CORRELATIONS BETWEEN SOIL PROPERTIES AND ANT POPULATION IN AGRICULTURAL HABITAT AT AURANGABAD MAHARASHTRA, INDIA

CHATE, S.

Dept of Zoology, Smt. G. G. Khadse College, Muktainagar 425306, India
e-mail: chatesurekha16@gmail.com

(Received 28th Sep 2021; accepted 22nd Dec 2021)

Abstract. Ants have a profound impact on the edaphic factors of the agricultural ecosystem as they increase the soil nutrient and plant growth. Hence in agricultural ecosystem farmers promote ant populations in their farm. Ants help to investigated soil properties included Nitrogen, Phosphorus, Potassium and organic carbon as well as Water holding capacity, pH etc. on agriculture field. The Ants were collected by using handpick, pitfall trap, scented trap methods. The soil properties Some of the environmental variables like rainfall, temperature, and relative humidity were analyzed from June 2015 to May 2016 at an agricultural field at Aurangabad city. The correlation coefficient of ant's population with soil properties and climatic factors were studied. In that nitrogen, organic carbon, relative humidity, rainy season shows significant positive correlation with all ant species $r = 0.507$, $r = 0.649$ at $p = 0.05$ level, and $r = 0.825$, $r = 0.793$ at $p = 0.01$ level of significant, respectively. The present study revealed that ants had the ability to modify chemical properties of soils and showed the correlation between ant diversity and soil.
Keywords: *agricultural field, ants, correlation coefficient, soil disturbance*

Introduction

There are various studies that reveal the role of ants in the maintenance of the ecosystem in which they live. Ants positively impact agricultural systems by rapidly consuming large numbers of pest insects, disturbing pests during feeding and oviposition, and increasing soil quality and nutrients. Naturally occurring ant species in milpas, mango, citrus, coconut, cashews, and cotton control many pest insects (Choate and Drummond, 2011). In food chains ants are considered as an integral part because of their capability to affect the flow of water, energy and nutrients through many terrestrial ecosystems (Jurgensen et al., 2008). Species of ants differentially affects the soil environment and it is of significant interest to understand how the distribution and composition of ant species are affected by environmental factors. Soil heterogeneity is increased by the activity of ants and reflects their long term engineering activities (Jouquet et al., 2006). In turn while searching a spot for building their nest, ants select microhabitats with specific physico-chemical conditions according to the species preferences (Johnson, 2000). In soil ants build several types of nest some are completely or partially present in the soil that consist of corridors and chambers can be covered by dead wood, stones and some other natural structure on the soil surface. In nest ants accumulates food in large amounts and deposits some food in the nest, which may alter the nutrient status of the soil and increase drainage and soil aeration, increasing the porosity of soil (Pokarzhevskij, 1981). How ants affect soil properties is determined by many factors such as nesting strategy, colony age, mound size, feeding behavior, and nutritional demand (Dauber and Wolters, 2000). Several biological and physical factors such as solar radiation, water, temperature, affect abundance and species richness of community of ant inhibiting particular environments because insects ants are small

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

sized with high surface to volume ratio that make them prone to desiccation (Edney, 1977). Ants are very important in below ground processes by altering chemical and physical environment and their effects on soil organisms, microorganisms, plants (Folgarait, 1998). In the colony of ants, there are many workers, this leads to intensive mixing of soil from different soil depths and changes soil textural properties (Cammeraat and Risch, 2008). Ants are not considered as soil biota but in relation to their contact with soil, soil biota categorized into three groups such as endogeic (those living in soil), anecic (those which transfer materials between soil and litter habitats) and epigeic (those which process organic matter on or near the soil surface). In these ants could be placed in either the epigeic or anecic groups. In the present study twenty-three ant species collected in that *Dorylus labiatus* are endogeic species. Ant species *Tetramorium walshi, Meranoplus bicolor, Leptogenys chinensis, Solenopsis geminata* are epigeic species. In anecic group *Myrmicaria brunnea, Camponotus compressus*, *Camponotus sericeus* are present. These suggestions should be tested on the level of population because the significant evidence of the habitation is not present on these species. Soil biota categorized according to size and ants are considered to be microfauna. It is seen that ants' role in soil functioning are similar to earthworms, termites (Bouche, 1977). Ants act as an indicator because ants respond quickly to the surrounding environment. The process of construction of the nest, foraging activity increases the fertility of the soil. The contribution of active ants mounds to the surrounding soil ecosystems involves long-term nutrient release into the system (Chate and Chavan, 2021). Ants are abundant and diverse part of soil fauna to increase crop yield and restore soil quality in agroecosystems (Jesovnik et al., 2019). Hence the present study was undertaken to study the correlation coefficient (r) of ant population in agriculture fields of periurban site, with soil parameters like nitrogen, phosphorus, potassium, organic carbon, water holding capacity, pH and climatic parameters such as rainfall, temperature, and relative humidity.

Materials and Methods

Study Site

Aurangabad city is located mainly in Godavari Basin on the bank of its tributary Khamriver. The city is surrounded by hills in all directions, latitude $19^0$53’ and longitude $75^0$23’ of Aurangabad. Aurangabad city experiences three distinct seasons: the rainy season from June to September, winter season from October to January and summer season from February to May. The average rainfall of Aurangabad district is 734 mm and minimum temperature is 5.6^0 C and maximum temperature is 45.9^0 C (www.aurangabad.gov.in.). The study area was agriculture field is located within 15 km of the city center near about 6 ha or more in size planted with *Zea mays* (Maize), *Saccharum officinarum* (Sugarcane), *Gossypium* (cotton), vegetables such as *Spinacea oleracea* (Spinach), *Rhaphanus sativus* (Radish) and major trees were *Mangifera indica*, *Tamarindus indica* etc. (*Fig. 1*). This historic Aurangabad city is facing civilization and urbanization during a couple of decades with modification of natural and artificial habitats for different purposes. In the present study ant sampling was carried by three methods as handpick, pitfall trap, scented trap, all out search method was in morning 6 to 8 am once in a month. In agriculture field in each cultivated plants as Zea mays (Maize), Saccharum officinarum (Sugarcane), Gossypium (cotton) six ant colony were observed and for soil analysis soil sample was collected from near the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

colony of ants once in the month. Blocks of soil 15 cm long, 6 cm wide and 16 cm deep were excavated from each of six ants mounds the section of cut soil sample 0-5 cm deep were taken 20 m x 20 m in rectangular area of one-hectare plot of surroundings ants mounds in agriculture field. Collected ants specimens and soil samples were brought to the laboratory. Soil samples were air dried overnight and next day sieved soil through a 2 mm screen. Ants were preserved in 70% alcohol. Identification is made with the help of stereoscope trinocular microscope based on standard taxonomic keys suggested by Bolton (1994), Holldobler and Wilson (1990), Mathew and Tiwari (2000) and Sheela (2008) etc. Physico-chemical parameters such as nitrogen, phosphorus, potassium, organic carbon, water holding capacity, and pH were analyzed in soil testing Marathwada Institute of Technology laboratory Aurangabad as per standard protocol described by Somawanshi et al. (2012), and Trivedy and Goel (1987). Meteorological data such as rainfall, temperature, and relative humidity were obtained from the Government of Maharashtra Water Resource Department, Aurangabad. The study was done in the agriculture field in Aurangabad city from June 2015 to May 2016. The study evaluate how nest of ants affects different characteristic on soil nutrient, soil cation. The article aimed to investigate the way ant populations influence physical and chemical soil properties of agricultural fields near Aurangabad city, India, focusing on the correlation between ant populations, soil properties and climatic factors.

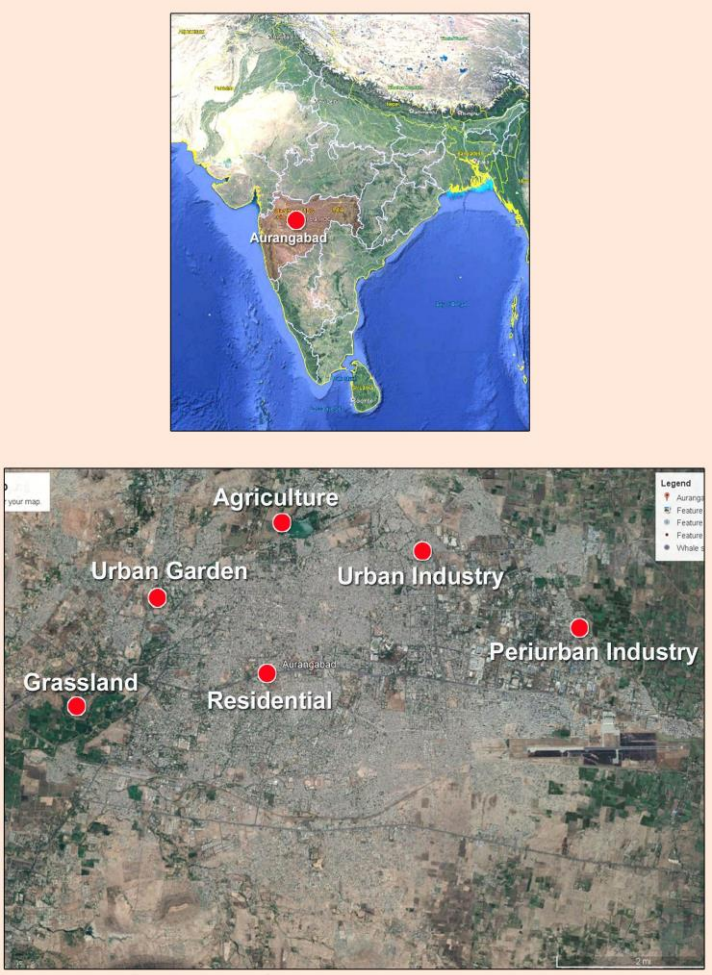

Figure 1. *Map of Agriculture site from Aurangabad*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

Site of agriculture field shows in *Fig. 2A* and in *Fig. 2B* shows Pitfall trap.

(A) (B)

Figure 2. *(A) Agriculture field, (B) Pitfall trap*

Result and Discussion

In the present study total twenty-three species of ants belonging to seventeen genera and six subfamilies were recorded. Month wise climatic parameters in the agriculture field represent in *Table 1*. Month wise soil parameters such as nitrogen, phosphorus, potassium, organic carbon, water holding capacity, pH are shown in *Table 2*.

Table 1. *Month wise climatic parameter in Agriculture Field. (Government of Maharashtra, Water Resource Department, Aurangabad)*

Month	Rainfall (mm)	RH (%)	Temperature (^{0}C)
June	243	83.0	30
July	32	57.1	33.3
August	82	78.7	32
September	(Max.245.8)	(Max.84.2)	30.1
October	33.2	64.0	34.8
November	0	45.2	35.5
December	0	51.5	29.8
January	0	47.1	(Min.28.6)
February	0	(Min.44.1)	34.0
March	13.3	49	38.2
April	0	55	40.5
May	(Min.2)	46.4	(Max.42.5)

Correlation coefficient (r) of ant species diversity are shown in *Table 3*, with soil properties and climatic factors in the agriculture field. Nitrogen shows significant positive correlation with subfamily Dolichoderinae (r = 0.567), subfamily Pseudomyrmecinae (r = 0.566) and all ants species (r = 0.507) at p = 0.05 level and negative correlation with phosphorus (r = -0.587). Potassium showed significant

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

positive correlation with p^H (r = 0.804) at p = 0.01 level and negative correlation with temperature (r = - 0.53). Organic carbon showed significant positive correlation with all ants species (r = 0.649) at p = 0.05. Water holding capacity showed negative correlation with subfamily Dolichoderinae (r = - 0.723) at p = 0.01 level. Relative humidity showed significant positive correlation with subfamily Myrmicinae (r = 0.62), Ponerinae (r = 0.669), Pseudomyrmecinae (r = 0.74), all ants species (r = 0.825) at p = 0.01 and subfamily Formicinae (r = 0.535) at p = 0.05 level. Rain showed significant positive correlation with relative humidity (r = 0.897) at p = 0.01, subfamily Myrmicinae (r = 0.558), Formicinae (r = 0.574), Dolichoderinae (r = 0.583), Ponerinae (r = 0.56), Pseudomyrmecinae (r = 0.596) at p = 0.05, respectively and all ants species (r = 0.793) at p = 0.01. Temperature showed negative correlation with subfamily Dolichoderinae (r = -519), Pseudomyrmecinae (r = - 0.568) and all ants species (r = - 0.61) at p = 0.05 level (*Table 3*). In the agriculture field, climatic factors such as relative humidity and rainfall were positively correlated with ant communities. In this study 23 species of ants were sampled, which were distributed amongst 17 genera and six subfamilies (*Table 4*). Myrmicinae was most speciose subfamily belongs to eight species followed by subfamily Formicinae belongs to four species followed by subfamily Ponerinae and subfamily Pseudomyrmecinae belongs to three species and respectively subfamily Dolichoderinae and Dorylinae belongs to one species respectively. The species of the *Solenopsis geminate are* distinguished for their aggressiveness in the use of litter and soil found in agroecosystems. Ants of *Solenopsis* genera are able to withstands long periods of food scarcity and have effective strategies for mass recruitment. The *Camponotus* genus distributed wide consisting of terrestrial habit, dominant organism and omnivorous species. They are commonly known as Carpenter ants because of their ability to build nest in the dead or decaying logs at the base of trees. *Meranoplus bicolor* nest of these species present on ground surrounding with a small crater they feed on harvest grass seed and floral nectar. Species *Leptogenys Processionalis* are predatory and nomadic. These ants are ground dwelling, nest of these species seen in loose soil.

Table 2. *Month wise soil parameter in Agriculture Field during June 2015 - May 16. (Government of Maharashtra, Water Resource Department, Aurangabad)*

Month	**pH** (1 :2.5)	**OC (%)**	**N** (kg ha^{-1})	**P** (kg ha^{-1})	**K** (kg ha^{-1})	**WHC %**
June	7.66	2.17	(Max.815)	(Min.3.99)	450	69.3
July	7.98	1.16	250	16.4	637	(Min.11.5)
August	8.00	(Min.0.99)	(Max.815)	(Min.3.99)	450	72.6
September	8.16	1.66	250	45.6	655	50.1
October	7.48	2.92	388	27.9	453	78.1
November	8.13	3.88	551	66.1	585	94.9
December	(Max.8.28)	1.56	(Min.150)	(Max.70.4)	608	68.3
January	8.13	1.61	288	48.8	(Max.663)	46.3
February	7.30	(Max.4.25)	401	41.2	473	49.8
March	7.84	1.22	401	57.5	651	(Max.95.5)
April	(Min.6.97)	1.67	338	69.1	(Min.346)	65.9
May	7.53	2.16	338	28.1	393	82.13

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

Table 3. *Correlation coefficient (r) of ant population with soil properties and climatic factors in Agriculture Field site during June 2015 to May 2016*

	N	**P**	**K**	**OC**	**WHC**	**pH**	**RAIN**	**RH**	**TEMP**	**MYRME**	**FORMI**	**DOLICH**	**PONER**	**PSEUDO**	**DORYL**	**Total Ant**
N	0.000	-0.587	-0.401	0.1	0.36	-0.095	0.385	0.476	-0.084	0.295	0.246	**0.567**	0.088	**0.566**	-0.246	**0.507**
P		0.000	0.271	0.168	0.266	0.044	-0.463	-0.577	0.193	-0.28	0.097	-0.359	-0.295	-0.247	-0.309	-0.29
K			0.000	-0.228	-0.275	**0.804**	0.058	-0.092	-0.53	-0.104	-0.085	0.046	0.2	0.031	0.294	-0.01
OC				0.000	0.224	-0.304	-0.186	-0.355	0.127	-0.304	0.013	0.05	-0.179	-0.246	-0.281	**0.649**
WHC					0.000	-0.091	-0.129	-0.119	0.422	0.093	0.317	0.187	-0.253	0.025	-0.723	0.148
pH						0.000	0.18	0.139	-0.631	0.119	0.135	0.216	0.327	0.387	0.149	0.301
RAIN							0.000	**0.897**	-0.464	**0.558**	**0.574**	**0.583**	0.56	**0.596**	-0.076	**0.793**
RH								0.000	-0.443	0.62	0.535	0.449	**0.669**	0.74	-0.034	**0.825**
TEMP									0.000	-0.377	-0.38	-0.519	-0.338	-0.568	-0.057	-0.61
MYRME										0.000	0.319	**0.676**	-0.013	0.393	-0.078	**0.771**
FORMI											0.000	0.425	0.319	**0.641**	-0.740	**0.762**
DOLICH												0.000	-0.181	0.392	-0.236	**0.739**
PONER													0.000	**0.565**	0.085	0.344
PSEUDO														0.000	-0.201	**0.809**
DORYL															0.000	-0.47
Total Ant																0.000

N – Nitrogen, P – Phosphorus, K – Potassium, OC – Organic Carbon, WHC – Water holding capacity, RH – Relative humidity, Temp – Temperature, MYRME – Myrmicinae, FORMI – Formicinae, DOLICH – Dolichoderinae, PONER - Ponerinae PSEUDO - Pseudomyrmecinae, DORYL – Dorylinae

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

Table 4. *Ant distribution in agriculture field from Aurangabad city*

Subfamily	*Genus*	*Species*
Dorylinae	*Dorylus*	*Dorylus labiatus*
Myrmicinae	*Crematogaster*	*Crematogaster subnuda* *Crematogaster brunnea contemta*
	Solenopsis	*Solenopsis geminata*
	Pheidole	*Pheidole spathifera*
	Tetramorium	*Tetramorium walshi*
	Monomorium	*Monomorium indicum*
	Trichomyrmex	*Trichomyrmex destructor*
	Myrmicaria	*Myrmicaria brunnea*
	Meranoplus	*Meranoplus bicolor*
Formicinae	*Camponotus*	*Camponotus compressus* *Camponotus anguisticolis* *Camponotus sericeus*
	Oecophylla	*Oecophylla smaragdina*
	Paratrechina	*Paratrechina longicornis*
	Polyrhachis	*Polyrhachis dives*
Ponerinae	*Leptogenys*	*Leptogenys chinensis* *Leptogenys processonalis*
	Anochetus	*Anochetus graeffei*
Dolichoderinae	*Tapinoma*	*Tapinoma melanocephalum*
Pseudomyrmecinae	*Tetraponera*	*Tetraponera allaborans* *Tetraponera nigra* *Tetraponera rufonigra*

Ants act as ecosystem engineers and also respond quickly to change in soil chemical and physical properties by contributing in agriculture practices as increasing nutrient quantity, drainage and aeration (Folgarait, 1998). Studies on ant diversity in agriculture ecosystem help to identify species of ants with potential for biological control in different types of crops (Fernandes et al., 1994). During the present study the agricultural habitat was under investigation to study the correlation between nest soil parameters and 23 species of ants. Silva et al. (2017) studied the correlations between 34 species of ants with other arthropods. In the present study, temperature showed a significant negative correlation with ants species. This is in agreement with the result obtained by Watanasit et al. (2000) and Sudd and Franks (1987). It is observed that there is significant positive correlation of nitrogen, organic matter in agriculture ecosystem, this is due to ants burrowing activity, construction of ant nest this is in agreement with Wang (2017). Soil organic matter, total nitrogen, available Phosphorous, available potassium and total potassium increased in ant mound soil due

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

to excavation activities by ants, accumulation of organic matter and other nutrient at the time of building of mound construction. Chemical properties C, P, Na, K, pH, Ca, Organic matter were quantified in the nest of ant species *Myrmica ruginodis* and surrounding soil in the forest. All properties except Phosphorous were higher in the nest of ant species *Myrmica ruginodis* than in surrounding soil investigated by Vele et al. (2010). Cammeraat and Risch (2008) studied the effect of soil dwelling ants on properties of soil aggregate stability which were improved by ant activity. Nest of ants showed higher values for pH phosphorus, potassium, and nitrogen content, which help in soil turnover process in young spruce forest stands of steppe rangelands of Iran noticed by Ghobadi et al. (2016).

Conclusion

The present study concluded the correlation between diversity of ants in agriculture field periurban site from Aurangabad city, with soil properties that included the parameters as nitrogen ($r = 0.507$) at $p = 0.05$ level, potassium, phosphorus, organic matter ($r = 0.649$) at $p = 0.05$ level, water holding capacity and climatic factors such as humidity ($r = 0.825$) at $p = 0.01$ level, temperature, rainy season ($r = 0.793$) at $p = 0.01$ level. Except potassium, phosphorus, water holding capacity and temperature, all other parameters showed significant positive correlation with ants, this was due to bioturbation, nesting habitat and foraging activity of ants in the agriculture field. Such activities caused by ants will help to improve the properties of soil of the area.

Acknowledgements. Authors are grateful to the Professor and Head of the Department of Zoology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad for providing the necessary laboratory facilities for the completion of present research study.

REFERENCES

[1] Bolton, B. (1994): Identification guide to the ant genera of the world. – Cambridge, Mass: Harward University Press, 222 pp. DOI: https://doi.org/10.1017/S0007485300034453.
[2] Bouche, M. B. (1977): Strategies lombriciennes. – ln: Lohm, U., Persson, T. (eds.) Soil organisms as components of ecosystems. Ecological Bulletin 25: 122-132.
[3] Cammeraat, E. L. H., Risch, A. C. (2008): The impact of ants on mineral soil properties and processes at different scales. – J. Applied Entomol. 132: 285-294. https://doi.org/10.1111/j.1439-0418.2008.01281.x.
[4] Chate, S., Chavan, R. (2021): Nests and Habitats of Ants Observation in Aurangabad Maharashtra, India. – Journal of Biological Sciences 21: 45-51.
[5] Choate, B., Drummond, F. (2011): Ants as biological control agents in agricultural cropping systems. – Terrestrial Arthropod Reviews. https://doi.org/10.1163/187498311X571979.
[6] Dauber, J., Wolters, V. (2000): Microbial activity and functional diversity in the mounds of three different ant species. – Soil Biology. Biochem. 32: 93-99. https://doi.org/10.1016/S0038-0717(99)00135-2.
[7] Edney, E. B. (1977): Water balance in land Arthropods. – Springer Berlin. New York.
[8] Fernandes, W. D., Oliveira, P. S., Carvalho, S. L., Habib, M. E. M. (1994): Pheidole ants as potential biological control agents of the boll weewil, Anthonomus grandis (Col., Curculionidae) in Southeast Brazil. – Journal of Applied Entomology 118: 437-441.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111

[9] Folgarait, P. J. (1998): Ant biodiversity and its relationship to ecosystem functioning: a review. – Biodiversity and Conservation 7(9): 1221-1224. http://dx.doi.org/10.1023/A:1008891901953.
[10] Ghobadi, M., Mahdavi, M., Agosti, D., Jouri, M. H., Majer, J. (2016): Ants visible from space influence soil properties and vegetation in steppe Rangeland of Iran. – Sociobiology 63(4): 1063. DOI: 10.13102/sociobiology.v63i4.1195.
[11] Holldobler, B., Wilson, E. O. (1990): The Ants. – Cambridge, Belknap of Harvard University Press, 732p. https://www.hup.harvard.edu/catalog.php?isbn=9780674040755&content=toc.
[12] Jesovnik, A., Blazevic, I., Lemic, D., Pajac Zivkovic, I. (2019): Ant fauna of Annual and Perennial crops. – Applied Ecology and Environmental Research 17(6): 12709-12722. DOI: http://dx.doi.org/10.15666/aeer/1706_1270912722.
[13] Johnson, R. A. (2000): Habitat segregation based on soil texture and body size in the seed harvester ants *Pogonomyrmexrugosus*and *P. barbatus*. – Ecol. Entomol. 25: 403-412. https://doi.org/10.1046/j.1365-2311.2000.00286.x.
[14] Jouquet, P., Dauber, J., Lagerlof, J., Lavelle, P., Lepage, M. (2006): Soil invertebrates as ecosystem engineers: intended and accidental effects on soil and feedback loops. – Appl. Soil. Ecol. 32: 153-164. https://doi.org/10.1016/j.apsoil.2005.07.004.
[15] Jurgensen, M. F., Finer, L., Domisch, T., Kilpelainen, J., Punttila, P., Ohashi, M., Niemela, P., Sundstrom, L., Neuvonen, S., Risch, A. C. (2008): Organic mound - building ants: their impact on soil properties in temperate and boreal forests. – Journal of Applied Entomology 132(4): 266-275. 10.1111/j.1439-0418.2008.01280.x.
[16] Mathew, R., Tiwari, R. N. (2000): Insects: Hymenoptera: Formicidae. – Zool. Surv. India, State Fauna Series 4: Fauna of Meghalaya, Part 7: 251-409. https://www.antwiki.org/wiki/images/0/04/Mathew_%26_Tiwari_2000.pdf.
[17] Pokarzhevskij, A. D. (1981): The distribution and accumulation of nutrients in nests of ant Formica polyctena (Hymenoptera, Formicidae). – Pedobiologia 21: 117-124.
[18] Sheela, S. (2008): Handbook on Hymenoptera: Formicidae. – Zoological Survey of India, Kolkata. http://faunaofindia.nic.in/PDFVolumes/hpg/036/index.pdf.
[19] Silva, T. H., Saumya, E., Karunarathna, N. B., Karunaratne, W. A., Inoka, P. (2017): Competence of litter ants for rapid biodiversity Assessments. – International journal of biodiversity, Article ID: 6582191.
[20] Somawanshi, R. B., Kadlag, A. D., Deshpande, A. N., Tamboli, B. D., Kadu, P. P., Bhakare, B. D. (2012): Laboratory methods for analysis of soils, irrigation water and plants. – MPKV, Rahuri. (Refered by handbook).
[21] Sudd, J. H., Franks, N. R. (1987): The behavioral ecology of ants. – Chapman and Hall, New York, USA.
[22] Trivedy, R. K., Goel, P. K. (1987): Practical methods in ecology and environmental science. – Environmental Publications, Karad, India, 340p. https://www.worldcat.org/title/practical-methods-in-ecology-and-environmental-science/oclc/59050888.
[23] Vele, A., Frouz, J., Holusa, J., Kalcik, J. (2010): Chemical properties of forests soil as affected by nest of *Myrmicaruginodis* (Formicidae). – Biologia 65(1): 122-127. DOI: 10.1515/forj-2016-0026.
[24] Wang, C., Wang, G., Wu, P., Rafique, R., Zi, H., Li, X., Luo, Y. (2017): Effects of ant mounds on the plant and soil microbial community in an Alpine Meadow of Qinghai - Tibet Plateau. – Land Degradation and Development 28(5): 1538-1548. DOI: 10.1002/ldr.2681.
[25] Watanasit, S., Phaphunnn, C., Permkam, S. (2000): Diversity of ants (Hymenoptera: Formicidae) from Ton Nga Chang wildlife sanctuary, Songkhla, Thailand. – Science Asia 26: 187-194.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2002_11031111