982; Jolivet *et al*., 1988; Jolivet and Verma, 2002). Chrysomelids have worldwide distribution (except the arctic region) and its greatest diversity is found in the tropics (Riley *et al*., 2002).

The leaf beetles feed on a wide variety of host plants (Jolivet and Hawkeswood, 1995) and it exhibits phytophagous feeding habit (Hsiao, 1994). They are mostly oligophagous, though some groups tend to be polyphagous. Although the leaf beetles feed on a wide variety of host plants but presently 30% (approximately) of its host plants were estimated (Jolivet, 1988; Jolivet and Hawkeswood, 1995). They feed on both monocotyledonous and dicotyledonous families, but the sub-family Alticinae also prefers both gymnospermic and pteridophytic plants as its food plants (Jolivet and Hawkeswood, 1995; Riley *et al*., 2002). The various dicotyledonous family which the leaf beetles prefer as food plants include Asteraceae, Convolvulaceae, Brassicaceae, Cucurbitaceae, Lamiaceae, Verbenaceae, Fabaceae, Rosaceae and Solanaceae (Jolivet and Hawkeswood, 1995).

The leaf beetles feeding may remain confined to a single host plants or they may consume a large variety of host plants due to which they are considered as pest of agriculture and forestry (Jolivet *et al*., 1988). Many leaf beetles belonging to the subfamily Criocerinae, Eumolpinae, Galerucinae, Alticinae, Hispinae and Chrysomelinae are regarded as serious pest of agricultural crops and forestry (Jolivet *et al*., 1988). Both the adult and larval feeding have a destructive impact on the host plants where the adult beetle generally consumes the leaves, flowers, pollen and young shoots and the larva mainly feed on leaves and roots (Jolivet and Verma. 2002).Studies on beetles revealed that ¾ of the beetle species, both larval and adult stages are phytophagous, thriving on plants, wood, variety of stored products, including cereals, tobacco and dry fruits (Banerjee, 2014). In comparison to the

Corresponding author : tamulilipika@gmail.com

DOI number: 10.5958/2277-937X.2020.00011.8

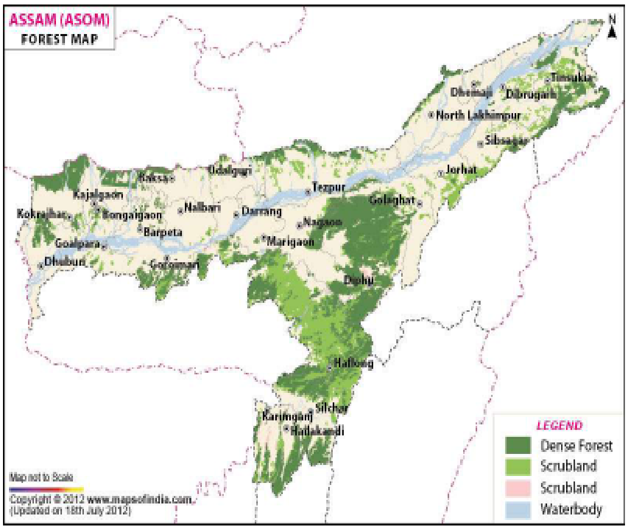
other beetles, the beetle belonging to Chrysomelidae family, both adult and larval stages are phytophagous (Jolivet and Hawkeswood, 1995) and a very strong relationship persists between the members of this group with the host plants (Marques and Oliveira, 2004). Both the adult and larva serves as an important pest of large variety of crops, trees, shrub plantation, medical herbs and animal fodder (Mirzoeva, 2001). Most of the leaf beetles are often used to investigate host specificity in phytophagous insects because majority of the Chrysomelidae species are monophagous or oligophagous (Mitchell, 1981; Smiley, 1982; Crowson, 1981; Jolivet, 1986). Since most of the Chrysomelid beetles feed on the plant species belonging one or two closely related families (oligogophagous), hence both the adult and larva feed on the same host resource (Raupp and Denno, 1983). The damage caused by Chrysomelidae to the host plant varies from moderate to heavy level (Morrow, 1979; Louda, 1981) and the damage caused by them influences other co-occurring herbivores. For example, the leaf beetle, *Podontia quatuordecimpunctata* is looked upon as an important defoliating pest in the forest (Stebbing, 1914). Both the adult and larva cause heavy damage to the host plant, *Spondias pinnata* (Amara), and they appear in full foliage in the month of July to August and disappear in October. They generally attack young growing areas and inflict heavy damage to the host plants, and hence it is regarded as a serious pest (Corbett and Yusope, 1921).

Chrysomelidae composition and distribution are influenced by abiotic factors like precipitation and temperature (Bouzan *et al*., 2015). But these abiotic factors have a direct affect on vegetation composition and structure, which help in determining the composition and abundance of phytophagous insects (Sanchez-Reyes *et al*., 2014). Apart from these various geographical and environmental factors, species composition of phytophagous insects is also influenced by topography, vegetation, climate, altitude, habitat and human activities (Wallner, 1987; Lien and Yuan, 2003; Andrew and Hughes, 2004; Wasowska, 2004; Lassau *et al*., 2005). For example, Chrysomelids beetle found in the mountain show different pattern of species richness, composition and abundance (Carneiro *et al*., 1995; Flinte *et al*., 2009; Sanchez- Reyes *et al*., 2014). But in the tropics insect abundance are more during the rainy season (Wolda, 1978). A heterogeneous habitat harbor a large variety of insect species leading to an increase in species richness compared to any kind of monoculture practice (Sanjayan, 1993). The insect diversity greatly depends on the availability of mixed plant species (Mathew and Rahmathulla, 1993).

2. Materials and methods

Study area

The present study on the diversity of Chysomelids beetle was conducted in Garbhanga Reserve Forest which is situated on the south western side of Guwahati city bordering the state of Meghalaya on the south side, the part of Rani Reserve forest in the western side, the famous Basistha temple and home- stead private lands in the Eastern and Northern side. The forest is located within the geographical limits of longitudes $91^{0}35.406^{/}$ E to $91^{0}47.517^{/}$ E and latitude $25^{0}56.528^{/}$N to $26^{0}06.584^{/}$N. The area of Garbhanga Reserve forest is 114.64 square kilometers.



Forest Map of Assam

Location Map Of Garbhanga Reserve Forest

Based on habitat type, five plots were selected with different vegetation type in the central region of the forest (Plot-1) and the other four plots in the Eastern (Plot-2), Western (Plot-3), Northern (Plot-4) and Southern (Plot-5) region of the forest. The forest type of the study area include Eastern hill Sal type, Mixed moist deciduous forest, Evergreen patches, Secondary moist bamboo brakes and Secondary Euphorbiaceous scrub type.

Climatic Condition

The climate of Garbhanga Reserve Forest is characterized by high humidity and moderate temperature with heavy rainfall (300-450 cm) in addition to periodic wind, storm and thunders (Borthakur, 1986). The June is considered as the warmest month of the year while the coolest month is January.

The climate of Garbhanga Reserve forest is divided into four seasons' viz .Pre-monsoon, Monsoon, Retreating monsoon and winter on the basis of temperature, humidity and precipitation (Saikia *et al.*, 2009).

The three years data of monthly total rainfall, monthly mean relative humidity and monthly mean maximum temperature for the period 2011-2013 were collected from the Indian Meteorological department, Guwahati.

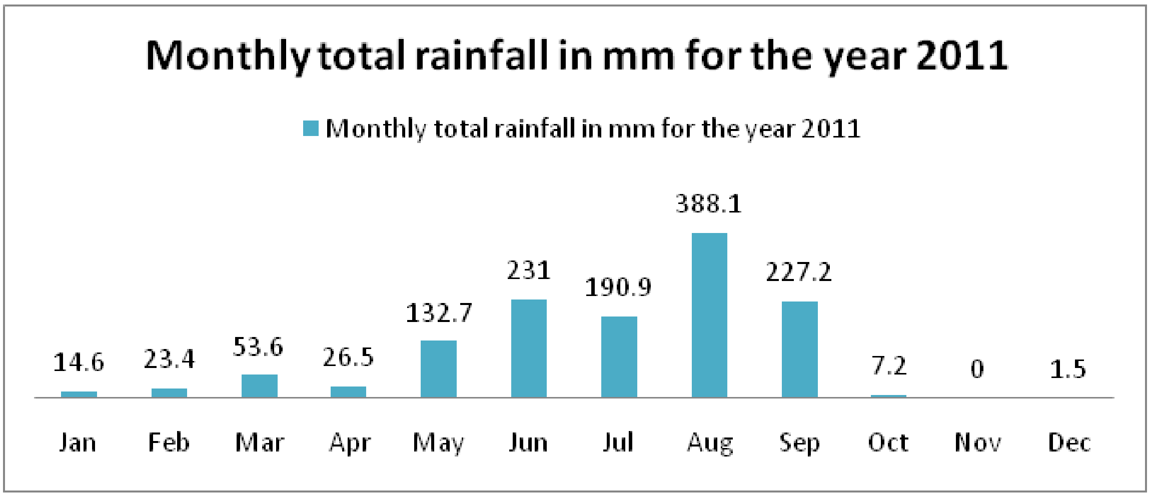


Fig : Monthly total rainfall in mm for the year 2011

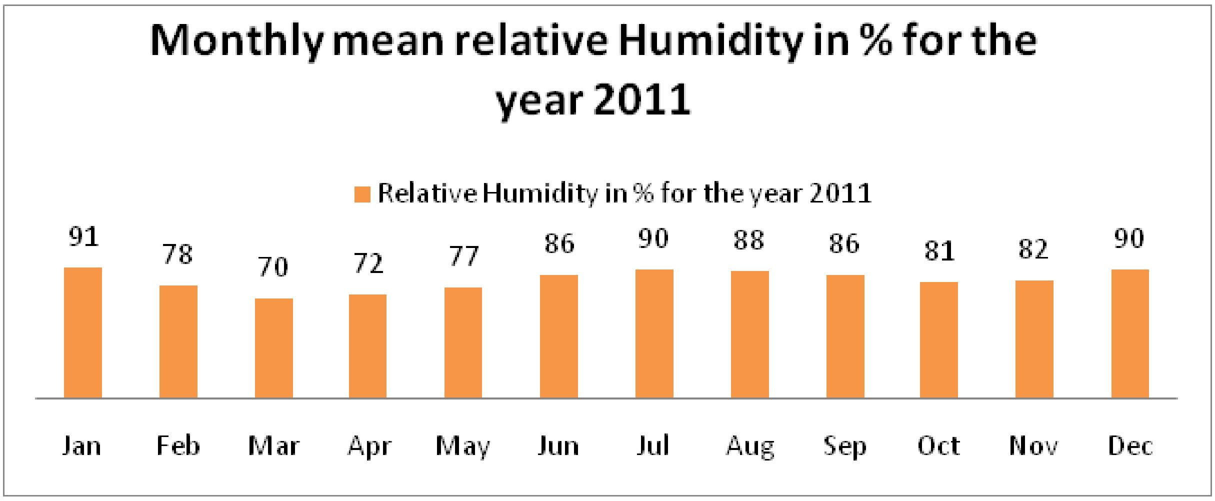


Fig : Monthly mean relative humidity in % for the year 2011

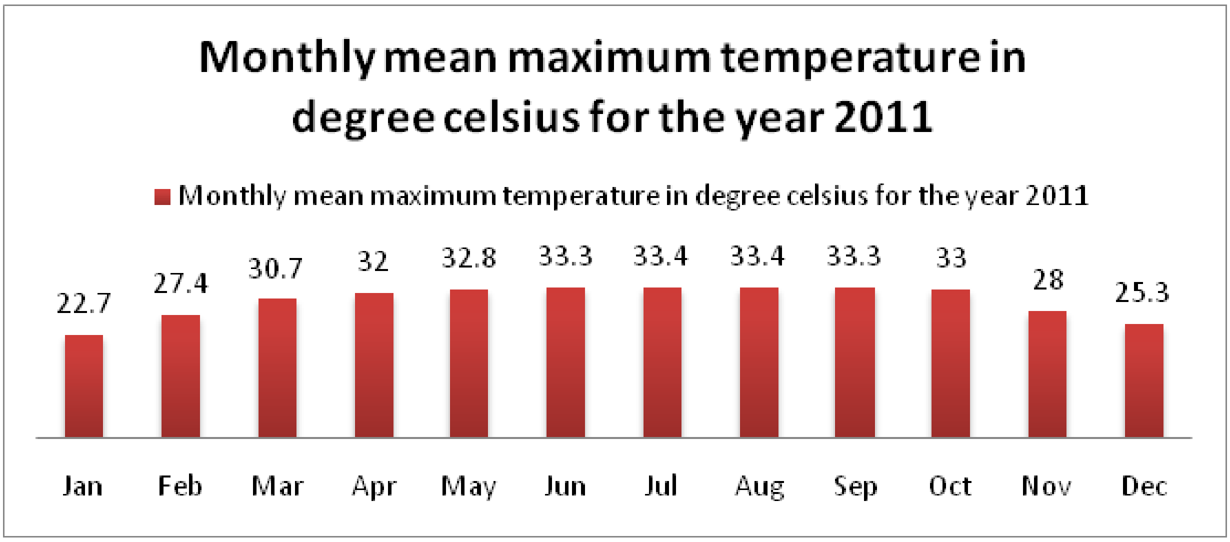


Fig: Monthly mean maximum temperature in degree Celsius for the year 2011

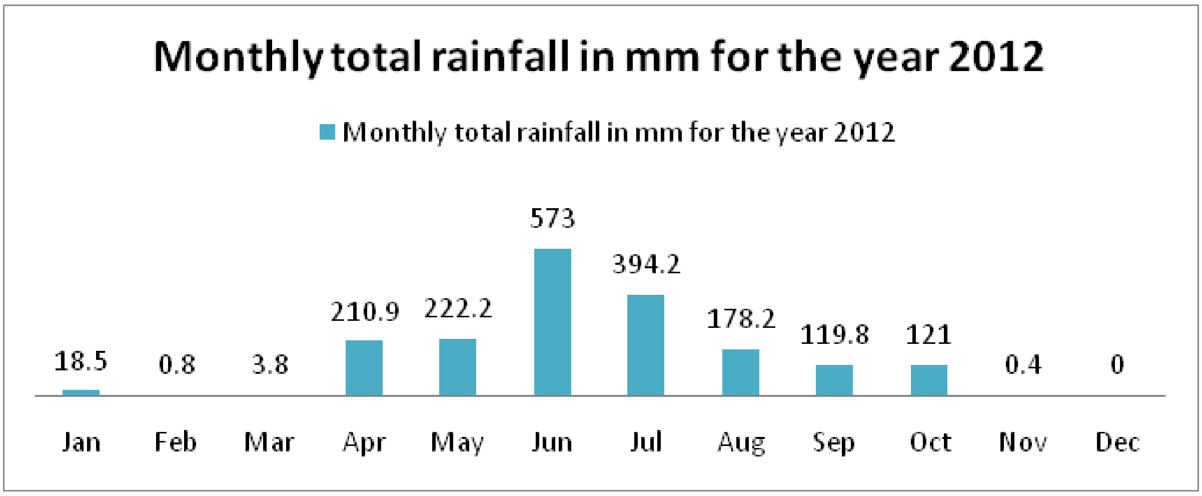


Fig : Monthly total rainfall in mm for the year 2012

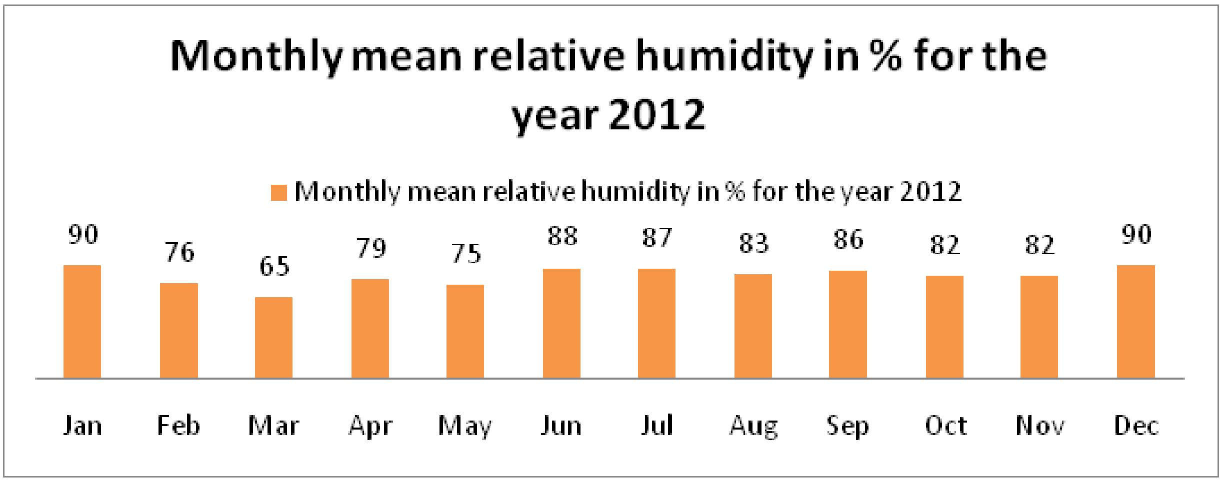


Fig : Monthly mean relative humidity in % for the year 2012

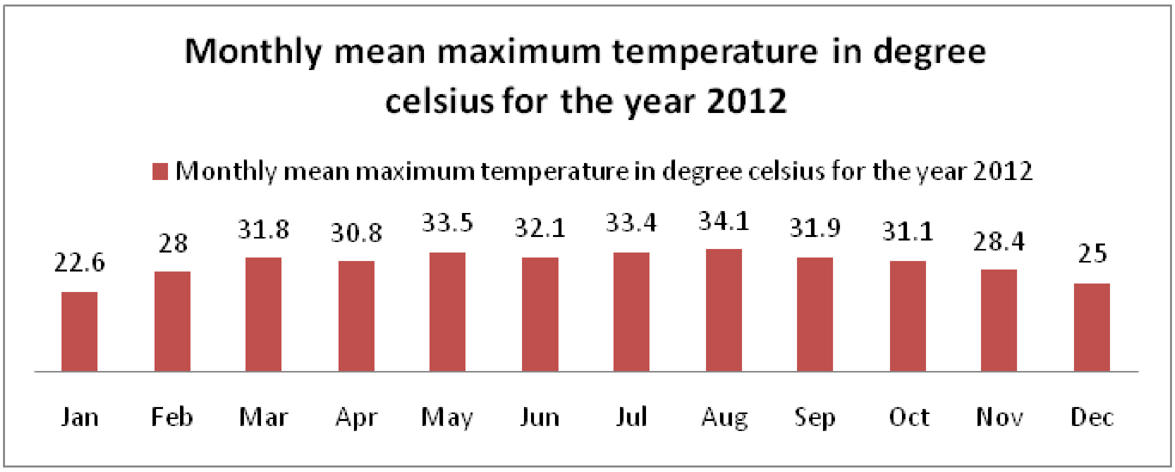


Fig : Monthly mean maximum temperature in degree Celsius for the year 2012

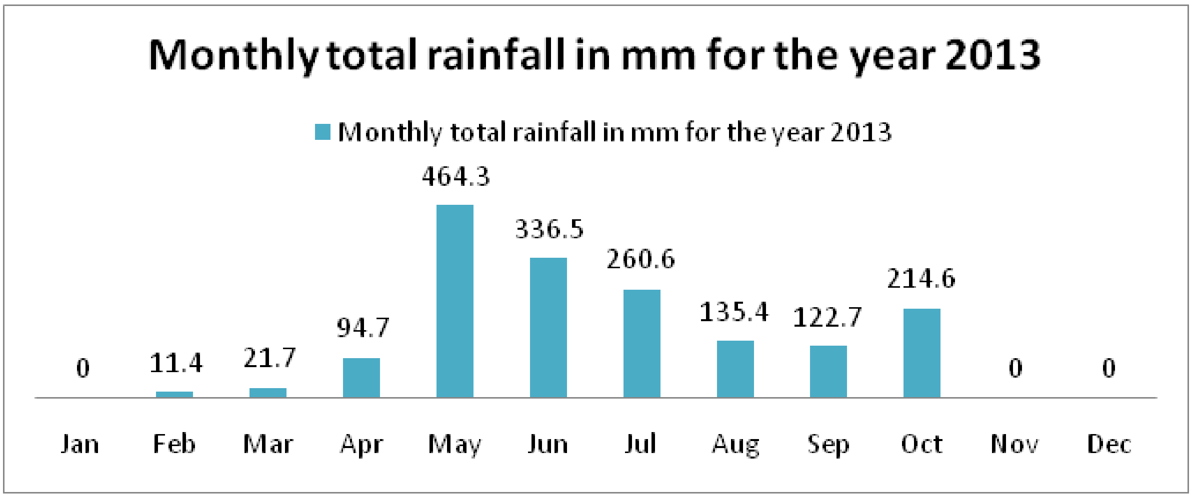


Fig : Monthly total rainfall in mm for the year 2013

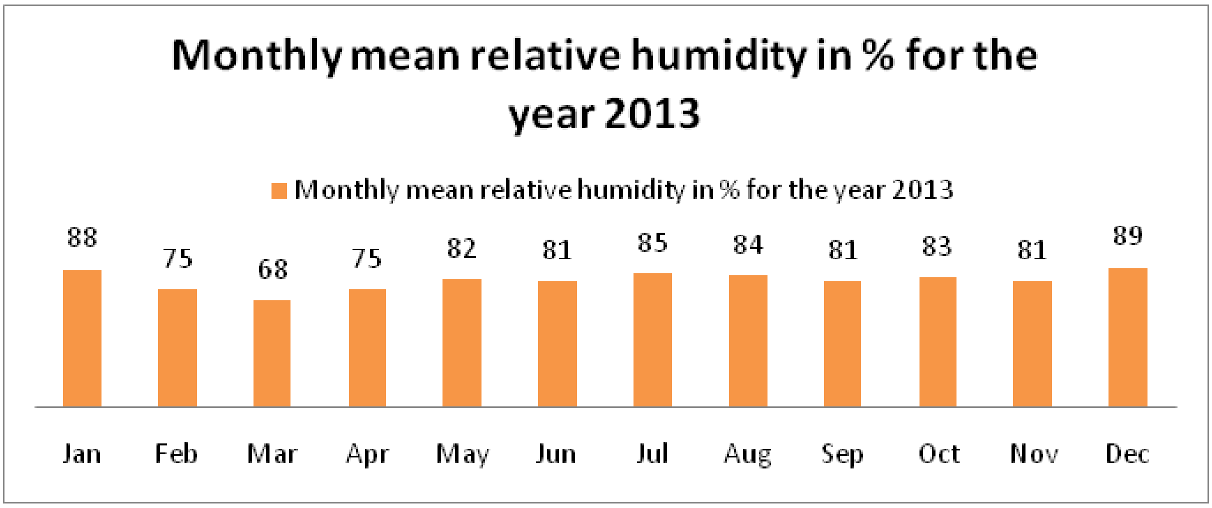


Fig : Monthly mean relative humidity in % for the year 2013

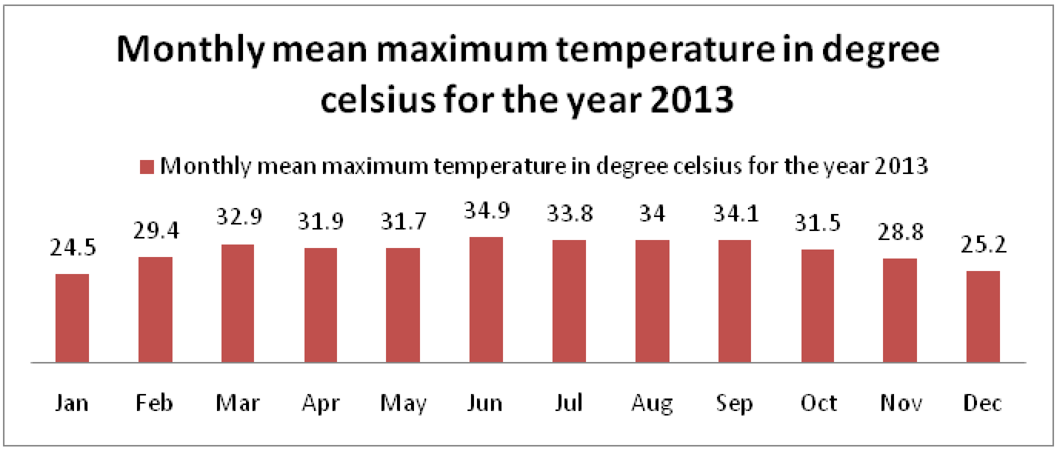


Fig : Monthly mean maximum temperature in degree Celsius for the year 2013

Sampling

For the sampling of Chrysomelids beetle both transect and quadrate method were used according to the methodology followed by Joseph and Balakrishnan (2005). Based on habitat type five plots were selected, one on the middle (Plot-1), and the other four plots in the Eastern (Plot-2), Western (Plot-3), Northern (Plot-4) and Southern (Plot-5) region of the forest. Sampling of beetle is initiated by marking one transect each of 2 km in each plot, and this is followed in the five selected plots. Six quadrates are marked along each transect of 500m x 500m in the two extreme and middle position of the transect in each plot. Hence a total of 5 transect and 30 quadrates were taken in the five chosen plots. Every year 30 quadrates are sampled in the five chosen plots, and a total of 90 quadrates are sampled from all the five plots during the entire study period.

Data collection

Depending on the behavior of Chrysomelids beetle in the field condition various methods were used for data collection according to the methodology followed by Sen and Gok (2009). Hand capturing method, sweep net method and shaking or beating trap method were used for sampling of the Chrysomelids beetle.

Killing and preservation

The collected Chrysomelids beetle were killed by transferring them into a bottle containing a small cotton swab with ethyl alcohol and stored as dry preservation on entomological pins or glued on sample cards according to the methodology followed by Sen and Gok (2009).

Identification

The identification of Chrysomelids beetle was done in Zoological Survey of India, Kolkata. The observed specimen were identified according to the keys provided by Jacoby (1908), Maulik (1919, 1926), Mohr (1966), Gruev and Tomov (1984, 1986), Lopatin (1984), Warchalowski (1991, 1993, 1994, 2003) and Reid (1995).The identified beetles were assigned into vegetation association type according to their current occurences on the plants. The association of species with the host plants are done in accordance with the literature provided by Jolivet and Hawkeswood (1995), Gruev and Tomov (1984, 1986) and Jolivet and Verma (2002).

Data Analysis

The diversity of Chrysomelids beetle in the five chosen plot were compared by using different parameters – species composition, total abundance, species richness and diversity. For calculating the diversity indices, Shannon's index of total species diversity (H') and Pielou's Evenness index was used as diversity index (Kreb, 1994).

3. Experimental findings

Diversity of chrysomelids Beetle

Species composition

The present study revealed 24 species under 14 genera and 5 subfamilies.

On the basis of the total number species, Cassidinae was the most dominant subfamily which recorded a total of 9 species, followed by subfamily Galerucinae (8 species), Alticinae (4 species), Chrysomelinae (2 species) and Criocerinae (1 species). Regarding species richness, the percentage contribution of the subfamily Cassidinae is the highest (37.5%) followed by subfamily Galerucinae (33.33%), Alticinae (16.67%), Chrysomelinae (8.33%) and Criocerinae (4.17%).(Table-1)

Species richness

Species richness refers to the number of species present in a particular region. A total of 24 species were recorded from the Garbhanga Reserve Forest in the five selected plots during the study period (2011-2013).

In the year 2011, the highest number of species was recorded in the plot-2 with a total of 20 species. The next highest number of species were recorded from the plot-1 (19 species) followed by plot-4 (17 species), plot-5 (12 species) and lastly plot-3 with a total of 11 species. In the year 2012, the highest number of species was recorded from plot- 2 with a total of 19 species. The next highest number of species was recorded from both plot-1 and plot-4 with a total of 15 species, followed by plot-3 with a total of 12 species. The species richness was found to be very less in plot-5 in 2012 with a total of 11 species. In the year 2013, the highest number of species was recorded from plot-2 only, with a total of 21 species. The next highest number of species was recorded from plot-1 with a total of 18 species, followed by plot- 4 with a total of 15 species and plot-3 with a total of 13 species. The number of species was found less in plot-5 in 2013 with a total of 12 species.(Table-2).

Table-1: Percentage contribution of relative number of species and individuals of Chrysomelids Beetle collected from each subfamily during the entire study period (2011-2013)

S.N.	Subfamily	Number of species	% of species	Total number of individuals	% of individuals
1.	Criocerinae	1	4.17	7	0.42
2.	Chrysomelinae	2	8.33	15	0.90
3.	Galerucinae	8	33.33	1240	74.12
4.	Alticinae	4	16.67	74	4.42
5.	Cassidinae	9	37.5	337	20.14
	Total	**24**	**100**	**1673**	**100**

Table-2: Table showing the variation in species richness, abundance and diversity of Chrysomelids Beetle in different study plots during the entire study period (2011-2013)

Years	Study Plots	Species Richness	No of individuals	Shannon index	Evenness
First Year 2011	Plot-1	19	154	2.62	0.891
	Plot-2	20	210	2.63	0.879
	Plot-3	11	80	1.97	0.824
	Plot-4	17	73	2.33	0.823
	Plot-5	12	44	2.09	0.842
	Across the year	24	561	2.65	0.836
Second Year 2012	Plot-1	15	99	2.32	0.856
	Plot-2	19	197	2.38	0.809
	Plot-3	12	76	1.94	0.782
	Plot-4	15	64	2.29	0.845
	Plot-5	11	39	2.08	0.870
	Across the year	23	475	2.51	0.802
Third Year 2013	Plot-1	18	169	2.57	0.889
	Plot-2	21	207	2.58	0.848
	Plot-3	13	111	2.15	0.839
	Plot-4	15	79	2.34	0.863
	Plot-5	12	71	2.21	0.891
	Across the year	24	637	2.60	0.820

Species diversity

Each species in the Garbhanga Reserve forest are considered as a distinct unit of diversity, playing a specific role in the ecosystem. Hence the Chrysomelids beetles also constitute an important component of the Garbhanga Reserve forest. The annual species diversity was 2.65 in the year 2011, 2.51 in the year 2012 and 2.60 in the year 2013.

In the year 2011, 2012 and 2013 the diversity of the entire plot were calculated by using Shannon index. In the year 2011, the highest diversity was observed in plot 2, which has a Shannon wiener diversity index of 2.63. In terms of Shannon wiener diversity index, the next highest diversity was observed in plot-1 with a diversity index of 2.62, followed by plot-4 with a diversity index of 2.33, plot-5 with a diversity index of 2.09 and plot-3 with a diversity index of 1.97 (Table-2).

In the year 2012, in terms of Shannon wiener diversity index, the highest diversity was observed in plot-2 with a diversity index of 2.38, followed by plot-1 with a diversity index of 2.32, plot- 4 with a diversity index 2.29, and plot-5 with a diversity index of 2.08 and lastly plot-3 with a diversity index of 1.94. Hence in the year 2012 also the highest diversity was observed in plot-2, followed by plot-1, plot-4, plot-5 and plot- 3 (Table-2).

In the year 2013, the diversity of all five plots was calculated by using the Shannon wiener diversity index. Similarly, in the year 2013 also the highest diversity was noticed in plot- 2 with a diversity index 2.58, followed by plot- 1 with a diversity index of 2.57, plot- 4 with a diversity index of 2.34, plot-5 with a diversity index of 2.21 and lastly plot- 3 with a diversity index of 2.15 (Table-2).

The variation of diversity in each of the five plots in the year 2011, 2012 and 2013 largely revealed that the diversity of Chrysomlids beetle population is related with habitat, temperature and rainfall. Hence Linzmeir and Ribero-casta (2008) hypothesis strongly proved that the leaf beetle population varies with geographical and environmental factors like vegetation pattern, climate and habitat.

During the present study, the leaf beetles have been collected from large variety of host plants. They were found feeding on the leaves forming holes of variable size in between the veins of the leaf. It was found that most of the leaf beetles do not eat the veins of the leaves, and they exhibit phytophagous feeding habit completing their life cycle within a small area. Riley *et al.,* (1992) is his study mentioned the chrysomelids beetle as the second largest phytophagous family and said that the leaf beetles complete their life cycle within a small geographical area. Studies performed by Jolivet and Petitpierre (1981) revealed that the members of the family Chrysomelidae are of great economic importance but most of the species belonging to different genera are also regarded as pest because they harm the host plants by attacking its roots, stems, leaves and fruits of flowering plants. Also, according to them, most of the chrysomelids like *Diabrotica, Chaetocnema* and various species of Alticinae and Galerucinae are directly or indirectly involved in the transmission of some important fungal, bacterial and viral diseases of plants. Hence, it is totally agreeable that the leaf beetles exhibit phytophagous feeding habit and they complete their life cycle within a small geographical area.

4. Conclusion

The present study revealed the diversity of chrysomelids beetle in the five selected plots of Garbhanga reserve forest (Assam) along with the association of the recorded species with the host plants.

For the diversity study of chrysomelids beetle in Garbhanga Reserve five plots were selected in the middle (Plot-1), Eastern (Plot-2), Western (Plot-3), Northern (Plot-4) and Southern (Plot-5) part of the forest with different vegetation structure. The study was conducted in the year 2011, 2012 and 2013. In the three year study, climatic variation has been observed in terms rainfall, humidity and temperature which had lead to variation of Chrysomelids beetles found in the Garbhanga reserve forest in term of abundance, Richness, Diversity and evenness.

In the present study, most of leaf beetles in the Garbhanga Reserve forest were collected during the spring season, especially in the month of May and June because this period is characterized by heavy rainfall. The leaf beetle population generally increases in the rainy season, as in this period the leaf sprouts and the leaf beetles generally consume young leaves because during this period the leaves are highly nutritious. Stork *et al.,* (2001) and Wagner (2003) in their study on leaf beetles commented that leaf beetle occurrence are generally related to species characteristics (i.e. emergence schedule, generation time, Voltinism), phytoresource availability and habitat structure. Basset (1991), Wagner (1999) and Leksone *et al*., (2005a, 2006) further commented that leaf beetle population generally peaks during the spring season, as during this period the leaf flush occurs. Jolivet (1988), Novotny and Basset (1998) and Alonso and Herrare (2000) also agreed to the above fact and added that during this period the leaves are more nutritious, with higher water and nitrogen content. Basset and Novotny (1998) further added that the young leaves are tender and nutritious but as the leaves mature, leaves becomes tougher and less nutritious. Southwood*et al*., (2004) also observed that the older leaves act as a barrier to phytophagous insects. Hence, majority of leaf beetles during the study period (2011- 2013) were collected in the spring season, especially in the month of May and June due to the host plant abundance and the leaves are nutritious with higher water content. Hence, it is agreeable that with the advent of rainy season, the leaf sprouts providing adequate amount of food for the leaf beetles leading to its growth and increase in population.

In the present investigation, marked variation has been observed, in terms of leaf beetle abundance in the three consecutive years (2011, 2012 and 2013) and the five selected plots as shown in the table-5 and 6. A total of 561 individuals were recorded in the year 2011, 475 individuals in the year 2012 and 637 individuals in the year 2013. The variation in the abundance of leaf beetles in 2011, 2012 and 2013 may be directly linked with temperature and rainfall. In the year 2011 and 2013 the rainfall was moderate followed by high temperature. But compared to 2011, the rainfall was high in the year 2013 which must have largely helped in the growth of the herbaceous plant. But 2012, received the highest rainfall compared to the other two years, which might have washed away most of the eggs and larva from the host plants leading to the disruption of life cycle. Linzmeier and Ribero costa (2008) in their study noticed the variation of chrysomelids beetle with seasonal pattern and observed that the geographical and environmental factors like vegetation pattern, climate and habitat influence the occurrence of leaf beetles. Wallner (1987), Lein and Yuan (2003), Andrew and Hughes (2004) and Lassau *et al*., (2005) in connection with their study on phytophagous insect communities also agreed with the observation of the present study. Hence it is totally agreeable that the abundance of leaf beetle population in a particular region is directly linked to its host plant and the availability of host plant in any particular area is related to its environmental condition, which largely help in the growth of the host plants.

Most of the chrysomelids beetle was collected from the host plants excepting the polyphagous beetle which were found associated with a large variety of host plants. The following species were closely found associated with their host plants,*Lema singularis* Jacoby (*Dioscorea alata*),*Phaedon assamenis* Jacoby (*Solanum carolinensa*), *Chrysolina* species (*Euphorbia hirta*), *Altica Oleracea* Linnaeus (*Amaranthus virdis), Chaetocnema confinis* Crotch (*Ipomoea aquatica), Aplosonyx chalybaeus* Hope (*Colacasia esculenta), Phyllotreta atra* Fabricius (*Brassica oleracea*), *Phyllotreta Cruciferae* Goeze (*Solanum melongena*), *Podontia quatuordecim-punctata (Spondias pinnata), Aspidomorpha milliaris* Fabricius (*Ipomoea Carnae, Ipomoea aquatica), Aspidomorpha sanctaecrucis* Fabricius (*Ipomoea carnea, Ipomoea aquatica), Aspidomorpha furcata* Thunberg (*Ipomoea Carnea), Aspidomorpha indica* Boheman (*Ipomoea aquatica, Ipomoea Carnae), Cassida circumdata* Herbst (*Ipomoea aquatica), Monolepta signata* (*Commelina nudiflora), Cassida margaritacea* Schaller (*Ipomoea carnea), Cassida* sp (*Ipomoea Carnea), Deloyala Guttata*Olivier (*Ipomoea Carnea*)and *Laccoptera nepalensis* Boheman (*Ipomoea carnea* and *Ipomoea aquatica*).Hence majority of the chrysomelids beetle are collected from their host plant excepting few species of the subfamily Galerucinae. The polyphagous beetle which was recorded from a wide variety of plants includes *Aulacophora bhamoensis* Jacoby, *Aulacophora, dorsalis* Boisduval, *Aulacophora, frontalis* Blay, *Aulacophora indica* Gmelin, *Aulacophora foveicollis* Lucas. Hence the present study showed the association of the Chrysomelids beetle with their host plants which largely revealed that majority of the leaf beetles were collected from herbaceous plants excepting few. The few species which were collected from the shrub plants include members of subfamily Cassidinae and the only member which is collected from the tree is *Podontia quatuordecimpunctata* collected from host plant *Spondias pinnata.* Similarly, Furth (1979) in his study suggested that majority of leaf beetles are found in areas of diverse herbaceous cover and Strauss (1988) also in his study regarded Chrysomelidae as one of the most abundant and diverse families of herbivorous insect. Hence, it is totally agreeable that leaf beetle population is generally found abundantly in areas of good herbaceous cover and also their feeding pattern shows that they feed in between the veins of the leaf forming holes of variable size.

The present study emphasized the need for further investigation on insect population in the forest to understand more about insect diversity. Simultaneously, it is extremely necessary to carry out conservation strategies to protect the forest floral and faunal resources and diversity.

References

Andrew, N. and Hughes, L. 2004. Species diversity and structure of phytophagousbeetle assemblages along a latitudinal gradient: predicting the potential impactsof climate change. Ecological Entomology, 29(5):527–542.

Alonso, C. and Herrera, C.M. 2000. Seasonal variation in leaf characteristics and food selection by larval noctuids on an evergreen Mediterranean shrub.Acta Oecol.21:257-265.

Banerjee, M. 2014. Diversity and Composition of Beetles (Order: Coleoptera) of Durgapur, West Bengal, India. Hindawi Publishing Corporation. Volume 2014.

Basset,Y. 1991. Leaf production of an overstorey rainforest tree and its effect on the temporal distribution of associated insect herbivores. Oecologia 88: 211-219.

Biswas, S.C.1995.Coleoptera. Fauna of Western Himalaya (U.P.).Zool.Surv. Ind. Him.Ecosy.Seri., 1995.1: 55-60.

Borthakur, M. 1986.Weather and climate of North East India. Northeast Geogr., 18(1&2): 20-27.

Bouzan, A.M. Flinte, V. Macedo, M.V. and Monteiro, R.F 2015.Elevation and temporal distributions of Chrysomelidae in Southeast Brazil with emphasis on the Galerucinae. Zookeys 547: 103-117.

Carneiro, M.A. Ribeiro, S.P. and Fernandes, G.W. 1995 Artropodos de um gradiente altitudinal na Serra do Cipo, Minas Gerais, Brasil. Revista Brasileira de Entomologia 39(3): 597–604.

Corbett, G.H. and Yusope, M. 1921.Preliminary notes on the "Kadongong" beetle, *Podontia* 14-punctata Linn. Agricultural Bulletin of the Federated Malay States 9: 192-200.

Crowson, R.A.1981. The biology of Coleoptera.Academic Press, London, N.Y.

Flinte, V. Macedo, V.M. and Monteiro, F.R. 2009 Chrysomelids and their host plants along an altitudinal gradient in a tropical Atlantic Rain Forest in Rio de Janeiro, Brazil. In: Jolivet P, Santiago-Blay J, Schmitt M. (Eds). Research on Chrysomelidae, vol.2. Brill, Leiden: 31-56.

Furth, D.G. 1979. Zoogeography and host plant ecology of the Alticinae of Israel, especially *Phyllotreta*; with descriptions of three new species (Coleoptera: Chrysomelidae). Israel J.Zool. 28: 1-37.

Gruev, B. and Tomov, V. 1984. (Fauna Bulgarica 13, Coleoptera, Chrysomelidae, Part-I, Orsodacninae, Zeugophorinae, Donaciinae, Criocerinae,Clytrinae, Cryptocephalinae, Lamprosomatinae, Eumolpinae).-Aedibus Academie Scientiarum Bulgaricae, Sofia.

Gruev, B. and Tomov, V. 1986.(Fauna Bulgarica, 16, Coleoptera, Chrysomelidae Part II Chrysomelinae, Galerucinae, Alticinae, Hispinae, Cassidinae).Aedibus Academie Scientiarum Bulgaricae, Sofia.

Hsiao, T.H. 1994. Molecular techniques for studying systematics and phylogeny of Chrysomelidae –In: Jolivet, P., Cox, M.L.& Petitpierre, E.(eds.), Novel aspects of the Biology of the Chrysomelidae: 237-248.

Hunt, T. Bergsten, J. Levkanicova, Z. Papadopoulou, A. John, O. Wild, R., Hammond, P. Ahrens, D. Balke, M. Caterino, M. Gomez-Zurita, J. Ribera,I., Barraclough, T. Bocakova, M. Bocak, L. and Vogler, A. 2007. A comprehensivephylogeny of beetles reveals the evolutionary origins of a superradiation.Science, 318(5858):1913–1916.

Jacoby, M. 1908.Fauna of British India (Chrysomelidae).Taylor & Francis, 521pp.

Jolivet, P. 1988. Food habits and food selection of Chrysomelidae.Bionomics and evolutionary perspectives. In: Jolivet, P., Petitpierre, E. &Hsiao, T.H.(eds.),Biology of Chrysomelidae: 1-24.

Jolivet,P.1986. Insects and Plants: parallel evolution and adaptations.Flora and Fauna Handbook#2, E.J.Brill, Flora and Fauna Publication, N.Y.

Jolivet, P. Petitpierre, E. and Hsiao, T.H. 1988. Biology of Chrysomelidae. Kluwer Academic Publishers,Dordrecht, The Netherlands.

Jolivet, P. and Hawkeswood, T.H. 1995. Host-plants of Chrysomelidae of the world.Buckhuys. Leiden, The Netherlands, 281pp.

Jolivet, P. and Petitpierre, E. 1981. Biology of Chrysomelidae (Coleoptera).Butll. Inst. Cat. Hist. Nat., (Sec. Zool., 4): 105-138.

Jolivet, P. and Verma, K.K. 2002. Biology of leaf beetles. Intercept Ltd. Andover, Hampshire, UK, 332pp.

Joseph,C.A. and Balakrishnan, M. 2005. Abundance and Richness of Insects in Kazhakuttom Grama Panchayat in Kerela. Bulletin of the National Institute of Ecology 16: 19-27.

Krebs, C.J. 1994. Ecology: the experimental analysis of distribution and abundance. Addison-Wesley Educational Publishers, UK.

Lassau, S.A. Hochuli, D.F. Cassis, G. and Reid, C.A.M. 2005. Effects of habitat complexity on forest beetle diversity: do functional groups respond consistently? Divers.Distrib. 11:73-82.

Linzmeier, A.M.and Ribeiro-Costa, C.S.2008.Seasonality and temporal structuration of Alticini community(Coleoptera,Chrysomelidae, Galerucinae) in the Araucaria Forest of Parana, Brazil. Rev. Bras. Entomol.52 (2): 289-295.

Lien, V.V. and Yuan, D. 2003. The differences of butterfly (Lepidoptera, Papilionoidea) communities in habitats with various degrees of disturbance and altitudes in tropical forests of Vietnam.Biodivers.Conserv. 12: 1099-1111.

Leksono, A.S. Nakagoshi, N. Takada, K. and Nakamura, K. 2005-a. Vertical and seasonal variation in the abundance and the species richness of Attelabidae and Cantharidae (Coleoptera) in a suburban mixed forest. Entomological Science 8: 235-243.

Leksono, A.S. Takada, K. Nakagoshi, N. and Nakamura, K. 2006. Species composition of Modellidae and Cerambycidae (Coleoptera) in a coppice woodland. Journal of Forest Research 11: 61-64.

Louda, S.M. 1984. Herbivore effect on stature, fruiting, and leaf dynamics of a native crucifer. Ecology 65: 1375-1386.

Lopatin, I.K. 1984: Leaf beetles (Chrysomelidae) of the Central Asia and Kazakhstan.- Oxonian Press, New Delhi.

Maulik, S. 1919.The Fauna of British India, Chrysomelidae (Hispinae & Cassidinae). Taylor & Francis, London, 439pp.

Maulik, S. 1926.The Fauna of British India, Chrysomelidae (Chrysomelinae & Halticinae). Taylor & Francis, London, 442pp.

Mohr, K.H. 1966. Chrysomelidae-In: Freude, H.,Harde, K.& Lohse, G.A. (eds), Die Kafer Mitteleuropas: 95-299.

Morrow,P.A. 1979. Host specificity of insects in a community of three co-dominant *Eucalyptus* species. Aus. J. Ecol. 2:89-106.

Marques, M.C.and Oliveira, P.E.A.M. 2004. Fenologia de espécies do dossel e do sub-bosque de duas Florestas de Restinga na Ilha do Mel, sul do Brasil. Revista Brasileira de Botânica 27(4): 713–723.

Mathew, G. and Rahamathulla, V.K. 1993.Studies on the butterflies of Silent ValleyNational Park.*Entomon*.**18**: 185-192.

Mirzoeva, N. 2001. A study of the ecofaunal complexes of the leaf-eating beetles (Coleoptera, Chrysomelidae) in Azerbaijan. Turkish Journal of Zoology 25: 41-52.

Mitchell, R. 1981. Insect behavior, resource exploitation and fitness. Ann. Rev. Ent.26: 373-396.

Novotny,V. and Basset, Y. 1998. Seasonality of sap-sucking insects (Auchenorrhyncha,Hemiptera)feeding on Ficus (Moraceae) in a lowland rain forest in New Guinea.Oecologia115:514-522.

Powell, J.A. 2009. "Coleoptera," in Encyclopedia of Insects, H. Vincent Resh and T.Ring Carde,Eds.,p.199, Academic Press, New York, NY,USA,2nd edition.-

Raupp, M.J. and Denno, R.F. 1983.Leaf age as a predictor of herbivore distribution and abundance. In: Variable plants and herbivores in natural and managed systems.Academic Press, pp.91-124.

Reid, C. 1995. A cladistic analysis of subfamilial relationships in the Chrysomelidaesensu lato (Chrysomeloidea). Biology, phylogeny and classification of Coleoptera: papers celebrating the 80th birthday of Roy A.Crowson, 2:559–631.

Riley, E. Clark, S. Flowers, R. and Gilbert, A. 2002. Chrysomelidae Latreille 1802. In Arnett, R., Thomas, M., Skelley, P., and Frank, J., editors, American Beetles:Polyphaga:Scarabaeoidea through Curculionoidea. Vol. 2: 617–691.

Riley, D.G. and Schuster, D.J. 1992.The occurrence of *Catolaccushunteri*, a parasitoid of *Anthonomus eugenii*, in insecticidetreated bell pepper. Southwestern Entomologist 17:71-72.

Rodriguez, V. 1995. Relation of flagellum lengthto reproductive success in male Chelymorphaalternans Boheman. Coleopterists Bulletin 49(3):201–205.

Saikia, M.K. Kalita, J. and Saikia.P.K. 2009. Ecology and conservation needs of nymphalid butterflies in disturbed tropical forest of Eastern Himalayan biodiversity hotspots, Assam, India.International Journal of Biodiversity and Conservation Vol.1 (7) pp.231-250.

Sanchez-Reyes, U.J. Nino-Maldonado, S. and Jones, R.W. 2014 Diversity and altitudinal distribu-tion of Chrysomelidae (Coleoptera) in Peregrina Canyon, Tamaulipas, Mexico. ZooKeys 417: 103–132.

Sen, I. and Gok, A. 2009. Leaf beetle communities (Coleoptera: Chrysomelidae) of two mixed forest ecosystem dominated by pine-oak-hawthorn in Isparta province, Turkey. Ann. Zool. Fennici 46: 217-232.

Smiley, J.T. 1982. The herbivores of *Passiflora*: comparison of monophyletic and polyphyletic feeding guilds. In: J.H.Visser and A.K.Minks (eds) Proc.5th Int.Symp. on Insect-Plant Relationships. Pudoc, Wageningen, pp.325-330.

Seeno, T.N. and Wilcox, J.A. 1982. Leaf beetles Genera (Coleoptera: Chrysomelidae).Entomography Publications, Sacramento, California, 223p.

Jolivet, P. Petitpierre, E. and Hsiao, T.H. 1988. Biology of Chrysomelidae. Kluwer Academic Publishers,Dordrecht, The Netherlands.

Sanjayan, K.P. 1993. An overview of heterogenity in grasshopper assembleges.Hexapoda5: 133-143.

Southwood, T.R.E. Wint, G.R.W. Kennedy, C.E.J. and Greenwood, S.R. 2004. Seasonality, abundance, species richness, and specificity of the phytophagous guild of insects on oak (Quercus) canopies. European Journal of Entomology 101: 43-50.

Stebbing, E.P. 1914. Indian Forest insects of economic importance.Eyre and Spottiswoode Ltd., London, 648pp.

Stork, N.E. Hammond, P.M.Russel, B.L. and Hadwen, W.L. 2001.The spatial distribution of beetles within the canopies of oak trees in Richmond Park, UK. Ecological Entomology 26: 302-311.

Strauss.S.Y. 1988. The Chrysomelidae: a useful group for investigating herbivore-herbivore interactions. Kluwer Academic Publishers. pp. 91-105.

Wagner, T. 1999. Arboreal chrysomelid community structure and faunal overlapbetween different types of forests in Central Africa. In Cox, M., editor, Advances in Chrysomelidae biology 1: 247–270.

Wagner, T. 2003. Seasonality of canopy beetles in Uganda. Arthropods of tropical forests: 146-158.

Wallner, W.E. 1987. Factors affecting insect population dynamics:Differences between outbreak and non-outbreak species. Annu. Rev. Entomol. 32: 317-340.

Wasowska, M. 2004. Impact of humidity and mowing on Chrysomelid communities (Coleoptera: Chrysomelidae) in meadows of the Wierzbanowka valley (Pogorze Weilickie hills, Southern Poland).Biol. Brat. 59: 601-611.

Warchalowski, A. 1991. Chrysomelidae, stonkowate (Insecta: Coleoptera) (Clytrinae I Cryptocephalinae). Fauna Polski, Tom 13- Polska Akademia Nauk, Muzeum I Instytut Zoologii, Warszawa.

Warchalowski, A. 1993. Chrysomelidae, stonkowate (Insecta: Coleoptera) (Lamprosomatinae, Eumolpinae, Chrysomelinae,Timarchini, Chrysomelinae).Fauna Polski, Tom 15- Polska Akademia Nauk, Muzeum I Instytut Zoologii, Warszawa.

Warchalowski,A. 1994.Chrysomelidae, stonkowate (Insecta:Coleoptera) (Chrysomelinae, Gonioctenina, Entomoscelina, Galerucinae).Fauna Polski, Tom 16- Polska Akademia Nauk, Muzeum I Instytut Zoologii, Warszawa.

Warchalowski, A. 2003. The leaf beetles of Europe and the Meditterranean area. Natura optima dux foundation, Warszawa.

Wolda H. 1978 Seasonal fluctuations in rainfall, food and abundance of tropical insects.Journal of Animal Ecology47: 369–381.

□ □ □