Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(1): 711-716

Received: 07-11-2016
Accepted: 08-12-2016

Badal Bhattacharyya
All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

Gautam Handique
Ex-Senior Research Fellow, All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

D Pujari
Ex-Senior Research Fellow, All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

S Bhagawati
All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

H Mishra
All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

D Gogoi
All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

H Debnath
Subject Matter Specialist (Plant Protection), Krishi Vigyan Kendra, Karimganj, Cachar, Assam, India

Correspondence
Gautam Handique
Ex-Senior Research Fellow, All India Network Project on Soil Arthropod Pests, Department of Entomology, Assam Agricultural University, Jorhat, Assam, India

Species diversity and relative abundance of scarab beetle fauna in Assam, northeast India

Badal Bhattacharyya, Gautam Handique, D Pujari, S Bhagawati, H Mishra, D Gogoi and H Debnath

Abstract
Species diversity and abundance of scarab beetles was studied from Assam, northeast India from 2007-2013. A total of 44 species of scarabs under 6 sub families and 21 genera were identified, out of which 41 species are new records. Majority of the phytophagous species belonged to the subfamily Melolonthinae and Rutelinae while the coprophagous species belonged to Dynastinae and Cetoniinae. Species profiling revealed that *Apogonia ferruginea* was the most predominant species and contributed 17.60 per cent out of the total number of beetles followed by *Anomala chlorosoma* (14.56%), *Adoretus* spp. (12.75%), *Apogonia area* (10.94%) and *Sophrops irridipennis* (10.63%) with peak population in the month of July (419.14). Multiple regression analysis with weather parameters revealed that beetle population was influenced by combined effects of maximum temperature, total rainfall and wind speed in all years with maximum variation in 2007 (78.66%) and minimum in 2012 (59.56%).

Keywords: Abundance, Assam, diversity, scarab beetle, species profiling

1. Introduction

Northeast India is considered as one of the major biodiversity hotspot around the world [1]. For this fact, exhaustive studies have been conducted on species diversity and abundance of lepidopteran insects, especially the butterflies. On the contrary, very few reports or studies have been undertaken on scarab beetles which conspicuously form a large group of insects from this region. Scarab beetles contain both beneficial and harmful species [2]. The beneficial coprophagous beetles, through their habitat of burrowing and burying of dung, perform a series of ecological functions such as nutrient cycling, soil aeration [3], secondary seed dispersal [4] and regulation of enteric parasites and dung breeding dipterans pests [5, 6] while the harmful phytophagous beetles or leaf-chafers are agricultural pests of various commercial crops, feeding mostly on leaves, flowers, fruits, roots and other parts of the plants [2]. Notable contributions were made by Chatterjee and Biswas (2000) [7], Sewak (2006) [8], Singh *et al*. (2010) [9] and Li *et al*. (2010) [10] who tried to describe few of the species from northeast India.

Recently, the phytophagous scarab beetles have emerged as major pest of several economically important crops of northeast India. Some of the species showed endemism to a particular habitat and few species are spreading to regions where they had not been recorded in the past. Despite this fact, no concentrated studies on species diversity and abundance, identification of most damaging species and host range were taken up on a serious note, especially from Assam, northeast India. Keeping this in view, the present investigation was undertaken to document the species diversity, host preference and seasonal abundance of scarab beetles in Assam, northeast India.

2. Materials and Methods

2.1 Collection of scarab beetles by light trap and scouting

Surveys were randomly conducted at various locations in 10 districts of Assam from 2007-2013. The collection of scarab beetles started immediately after the onset of pre-monsoon rain in the month of April-May which is considered to be the peak season of beetle emergence in diverse habitats [11, 12]. Collections were made by scouting on host trees [13] as well as by light trapping [14] at several locations at 18.00-21.00 hours. Light trap catches were preserved in bulk while those collected thorough scouting were sorted as host-wise in glass vials containing 70% alcohol. The collected beetles were brought to the laboratory of All India Network Project (AINP) on Soil Arthropod Pests, Assam Agricultural University (AAU), Jorhat and preserved for further identification. The collected and preserved beetle specimens were sent to the Division of Entomology, Indian Agricultural Research Institute, New Delhi, India and to AINP on Soil arthropod Pests, Bangalore, India for taxonomic identification.

2.2 Species profiling of scarab beetles through light trapping

In order to monitor the incidence of scarab beetles in a fixed location, a light trap (Pest-O-Flash) with known wavelength (320-380 nm) was installed at Instructional cum Research Farm, AAU, Jorhat during 2007-2013. From 2012 onwards, this light trap was replaced with "Light trap safer to beneficial insects" (National Centre for Integrated Pest Management, New Delhi) for trapping the beetles. The light trap was continuously operated from March-September from 18.00 to 21.00 hours during this period [14]. The light trap catches of scarab beetles were collected daily and counted. Further the beetles were sorted species wise. After sorting, the beetles were pinned with the help of entomological pins (41mm), labelled and kept in insect boxes (3 × 6 × 8 inch). The data on monthly collection of beetles and their average population per day were calculated out.

2.3 Correlation studies with weather parameters

The different weather parameters *viz*., temperature (maximum and minimum), relative humidity (morning and evening), total rainfall, number of rainy days, bright sunshine hours and wind speed data were collected (2007-2013) from the Department of Agricultural Meteorology, AAU, Jorhat. The monthly population of scarab beetles was correlated with different weather parameters by following the standard statistical procedure as described by Snedecor and Cochran (1956) [15].

3. Results and Discussion

3.1 Collection of scarab beetles by light trap and scouting

A total of 44 species of scarabs under 6 sub families and 21 genera were identified (Table 1), out of which 39 species were found to be phytophagous and fed on varieties of host plants. Species richness may be attributed to availability of preferred host, both in terms of quality and quantity [16] and suitability of various abiotic factors like light intensity [17] which can attract more number of beetles [18]. Majority of the phytophagous scarab beetles belonged to the subfamily Melolonthinae and Rutelinae. Melonlonthinae species form a dominant group among the phytophagous beetles followed by Rutelinae and Cetoniinae even in other regions of India [19]. Other subfamilies included Scarabaeinae, Dynastinae, Cetoniinae and Geotrupinae. Although few flower feeding Cetoniids [20] were recorded, their abundance and diversity was relatively less. Under the subfamily Melolonthinae, a total of 17 species were identified of which *Holotrichia serrata, Apogonia* sp., *A. aerea*, *A. ferruginea*, *Sophrops irridipennis* and *Lepidiota mansueta* were most abundant. Under the subfamily Rutelinae, *Adoretus* sp., *A. aerial*, *A. pallens*, *A. bicolor*, *Anomala chlorosoma*, *A. chloropus* and *Heteronychus* sp. were found to be most copious. From the subfamily Cetoniinae, 2 species were identified and 3 from the subfamily Dynastinae, among which *Xylotrupes gideon* and *Pentadon* sp. were abundant while *Eupatorus hardwickii* was less abundant. Some of the species *viz*., *Sophrops iridipennis*, *Anomala perplexa*, *A. dussumieri* and *Adoretus renardi* have been reported from Assam and responsible for causing economic losses in mango, lemon, green gram, jackfruit, drumstick *etc*. [13] while some are new records. Among the coprophagous beetles, 4 species from the subfamily Scarabaeinae and 1 species from the subfamily Geotrupinae was recorded which is conspicuous with the findings of Thakare and Zade (2012) [21] who had recorded Scarabaeinae to be a dominant subfamily in terms of species richness and abundance among the coprophagous beetles in Maharashtra as well as in other regions of the world [22, 23]. Among them, *Catharsius molossus*, *Onthophagus* sp. and *Onitis philemon* were the most abundant.

3.2 Species profiling of scarab beetles through light trapping

The relative abundance of light trapped catches of ten species of scarab beetles (8 phytophagous and 2 coprophagous) based on light trap data generated from 2007-13 is presented in Fig. 1. Out of the eight phytophagous scarab species, *A. ferruginea* was the most predominant species and contributed 17.60% out of the total number of beetles trapped during the period of investigation. The second most abundant species was *Anomala chlorosoma* (14.56%) followed by *Adoretus* spp. (12.75%). *Apogonia area* and *Sophrops irridipennis* registered 10.94% and 10.63% of abundance respectively. The remaining three species *viz*., *Anomala chloropus, Holotrichia serrata* and *Coprus* sp. recorded 8.85%, 7.08% and 3.83% abundance, respectively. In case of coprophagous beetles, only two species *viz*., *Catharsius molossus* and *Onthophagus* sp. were trapped with 8% and 5.76% abundance, respectively. Light trap data on monthly population of beetles and the weather parameters from 2007-13 are graphically depicted in Fig. 2. The mean emergence of beetles was observed from the month of March (106.14 numbers) of each year and showed a gradually increasing trend up to July, where maximum numbers of beetles (419.14 numbers) were recorded. Thereafter, the population of beetles declined and lowest population was observed during September (101.29 numbers). Further, light trap catches revealed that, among the phytophagous beetles, *A. ferruginea* was the dominant species followed by *A. chlorosoma* and *Adoretus* spp. while only two species of coprophagous beetles were recorded. A high affinity towards light may be the apparent reason that *A. ferruginea* was the leading species caught in light traps as evident from the findings of Parvez and Srivastava (2010) [24] and Sima and Srivastava (2012) [25] from Rajasthan. However, their abundance is relatively less in cooler regions of India [26].

Table 1: Scarab beetles recorded from Assam, northeast India from 2007 to 2013

Sl. No.	Species identified	Host records		Relative Abundance*
		Larval	Adult	
A. Sub Family: Melolonthinae				
1.	*Holotrichia* sp.	1	2, 3	++
2.	*Holotrichia consanguinea* Blanchard	4, 5, 6, 7, 8	2, 3, 9, 10, 11	+
3.	*Holotrichia longipennis* Blanchard	1	-	+
4.	*Holotrichia sikkimensis* Blanchard	1, 12	-	+
5.	*Holotrichia serrata* Fabricius	5, 6, 13	3, 14, 16, 17,18,19	+++
6.	*Apogonia* sp.	20, 21	14, 19, 23, 24, 25, 38	+++
7.	*Apogonia aerea* Blanchard	20, 21	14, 22, 23	+++
8.	*Apogonia ferruginea* Fabricius	23	14, 23	+++
9.	*Apogonia blanchardi* Ritsema	-	14, 26	++
10.	*Sophrops* sp.	-	27	+
11.	*S. irridipennis*	16, 27, 28, 29	14, 16, 19, 24, 27, 28, 30	+++
12.	*Coprus* sp.	-	17	++
13.	*Maladera* sp.	-	2,23, 28	+
14.	*Maladera insanabilis* (Brenske)	-	2,23, 28	+
15.	*Lepidiota mansueta* Burmeister	1, 5, 20, 21, 31	Non-feeding	+++
16.	*Lepidiota sp.* Indet.	1, 32	13, 19, 32, 33, 34	
17.	*Schizonycha ruficollis* Olivier	35	17	++
18.	*Brahmina coriacea* Hope	1	28	+
B. Sub Family: Rutelinae				
19.	*Adoretus* sp.	21, 20, 36, 37	38, 14, 20, 21, 26, 45, 46	+++
20.	*Adoretus aerial* Arrow	20, 21	2, 14, 16, 20, 21	+++
21.	*Adoretus pallens* Blanchard	2	23	+++
22.	*Adoretus bicolor* Brenske	-	23, 26	+++
23.	*Adoretus bomblinota* Gurm.	-	26	++
24.	*Adoretus renardi* Brenske	-	23, 26	+
25.	*Adoretus versutus* Harold	-	23	++
26.	*Anomala* sp.	20, 21, 37, 39, 4	20, 21	++
27.	*Anomala dorsalis* Fabricius	23	23	++
28.	*Anomala chlorosoma* Arrow	-	2, 14, 26	+++
29.	*Anomala chloropus* Arrow	-	2, 14, 26	+++
30.	*Anomala pellucida* Arrow	-	40	++
31.	*Anomala perplexa* Hope	-	2, 14, 26	+
32.	*Anomala dussumieri* Blanchard	-	2, 14, 26	+
33.	*Anomala dimidiata* (Hope)	1, 47, 6, 8, 41	-	++
34.	*Heteronychus* sp.	5	-	+++
C. Sub Family: Scarabaeinae				
35.	*Catharsius molossus* Linnaeus	48	-	+++
36.	*Onthophagus* sp.	48	-	+++
37.	*Onitis philemon* Fabricius	48	-	+++
38.	*Heliocopris* sp.	48	-	+
D. Sub Family: Dynastinae				
39.	*Pentodon* sp.	1, 5	5	+
40.	*Xylotrupes gideon* Linnaeus	42, 6, 43	44, 35	+++
41.	*Eupatorus hardwickii* (Hope)	-	-	+
E. Sub Family: Cetoniinae				
42.	*Anthracophora* sp.	-	26	+
43.	*Oxycetonia albopunctata* (Fabricius)	-	28	+
F. Sub Family: Geotrupidae				
44.	*Bolbocerus* sp.	48	-	++

* Less common: +, Common: ++, Abundant: +++, Information unavailable: -

Sl. No. 35-38 and 44 are coprophagous while others are phytophagous

1: Potato (*Solanum tuberosum*), 2: Ber (*Ziziphus jujube*), 3: Jamun (*Syzygium cumini*), 4: Groundnut *(Arachis hypogaea)*, 5: Sugarcane (*Saccharum officinarum*), 6: Maize (*Zea mays*), 7: Cowpea (*Vigna unguiculata*), 8: Chilli (*Capsicum* spp.) 9: Drumstick (*Moringa oleifera*), 10: Fig (*Ficus carica*), 11: Neem (*Azadirachta indica*), 12: Ginger (*Zingiber officinale*),13: Arecanut (*Areca catechu*), 14: Guava (*Psidium guajava*), 15: Cocoa (*Theobroma cacao*), 16: Jackfruit (*Artocarpus heterophyllus*), 17: Agarwood (*Aquilaria spp.*),18: *Indigofera spp.*,19: Mango (*Magnifera indica),* 20: Black gram (*Vigna mungo*), 21: Green gram (*Vigna radiata*), 22: Jute (*Corchorus* spp.), 23: Rose (*Rosa spp.*), 24: Soalu (*Litsaea monopetala*), 25: Silk tree (*Albizia* spp.), 26: Confederate rose (*Hibiscus mutabilis*), 27: Dahlia (*Dahlia* spp.), 28: Assam Lemon (*Citrus limon*), 29: Ixora (*Ixora* spp.), 30: Indian devil tree (*Alstonia scholaris),* 31:Colocasia(*Colocasia esculenta*), 32: Ramie (*Boehmeria nivea*), 33: Betel vine (*Piper betel*), 34: Banana (*Musa* spp.), 35: Tea (*Camellia sinensis*), 36: Grass, 37: Forest trees, 38: Jute (*Corchorus* spp.), 39: Sweet potato (*Ipomoea batatas*)*,* 40: Indian Mast tree (*Polyalthia longifolia*), 41: Wheat (*Triticum* spp.), 42: Okra (*Abelmoschus esculentus*), 43: Passion fruit (*Passiflora edulis*), 44: Peepal tree (*Ficus* spp.), 45: Eucalyptus (*Eucalyptus obliqua*), 46: Rain tree (*Albizia saman*), 47: Rice (*Oryza sativa*), 48: Coprophagous

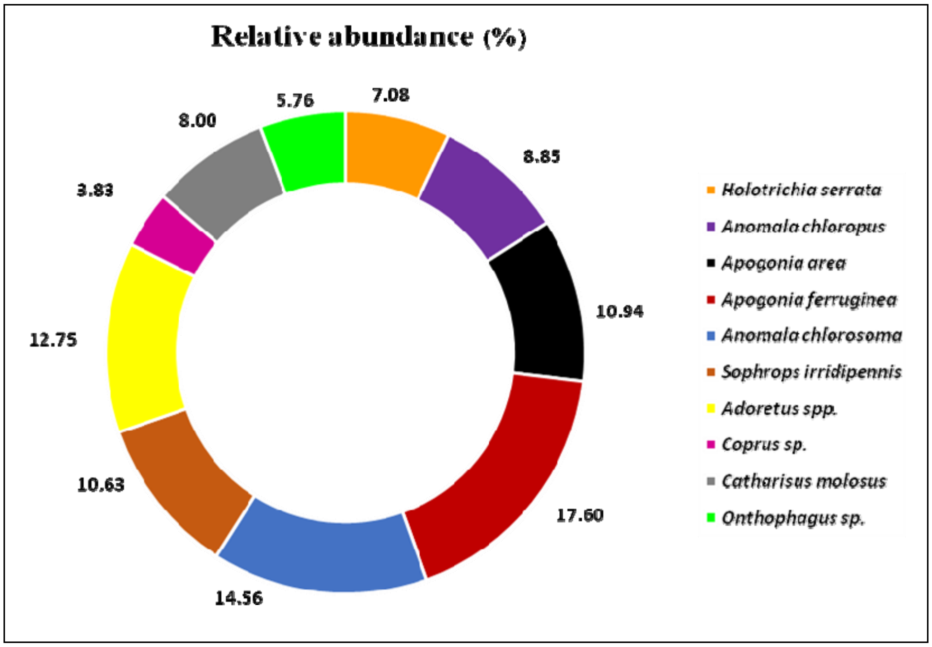

Fig 1: Relative abundance of different white grub species during 2007-2013

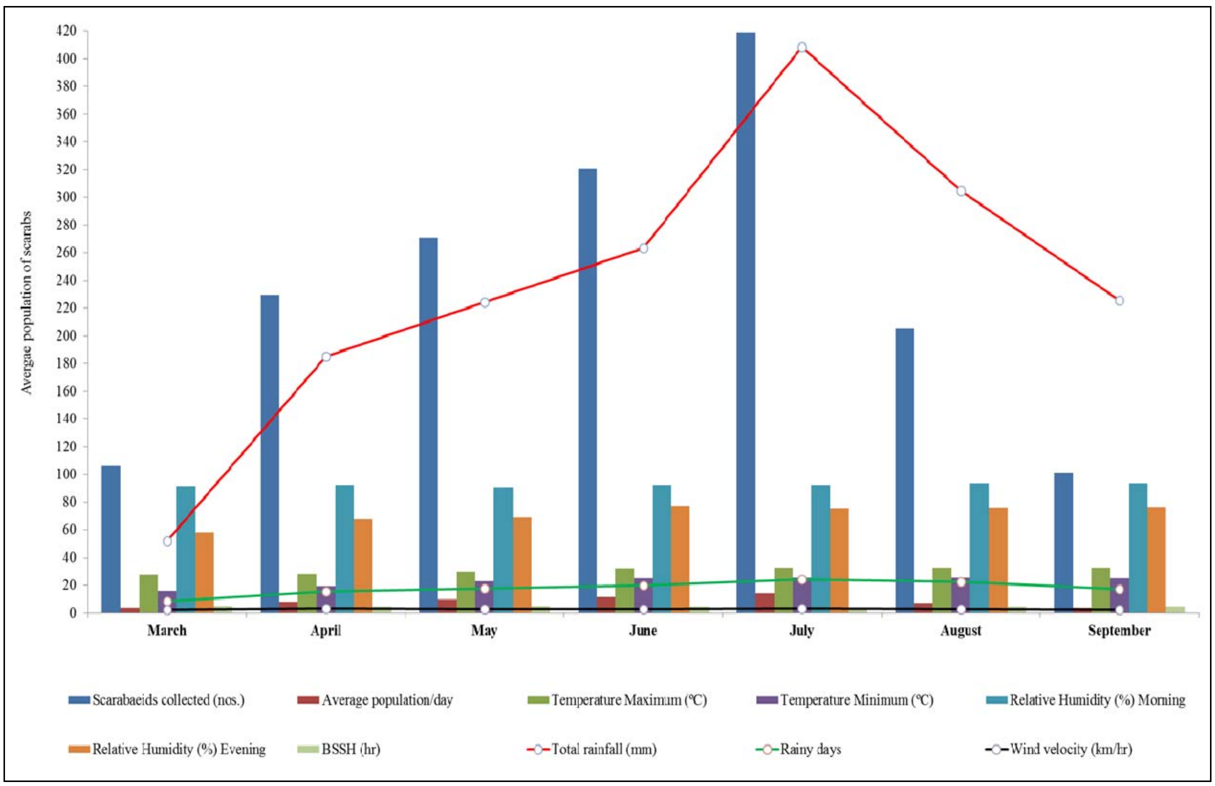

Fig 2: Influence of weather parameters on monthly scarab beetle population during 2007-13

3.3 Correlation studies with weather parameters

The different weather parameters were correlated with the monthly population of scarab beetles trapped in the light trap at AAU, Jorhat during 2007-13 and correlation coefficients are presented in Table 2. Out of the weather parameters, total rainfall, rainy days, wind speed and evening relative humidity had significant correlation with the monthly collection of light trap catches of scarab beetles. The data obtained from the correlation study were subjected to multiple regression analysis to assess the combined effect of different weather parameters on monthly population of scarab beetles. While analysing the data, multicolinearity among the different independent variables (weather parameters) was observed. Therefore, only three factors of weather viz., maximum temperature, total rainfall and wind speed were considered for regression analysis and the regression equations are presented in Table 3. The year wise regression equation indicated that 78.66 (2007), 76.78 (2008), 71.94 (2009), 56.27 (2010), 62.87 (2011), 59.56 (2012) and 66.45 (2013) per cent variation in population of scarab beetle (Y) was found to be controlled by the combined effect of maximum temperature, total rainfall and wind speed while the remaining per cent variation in scarab beetle population was due to some other meteorological factors. The beetles were observed to emerge in the month of March, reaching a peak in the month of July after which the population started declining which was at variance with the findings of Parvez and Srivastava (2010) [24] and Pathania *et al*. (2015) [26]. A variation in agroclimatic conditions prevailing between these regions possibly influenced the seasonal diversity and emergence of beetles which was found to have significant correlation with the existing weather parameters *viz*., total rainfall, rainy days, wind speed and evening relative humidity. It was also found that combined effect of maximum temperature, total rainfall and wind speed had the maximum influence on their emergence. Pal (1977) [17] and Sima and Srivastava (2012) [25] previously stated that weather factors such as temperature, relative humidity and rain fall positively influenced the flight activity and light trap catches of beetles. This clearly indicated that temperature and moisture shifts may have dramatic role in causing more and more outbreaks in this region as observed in other areas [27]. These climatic and weather changes not only affect the status of insect pests but also affect their population dynamics, distribution, abundance, intensity and feeding behaviour [28]. Intensity of change in climatic ecosystem noted by meteorological science has shown a direct and indirect effect on the prey and host relationship, their immune responses and rate of development, their fecundity and various physiological functions [29, 30].

Table 2: Correlation of scarab beetle population with meteorological parameters at AAU, Jorhat during 2007-13

Meteorological parameters	Correlation coefficients (r)						
	2007	2008	2009	2010	2011	2012	2013
Maximum temperature (^{0}C)	0.668*	0.649*	0.707*	0.333 NS	-0.260 NS	0.280 NS	0.049 NS
Minimum temperature (^{0}C)	0.755*	0.765*	0.806*	0.375 NS	-0.096 NS	0.388 NS	0.282 NS
Morning relative humidity (%)	-0.597*	-0.729*	0.429*	0.288 NS	0.152 NS	-0.278 NS	0.547 NS
Evening relative humidity (%)	0.723*	0.600*	0.716*	0.516*	0.419*	-0.188 NS	0.419 NS
Total rainfall (mm)	0.873*	0.824*	0.870*	0.834*	0.711*	0.585*	0.718*
Rainy days	0.846*	0.622*	0.902*	0.644*	0.767*	0.453*	0.671*
Bright sunshine hours (h)	-0.720*	-0.507*	-0.291 NS	-0.136NS	-0.803*	-0.255 NS	-0.799*
Wind velocity (km/h)	0.600*	0.630*	0.831*	0.437*	0.841*	0.673*	0.599 *

* Significant at 5 % probability level

Table 3: Multiple regression equation of scarab beetle population at AAU, Jorhat during 2007-13

Year	Regression Equation	Per cent variation in population*
2007	$Y= -209.084 + 3.413 X_1 + 1.203 X_2 + 50.681 X_3$	78.66
2008	$Y= -206.074 + 3.324 X_1 + 1.196 X_2 + 51.086 X_3$	76.78
2009	$Y= -204.124 + 2.297 X_1 + 2.098 X_2 + 50.876 X_3$	71.94
2010	$Y = -226.775 + 2.863 X_1 + 1.097 X_2 + 38.787 X_3$	56.27
2011	$Y = -303.465 + 2.019 X_1 + 1.176 X_2 + 58.077 X_3$	62.87
2012	$Y = -365.061 + 9.353 X_1 + 1.856 X_2 + 81.792 X_3$	59.56
2013	$Y= -3569.947 + 72.881 X_1 + 5.520 X_2 + 559.101 X_3$	66.45

*Influenced by combined effect of maximum temperature, total rainfall and wind speed

4. Conclusion

Keeping in view, the diversity of the scarab beetles and presence of a wide variety of food plants and congenial environment to sustain their population in the northeast region of India, serious efforts need to be taken up to study the potential pest species that might emerge or are already in the process of emerging as major pests of economy concern in the region. Moreover, under the changing scenario of climate change, there is likelihood that this group of insects may gain major pest status. There is further probability of hot and dry summer in this region in the years to come, which increases the probability of more frequent and intense damage. The implementation of a reliable risk assessment system needs accurate knowledge on ecological demands of at least the key species, mainly concerning soil, weather and biotic parameters. Preparedness backed by scouting, monitoring and forecasting are the best ways to prevent future outbreaks and spread of scarab beetles. There is an urgent need to educate the farmers about seriousness of the problem, recognizing the damage, use of proper thresholds for taking management decisions as well as gain confidence in non-chemical management options through community mobilization approaches.

5. Acknowledgement

The authors are thankful to Indian Council of Agricultural Research (ICAR), New Delhi for providing financial support to conduct this research. Thanks are due to Dr. V.V. Ramamurthy, Ex. Principal Scientist; Dr. K. Sreedevi, Principal Scientist, Division of Entomology, IARI, New Delhi and Dr. T.M.M. Ali, Professor Emeritus, Division of Entomology, UAS, Bangalore for the identification of the scarab beetles of Assam.

6. References

1. Mize D, Taba R, Sarma HN. Species diversity of birds in Dihang-Dibang Biosphere Reserve, Arunachal Pradesh. The Ecoscan. 2014; 8:77-84.
2. Chandra K, Gupta D, Uniyal VP, Bharadwaj M, Sanyal AK. Studies on scarabaeid beetles (Coleoptera) of Govind wildlife sanctuary, Garhwal, Uttarakhand, India. Biological Forum. 2012; 4:48-54.
3. Mittal IC. Natural manuring and soil conditioning by dung beetles. Tropical Ecology. 1993; 34:150-159.
4. Estrada A, Coates-Estrada R. Howler monkeys, dung beetles (Scarabaeidae) and seed dispersal: Ecological interactions in the tropical rainforest of Los tuxlas, Mexico. Journal of Tropical Ecology. 1991; 7:459-474.
5. Borenmissza GF. Insectary studies on the control of dungbreeding flies by the activity of dung beetle, *Onthophagus gazella* F. (Coleoptera: Scarabaeinae). Journal of Australian Entomological Society. 1970; 9:31-41.
6. Fincher GT. The potential value of dung beetles in pasture ecosystem. Journal of the Georgia Entomological Society. 1981; 16:316-333.

7. Chatterjee SK, Biswas S. Coleoptera: Scarabaeidae, Cetoniinae, Dynastinae, Rutelinae, Zoological Survey India. State Fauna Series 4: Fauna of Meghalaya. 2000; 5:161:199.
8. Sewak R. Insecta: Coleoptera: Scarabaeidae: Coprinae (Dungbeetles), Zoological Survey of India, Fauna of Arunachal Pradesh. State Fauna Series. 2006; 13:191-224.
9. Singh OT, Chakravorty J, Varatharajan R. Entomo fauna of Kane Wildlife Sanctuary, Arunachal Pradesh, northeastern India. Journal of Threatened Taxa. 2010; 2:1392-1400.
10. Li LC, Yang SP, Wang CC. Revision of the *Melolontha guttigera* group (Coleoptera: Scarabaeidae) with a key and an annotated checklist of the East and South-East Asian Melolontha Groups. Annals of the Entomological Society of America. 2010; 103:341-359.
11. Bhattacharyya B, Pujari D, Bhuyan U, Handique G, Baruah AALH, Dutta SK *et al*. Seasonal life cycle and biology of *Lepidiota mansueta* (Coleoptera: Scarabaeidae): a serious root-feeding pest in India. Applied Entomology and Zoology. 2015; 50:435-442.
12. Pathania M, Chandel RS. Life history strategy and behaviour of white grub, Brahmina *coriacea* (Hope) (Coleoptera: Scarabaeidae: Melolonthinae) an invasive pest of potato and apple agro-ecosystem in northwestern India. Oriental Insects. 2016; 51:46-69.
13. Das M, Bhattacharyya B, Pujari D, Handique G. Faunal composition of scarab beetles and their hosts in Assam. In: Chakravarthy, A.K., Shakunthala, S. (Eds) Arthropod diversity and conservation in the tropics and sub-tropics. Springer. Singapore. 2016, 335-344.
14. Maharjan B, Khanal D. Monitoring of scarab beetles using light trap in horticulture field of Paklihawa campus, Rupandehi, Nepal. Emergent Life Sciences Research. 2016; 2:5-9.
15. Snedecor GW, Cochran WG. Statistical methods applied to experiments in agriculture and biology. Iowa State University Press, Iowa. 1956, 251-288.
16. Bogawat JK, Pandey SN. Food preference in *Aulacophora* sp. Indian Journal of Entomology. 1967; 29:349-352.
17. Pal SK. Relative abundance of Scarabaeid beetles on light trap. Indian Journal of Entomology. 1977; 39:197-200.
18. Diagne A, Story RN, Hammond AM. Adult *Phyllophaga ephilida* host plant feeding preference. Florida Entomologist. 2006; 89:391-395.
19. Kumar S, Sankar M, Sethuramana V, Musthak A. Population dynamics of white grubs (Coleoptera: Scarabaeidae) in the rose environment of Northern Bangalore, India. Indian Journal of Science and Technology. 2009; 2:46-52.
20. Touroult J, Gall LP. Fruit feeding Cetoniinae community structure in an anthropogenic landscape in West Africa. Journal of Insect Conservation. 2013; 17:23-34.
21. Thakare VG, Zade VS. Diversity of beetles (Insecta: Coleoptera) from the vicinity of Semadoh-Makhala road, Sipna Range, Melghat Tiger Reserve, (M.S.) India. Bioscience Discovery. 2012; 3:112-115.
22. Kanda N, Yokota T, Shibata E, Sato H. Diversity of dung-beetle community in declining Japanese sub alpine forest caused by an increasing sika deer population. Ecological Research. 2005; 20:135-141.
23. Duraes R, Martins WP, Vaz-De-Mello FZ. Dung Beetle (Coleoptera: Scarabaeidae) assemblages across a natural forest-cerrado ecotone in Minas Gerais, Brazil. Neotropical Entomology. 2005; 34:721-731.
24. Parvez A, Srivastava M. A short-term surveillance of coleopteran fauna in an agro-ecosystem near Bikaner (Western Rajasthan), India. Biological Forum. 2010; 2:23-29.
25. Sima, Srivastava M. Entomofauna associated with bajra crop as observed in an agro-ecosystem in Rajasthan, India. International Journal of Theoretical and Applied Sciences. 2012; 4:109-121.
26. Pathania M, Chandel RS, Verma KS, Mehta PK. Studies on the preliminary ecology of invasive phytophagous Indian Scarabaeidae of North Western Himalaya. Science, Technology and Arts Research Journal. 2015; 4:127-138.
27. Jaworski T, Hilszczański J. The effect of temperature and humidity changes on insects development and their impact on forest ecosystems in the context of expected climate change. Forest Research Papers. 2013; 74:345-355.
28. Khaliq A, Javed M, Sohail M, Sagheer M. Environmental effects on insects and their populationdynamics. Journal of Entomology and Zoology Studies. 2014; 2:1-7.
29. Yamamura K, Kiritani KA. Simple method to estimate the potential increase in the number of generations under global warming in temperate zones. Applied Entomology and Zoology. 1998; 33:289-298.
30. Yumamura K, Yokazawa M, Nishimori M, Ueda Y, Yokosuka T. How to analyse long- term insect population dynamics under climate change: 50 year data of three insect pests in paddy fields. Population Ecology. 2006; 48:38-48.