Research Article

ABUNDANCE AND DIVERSITY OF SOIL ARTHROPODS IN DIFFERENT HABITATS IN CHITWAN NEPAL

A. Paudel[1]* and S. Tiwari[1]

ABSTRACT

Arthropod diversity is generally influenced by the type of habitat in an agro-ecosystem. Crop diversity, soil types, nature of habitats (intensive, semi-intensive and natural), proximity to natural habitats, landscape complexity etc. are the major arthropod diversity influencing factors. Hence, this study was designed to investigate the diversity of various arthropod species among different habitats such as mango orchard, litchi orchard, vegetable field, organic field and uncultivated land during March 2021. Arthropod sampling was taken on every three- day interval using pitfall trap. The composition, relative abundance, and diversity indices of the arthropods of five different habitats were analyzed. Maximum abundance was recorded in uncultivated land (N = 398) and minimum in the vegetable field (N = 61). Shannon-Weiner Diversity Index (1.76) and species richness (9.67) were found highest in mango orchards. The greatest evenness was recorded in the vegetable field (0.91) and more dominance index was recorded in uncultivated land (0.60). There was a significant difference in total abundances of arthropods between vegetable fields than in the organic and uncultivated fields, being highest in uncultivated land followed by litchi, mango and organic field. Hymenopterans were the most abundant order (53.55%) followed by Coleoptera and Arachnida. These arthropods were crop pests and beneficial. Beneficial arthropods population was more than crop pests. Such beneficial arthropods play a vital role to deliver an ecosystem service. This study can help to develop a conservation and management protocol for beneficial arthropods in the agro-ecosystem.

Keywords: *Biodiversity, ecosystem, insects, orchard, organic farm*

INTRODUCTION

Soil arthropods are a group of soil-inhabited arthropods belonging to the classes of Crustacea, Arachnida, Myriapoda, and Insecta (Eisenbeis and Wichard, 1987). They are generally characterized by the features, namely a hard chitinous exoskeleton, segmentation, multiple jointed appendages, and an open circulatory system. These are involved in many processes such as organic matter translocation, breaking and decomposition, nutrient

[1] Department of Entomology, Agriculture and Forestry University, Rampur, Chitwan, Nepal
*Email for corresspondance: archanapaudel053@gmail.com

cycling, soil structure formation, water regulation and consequently play important roles in maintaining soil quality and health and providing ecosystem services (Menta and Remelli, 2020). High biodiversity is perceived as synonymous with ecosystem health. Diverse communities are believed to have increased stability, increased productivity and resistance to invasion and other disturbances. In any ecosystem, determination of diversity, richness, evenness, and abundance of fauna is required for ecological studies, habitat management, and conservation programs (Nahmani *et al*., 2005). Agricultural landscape, habitat type, farming system, landscape composition and connectivity all contribute to explaining species biodiversity and richness (Leksono, 2017).

Orchards are complex ecosystems in which plants have adjacent associations with different living constituents. Consequently, the fundamental modification in the community of plants has an impact on the population of arthropods (Ramzan *et al*., 2021). Mango and litchi are essential groups of fruit crops with highly nutritious value (Lauricella *et al*., 2017; Zhao *et al.*, 2020). Organic farming, on the other hand, is considered to reduce the effects of conventional agricultural practices on the environment and especially halt the decline of biodiversity in the agricultural landscape (Boutin *et al*., 2009). The vegetable field is usually intensified. Since the intensification of production systems implies simplification, and consequent biodiversity losses leading to the reductions in ecosystem services, the use of arthropod biodiversity and dynamics can be a reliable indicator of system diversity, covering a wide range of ecological functions in the agro-ecosystem (Hendrickx *et al*., 2007). Arthropods help in the mineralization of some nutrients in the bacteria and fungi and release nutrients in plant-available forms, increase soil fertility by changing the physical properties of soil and many of these also compete with the root and foliage-feeders and protect plants from pest attack thereby increasing the production of the crops (Culliney, 2013).

Soil arthropod's diversity is very much determined by the vegetation above it. However, very few studies have only been done on the soil arthropod composition comparing different habitats with different vegetation types. Given that arthropods play a major role in nutrient cycling, community interactions and food webs (Losey and Vaughan, 2006), knowledge of arthropods' composition in different habitats are essential. The present study was done to address the diversity indices of arthropods and their abundances in different habitats by using pitfall traps. The objective was to determine which of the five habitats consist of the best overall population numbers of as many taxa as possible. The sampling method commonly used for measuring soil arthropods in different habitats is pitfall trapping. The fundamental design of a pitfall trap consists of a container buried into the ground with the top flush with the soil surface (Hohbein and Conway, 2018). In comparison to other collection methods, it has been considered the most ideal method for sampling soil arthropods (Sabu and Shiju, 2010).

MATERIALS AND METHODS

The study was conducted in five different habitats, namely mango orchard, litchi orchard, vegetable field, organic farm and uncultivated land at the Agriculture and Forestry University (AFU), Rampur (27˚39’23.6” N 84˚21’26.8” E), Chitwan in March 2021. The monitoring of arthropods was done using pitfall traps. Seven pitfall traps were set in each habitat using a plastic glass (9 cm long, 4.5cm diameter) one meter apart from each other (total traps set was thus thirty-five). The soil was dug about 9 cm deep by using a spade and the glass fit into the hole. Each glass received approximately 200 ml of water and 1 ml of detergent. The traps were removed after the third day of installation and the samples were collected and kept in insect collection bottles with 10% formalin. The trap was refilled with water and detergent and kept in the same manner as before. This way, soil insects were collected every 72 hrs and brought in the laboratory. They were sorted and preserved in the glass vials containing the alcohol (70%) and glycerin (30%) and identification was done up to the species level with the help of taxonomic keys and scientific literature. The numbers of insects of each family were recorded separately for each of the studied habitats.

Statistical analysis

All the collected data were analyzed by using statistical tools in Microsoft Office Excel. The numbers of insects of each family were presented by number, and that of orders was presented by percentage. Biodiversity was assessed using diversity-based indices. The diversity indices assume that individuals are randomly sampled from an infinitely large population.

Shannon-Weiner Diversity Index

Species distribution of arthropods was computed using the Shannon-Weiner Diversity Index:

$H = - \Sigma Pi (\ln Pi)$,

where H represents the index of species diversity in a given locality, Pi is the proportion of the total sample belonging to the ith species and ln = Natural logarithm.

Diversity is low if H is less than 1, moderate if H ranges from 1 to 3 and high if H is greater than 3 (Nisa *et al*., 2018).

Evenness

Evenness indicates the allotment of individuals among the species. It depicts the stability of the community and was calculated using Pielou’s Evenness Index:

$e = H/Hmax$, where e = evenness index, H = Shannon-Weiner Index, Hmax is the maximum possible value of H, equal to $Hmax = \ln(S)$

where ln = Natural logarithm, S= number of species.

A site with low evenness (less than 0.5) indicates that a few species dominate the site and the community is unstable. Evenness between 0.5-0.75 indicates moderate stability while more than 0.75 indicates higher stability of the community.

Simpson Dominance Index

Dominance Index was calculated by Simpson Dominance Index (Odum, 1993): $D = \Sigma(Pi)2$, here,

Pi = proportion of individual species (Ni/N), Ni represents the number of individual species and N represents the total number of species.

A value of less than 0.5 indicates less dominance of any species, 0.5-0.75 indicates moderate dominance of a few species while more than 0.75 indicates that the community is highly dominated by a particular species.

Species richness and relative abundance were based on the number of taxa found in the given areas. A t-test was also used to assess the data of abundance among different habitats at the level of significance (0.05).

RESULTS AND DISCUSSION

Total arthropods captured during the whole sampling period accounted to be 1141 individuals, of which 234 were trapped in the mango orchard, 273 in the litchi orchard, 61 in the vegetable garden, 175 in the organic farm and 398 in the uncultivated land (Table 1). The maximum diversity (H) 1.76 and species richness 9.67 was observed in a mango orchard and the lowest diversity 0.78 and species richness 5 was observed in the uncultivated land. Litchi orchard had diversity of 1.36 with species richness 8, vegetable field had 1.52 diversity and 5.33 species richness and the organic field had a diversity 1.65 and richness 6.67. Evenness was maximum in the vegetable garden (0.91) and lowest in uncultivated land (0.48) and the dominance was verified as maximum from the uncultivated land (0.60) and lowest from the organic field (0.23). The evenness of mango orchard, litchi orchard and the organic field was 0.78, 0.65, and 0.87 respectively. Likewise, the dominance index of mango, litchi and vegetable field was 0.24, 0.34 and 0.27 respectively.

A comparison of two different habitats showed highly significant differences in the total abundances between the arthropods of the vegetable field with that of the organic field and uncultivated land (Table 2). Likewise, the total abundance of arthropods of the vegetable field also showed a significant difference from that of the litchi orchard, however, it did not differ significantly from that of the mango orchard. Similarly, the total abundance of arthropods in organic fields differed significantly with that of uncultivated land. While all others showed non-significant differences from each other.

Table 1. Average species richness, abundance, Shannon-Weiner Diversity, Evenness, Simpson Dominance index and total abundance in different habitats in Agriculture and Forestry University (AFU), Rampur, Nepal

S. N.	Site	Species richness	Shannon-Weiner Diversity Index (H)	Evenness	Simpson Dominance Index	Total abundance
1	Mango	9.67	1.76	0.78	0.24	234
2	Litchi	8.00	1.36	0.65	0.34	273
3	Vegetable	5.33	1.52	0.91	0.27	61
4	Organic	6.67	1.65	0.87	0.23	175
5	Uncultivated	5.00	0.78	0.48	0.60	398
Total						1141

An obvious pattern of communities is the variation in species abundance. Uncultivated land accounted for the maximum abundance of arthropods, followed by litchi orchard, mango orchard and organic farm, with the lowest abundance on the vegetable field. Differences in the abundance of individuals of soil arthropods were influenced by the vegetation diversity, environmental conditions, and abundance of litter in these areas (Zayadi *et al*., 2013). Furthermore, frequent use of insecticides in the vegetable field may cause lowest abundance of arthropods. The Shannon-Weiner diversity index (H) is an indicator of diversity of arthropods. Our results showed that the Shannon diversity index ranged from 0.78 (in uncultivated land) to 1.76 (in mango orchard) which suggests low diversity in uncultivated land and moderate in case of mango orchard and other fields. Decrease in vegetation cover and/or changes in vegetation pattern toward small and over-dispersed vegetation leads to lower diversity of arthropods (Meloni *et al*., 2020).

Animal species richness may vary with the complexity of the habitat form, for example, vegetation structure. Mango orchard showed the highest species richness while the uncultivated land resulted in the lowest richness. However, the species richness was comparable. The finding of Goehring *et al*. (2002) was also in conformity with these results and reported no such differences in species richness across the habitats. In contrast to these results, Clark *et al*. (1997) found greater species richness in the organic system compared to the conventional system. The species evenness index was highest in the vegetable field (0.95). This suggests a highly stable community in the vegetable field. Mango and organic farm also have evenness above 0.75 which indicates higher evenness in these fields and the communities are thought to be stable. Litchi orchard has an evenness between 0.50 - 0.75, which indicates that the evenness is of medium level and the community is unstable. Similar results have been shown in the case of spider abundance in palm oil plantations (Solin *et al*., 2021). The lowest evenness was observed in the case of uncultivated land (less than 0.50) indicating that the ecosystem is dominated by a few species and the community is unstable because if the dominant species is affected by something such as disease, then the ripple effect will affect the entire ecosystem and greatly lower biodiversity.

The dominance index was less than 0.50 in all the habitats except uncultivated land (D = 0.60) which indicated a middle level of dominance of species in uncultivated land and a low level of dominance in the case of others. Community composition differed strikingly across habitat types. The vegetable field had significantly lower abundances than organic and uncultivated fields. It also had a significantly lower abundance than that of the litchi orchard. Similarly, the organic field had a significantly lower abundance than that of uncultivated land. Thus, different types of land cover vegetation have a significant impact on the diversity of the ground-dwelling arthropods. A similar result was observed by Kanedi *et al.* (2021) in the case of spiders. Goehring *et al.* (2002) also found significant changes in community composition associated with habitat.

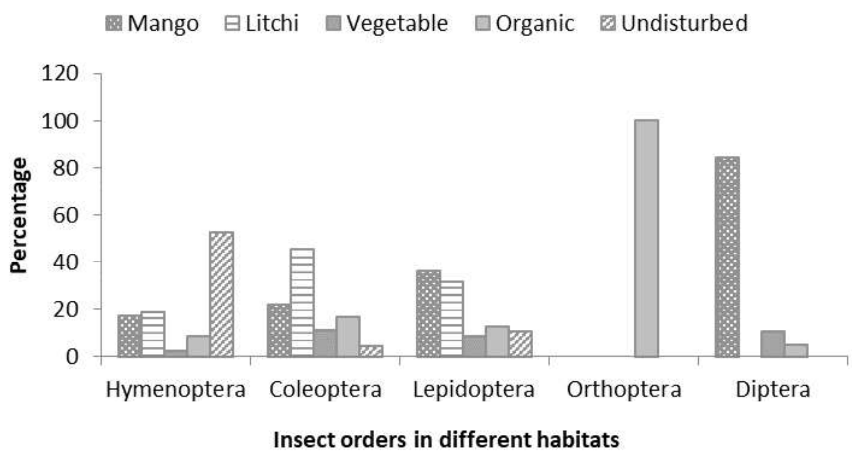

Fig. 1. Relative abundances (%) of insect orders in different habitats at AFU, Rampur, Nepal

Table 2. p-values and t-tests between the abundance in two different habitats at AFU, Rampur, Nepal

Habitat	Mango	Litchi	Vegetable	Organic	Uncultivated
Mango	-	0.702138^{NS}	0.0745178^{NS}	0.462862^{NS}	0.169046471^{NS}
Litchi	0.411	-	0.0285688*	0.946058^{NS}	0.966264231^{NS}
Vegetable	2.398	3.35*	-	0.002844**	0.007635195**
Organic	0.811	0.072	6.528*	-	0.031080816*
Uncultivated	1.676	0.045	4.973*	3.26*	-

NS= Non-significant value (p>0.05), *=significant differences in the abundances between two habitats (p<0.05), **= highly significant values (p<0.01)

The arthropods were classified into 19 taxa represented in all habitats (Table 3). The maximum number of the total collected specimen was insects (87.82%) and the rest were arachnids (12.09%) and diplopods (0.09%). Among the insects, the highest relative abundance was from the order Hymenoptera (53.55%). And also within Hymenoptera, the ants were found to be most abundant (610). The order Coleoptera (26.03%) was also important from the point of population density.

The maximum population of Hymenoptera (52.86%) was recorded from uncultivated land, while Coleoptera (45.45%) was recorded highest from the litchi orchard (Fig. 1). Similarly, orders Lepidoptera (36.17%) and Diptera (84.21%) were recorded maximum from mango orchard. Surprisingly, all the insects of order Orthoptera were recorded only from the organic field.

Table 3. List of taxa and abundances collected in pitfall traps in five different habitats at AFU, Rampur, Nepal

Class	Order	Family	Common name	Abun-dance	Relative abundance (%)
Insecta	**Blattodea**	Blattellidae	Cockroach	2	0.18
	Mantodea	Mantidae	Mantids	1	0.09
	Coleoptera	Carabidae	Ground beetles (227)+ Tiger beetle (12)	239	
		Staphylinidae	Rove beetle	1	
		Scarabaeidae	Dung beetle (13) + Chaffer beetle (1)	14	
		Meloidae	Striped blister beetle	4	26.03
		Coccinellidae	Ladybird beetle	3	
		Elateridae	Wireworms	5	
		NK (Not known)	Shredders	30	
		Curculionidae	Weevil	1	
	Hymenoptera	Formicidae	Ant	610	
		Apidae	Bees	1	53.55
	Lepidoptera	Erebidae Erebidae	Saltmarshmoth caterpillar (12) + Handmaiden moth (1)	13	
		Unidentified	Unidentified larva	28	4.12
		Noctuidae	Moth	6	
	Diptera	Tephritidae	Oriental fruit flies	16	
		Culicidae	Mosquito	3	1.66
	Orthoptera	Acrididae	Grasshopper	18	2.19
		Gryllotalpidae	Mole cricket	7	
Arachnida	**Araneae**	Salticidae	Spider	138	12.09
Diplopoda	**Polydesmida**	Eurymerodesmidae	Millipede	1	0.09
		Total		**1141**	**100**

In the present study, insects were found to be the most abundant arthropods, followed by Araneids. Among insects, Hymenoptera and Coleoptera were the most important and abundant orders. A comprehensive review of the composition of the terrestrial arthropod communities in arid systems of SE Spain reported that below-ground arthropod communities were dominated by ants and Coleoptera (Piñero *et al.*, 2011). Similarly, Cotes *et al*. (2010) reported Coleoptera to be the second most abundant order, differing significantly among organic, integrated and conventional management systems in June and October. Also, within Hymenoptera, ants (Hymenoptera: Formicidae) secured the most abundant position. However, more than half of the ant's population was found in the uncultivated land and the lowest (less than 3%) was observed on the vegetable farm. This finding was similar to that of Philpott *et al*. (2010) who concluded that habitat disturbance and transformation have an impact on local assemblages of ants both indirectly through changes to habitat structure, and directly, through reduced resource availability and removal of colonies. Pitfall traps mostly collect active and fast-moving invertebrates, such as Araneids and Hymenopterans (Standen, 2000), yet they may under-represent small arthropods with low mobility that live in the soil (Piñero *et al*., 2011). Furthermore, many abiotic (such as weather, season, slope and aspect) as well as biotic factors (such as insect size, behavior at the edge of trap and so on) influence the taxa collected through pitfall traps (Skvarla, 2015). Additionally, it is confirmed that our findings are similar to the literature reported by previous researchers; however, at some point, deviations were observed due to differences in environmental conditions, skill power, documentation of data, and handling expertise.

CONCLUSION

In this study, maximum abundance was found in the uncultivated land and Hymenoptera was present in a significant number compared to other orders. Ants (Hymenoptera: Formicidae) dominated others in terms of relative abundance. Shannon-Weiner diversity index and species richness both were found to be highest in mango orchards and lowest in the case of the uncultivated field while the result of the Simpson dominance index was higher in the case of uncultivated land because of the higher abundance of ants. Results predict that the diversity among the arthropods was different in the five habitats. This study presents the vegetable field as the most stable community for the arthropods. The vegetable field thus has good soil structure, nutrient cycling, and higher protection from crop pests leading to the higher productivity of the crops. This study will be endorsed for future research on biodiversity in different habitats to enhance the knowledge of the large group of arthropods. However, further studies are suggested with more and different sampling and planning approaches to elaborate soil arthropods in particular habitats.

ACKNOWLEDGEMENTS

Authors thank the Department of Entomology of Agriculture and Forestry University as well as colleagues who supported to collect the data from various field.

LITERATURE CITED

Boutin, C., P.A. Martin and A. Baril. 2009. Arthropod diversity as affected by agricultural management (Organic and Conventional Farming), plant species, and landscape context. Ecoscience. 16(4): 492–501. https://doi.org/10.2980/16-4-3250

Clark, M. S., S.H. Gage and J.R. Spence. 1997. Habitats and management associated with common ground beetles (Coleoptera: Carabidae) in a Michigan Agricultural Landscape. Environmental Entomology. 26(3): 519–527. https://doi.org/10.1093/ ee/26.3.519

Cotes, B., M. Campos, F. Pascual, P.A. García and F. Ruano. 2010. Comparing taxonomic levels of epigeal insects under different farming systems in Andalusian olive agroecosystems. Applied Soil Ecology. 44(3): 228–236. https://doi.org/10.1016 /j.apsoil.2009.12.011

Culliney, T.W. 2013. Role of arthropods in maintaining soil fertility. Agriculture (Switzerland). 3(4): 629-659. https://doi.org/10.3390/agriculture3040629

Eisenbeis, G. and W. Wichard. 1987. Atlas on the biology of soil arthropods. Springer-Verlag.

Goehring, D. M., G.C. Daily and C.H. Şekerçioğlu. 2002. Distribution of ground-dwelling arthropods in tropical countryside habitats. Journal of Insect Conservation. 6(2): 83–91. https://doi.org/10.1023/A:1020905307244

Hendrickx, F., J.P Maelfait, W. Van Wingerden, O. Schweiger, M. Speelmans, S. Aviron, I. Augenstein, R. Billeter, D. Bailey, R. Bukacek, F. Burel, T. Diekötter, J. Dirksen, F. Herzog, J. Liira, M. Roubalova, V. Vandomme and R. Bugter. 2007. How landscape structure, land-use intensity and habitat diversity affect components of total arthropod diversity in agricultural landscapes. Journal of Applied Ecology. 44(2): 340–351. https://doi.org/10.1111/j.1365-2664.2006.01270.x

Hohbein, R.R. and C.J. Conway. 2018. Pitfall traps: A review of methods for estimating arthropod abundance. Wildlife Society Bulletin. 42(4): 597–606. https://doi.org/ 10.1002/wsb.928

Kanedi, M., N. Nukmal, G.D Pratami, and Hajariyah. 2021. Impact of ground cover vegetation types on the diversity and similarity of spider assemblage at two adjacent sites. GSC Advanced Research and Reviews. 8(1):060–065. https://doi.org/10.30574/ gscarr.2021.8.1.0144

Lauricella, M., S. Emanuele, G. Calvaruso, M. Giuliano and A. D'Anneo. 2017. Multifaceted health benefits of *Mangifera indica* L. (Mango): The inestimable value of orchards recently planted in sicilian rural areas. Nutrients. 9(5). https://doi.org/ 10.3390/nu9050525

Leksono, A.S. 2017. The effect of organic farming systems on species diversity. AIP Conference Proceedings, 1908. https://doi.org/10.1063/1.5012701

Losey, J. E. and M. Vaughan. 2006. The economic value of ecological services provided by insects. BioScienc. 56(4): 311–323. https://doi.org/10.1641/0006-3568(2006)56 [311:TEVOES]2.0.CO;2

Meloni, F., B.F. Civieta, J.A. Zaragoza, M.L. Moraza, and S. Bautista, S. 2020. Vegetation pattern modulates ground arthropod diversity in semi-arid mediterranean steppes. Insects. 11(1): 1-17. https://doi.org/10.3390/insects11010059

Menta, C. and S. Remelli. 2020. Soil health and arthropods: From complex system to worthwhile investigation. Insects. 11(1). https://doi.org/10.3390/insects11010054

Nahmani, J., Y. Capowiez and P. Lavelle. 2005. Effects of metal pollution on soil macroinvertebrate burrow systems. Biology and Fertility of Soils. 42(1): 31–39. https://doi.org/10.1007/s00374-005-0865-4

Nisa, K., R. Wijayanti and E.S. Muliawati. 2018. Keragaman Arthropoda Pada Sacha Inchi Di Lahan Kering. Caraka Tani: Journal of Sustainable Agriculture. 32(2): 132. https://doi.org/10.20961/carakatani.v32i2.16330

Odum, E.P. 1993. Dasar-dasar ekologi edisi ketiga. Gadjah Mada Univesity Press, Yogyakarta.

Philpott, S. M., I. Perfecto, I. Armbrecht and C.L. Parr. 2010. Ant diversity and function in disturbed and changing habitats. Ant Ecology. 137–156. https://doi.org/10.1093/ acprof:oso/ 9780199544639.003.0008

Piñero, F. S., A. Tinaut, A. Aguirre-Segura, J. Miñano, J.L. Lencina, F.J. Ortiz-Sánchez and F.J. Pérez-López. 2011. Terrestrial arthropod fauna of arid areas of SE Spain: Diversity, biogeography, and conservation. Journal of Arid Environments. 75(12): 1321–1332. https://doi.org/10.1016/j.jaridenv.2011.06.014

Ramzan, U., W. Majeed, N. Rana, N. and S. Nargis. 2021. Occurrence of different insect species with emphasis on their abundance and diversity in different habitats of Faisalabad, Pakistan. International Journal of Tropical Insect Science. 41(2): 1237–1244. https://doi.org/10.1007/s42690-020-00314-5

Sabu, T. K. and R.T. Shiju. 2010. Efficacy of pitfall trapping, winkler and berlese extraction methods for measuring ground-dwelling arthropods in moist-deciduous forests in the western ghats. Journal of Insect Science. 10. https://doi.org/10.1673/031.010.9801

Skvarla, M. 2015. Sampling terrestrial arthropod biodiversity: A case study in Arkansas. Theses and Dissertations. https://scholarworks.uark.edu/etd/1408

Solin, H.A. and H. Husni and J. Jauharlina. 2021. Diversity and abundance of predatory arthropods on immature and mature oil palm (Elaeis guineensis) plantations. Pakistan Journal of Biological Sciences. 24(1): 25–34. https://doi.org/10.3923/pjbs. 2021.25.34

Standen, V. 2000. The adequacy of collecting techniques for estimating species richness of grassland invertebrates. Journal of Applied Ecology. 37(5): 884–893. https://doi.org/ 10.1046/j.1365-2664.2000.00532.x

Zayadi, H., L. Hakim and A. Setyo Leksono. 2013. Composition and diversity of soil arthropods of Rajegwesi Meru Betiri National Park. Journal of Tropical Life Science, 3(3): 166–171. https://doi.org/10.11594/jtls.03.03.04

Zhao, L., K. Wang, K. Wang, J. Zhu and Z. Hu. 2020. Nutrient components, health benefits, and safety of litchi (*Litchi chinensis* Sonn.): A review. Comprehensive Reviews in Food Science and Food Safety. 19(4): 2139–2163. https://doi.org/10.1111/1541-4337.12590