BIODIVERSITAS
Volume 24, Number 10, October 2023
Pages: 5336-5342

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d241015

Diversity and abundance of ants (Hymenoptera: Formicidae) as indicators of sugarcane agroecosystem stability in Blitar, East Java, Indonesia

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Manuscript received: 11 August 2023. Revision accepted: 15 October 2023.

Abstract. *Sujak, Rahardjo BT, Muhammad FN, Rizali A. 2023. Diversity and abundance of ants* (*Hymenoptera: Formicidae*) *as indicators of sugarcane agroecosystem stability in Blitar, East Java, Indonesia. Biodiversitas 24: 5336-5342.* The abundance of ant communities can be used as an indicator of stability in agroecosystems. This study was designed to evaluate the diversity and abundance of ant in three sugarcane cultivation ecosystems. The research was conducted in Ngembul Village, Binangun Subdistrict, Blitar, East Java, Indonesia from August 2021 to February 2022 The three observed sugarcane ecosystems were Ratoon Cane (RC) without tillage, Replanting Ratoon Cane (PRC) with tillage, and Newly Cultivated Plant Cane (NPC) with tillage. Ant collections were made using the pitfall trap method. In each field, pitfalls were systematically placed at 5 points. Pitfall traps were set for 24 hours, and samples were collected every 2 weeks. Identification was done at the genus level and further separated based on morphology (morphospecies). The research obtained 2,920 ant individuals belonging to 3 subfamilies, 7 genera, and 9 morphospecies. The highest diversity and abundance were found in the RC ecosystem compared to the PRC ecosystem and the NPC agroecosystem. The most dominant ant species was *Crematogaster* sp.1. The ant population in the RC ecosystem has more population growth compared to the PRC and NPC ecosystems. The results of the ANOSIM analysis indicated differences in ant community composition among the treatments. In conclusion, the ratoon sugarcane ecosystem sustains diversity and abundance of ants more compared to the other two ecosystems.

Keywords: Abundance, Formicidae, ratoon, similarity, species richness

Abbreviations: RC: Ratoon Cane, PRC: Replanting Ratoon Cane, NPC: Newly Cultivated Plant Cane

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the essential industrial crops in Indonesia (Sulaiman et al. 2023). In 2020, the total sugar production in Indonesia was 2.12 million tons with the largest sugar production coming from East Java Province, which is 47.24% of Indonesia's total sugar production (BPS 2021). The existence and diversity of arthropods in sugarcane plantations can be an indicator of agricultural sustainability in sugarcane agroecosystems and has an effect on increasing production yields (Prabowo et al. 2021). The presence of arthropods, especially soil arthropods, play an important role in soil health maintenance such as translocation of organic materials, decomposition, nutrient cycle, formation of soil structure, and water regulation in sugarcane plantation (Prabowo et al. 2022). Ants are one of the soil arthropods that have an important role in the ecosystem due to their contribution in recycling nutrients process and also as predators for several plant pests.

In sugarcane plantations, ant appearance in the fields is very important for pest suppression (Rahardjo et al. 2023). Ants (Hymenoptera: Formicidae) are insects found in nearly every type of ecosystem and have diverse roles within the ecosystem. The high diversity and evenness of ants indicate a stable ecosystem with a high level of elasticity (Latumahina et al. 2015). The higher the diversity and evenness, the more complex and varied the food chain processes, including predation, parasitism, competition, symbiosis, and predation, become within the ecosystem.

Ants play important ecological roles in agroecosystems as predators, organic matter decomposers, pest controllers, and even contributors to the pollination process (Diamé et al. 2018). Some ant species can also be detrimental to cultivated plants because they can enhance pest incidence and spread pathogens such as *Monomorium floricolae* (Rizali et al. 2018). The presence of ants is also beneficial for the order Hemiptera pests because they can form a mutually beneficial trophobiosis relationship (Moya-Raygoza and Martinez 2014). Ants were selected as the subject of this research due to their ecological significance in natural ecosystems.

Ant communities play a crucial role in the mineralization process due to the continuous soil excavation activities performed. The presence of ants in agricultural habitats is influenced by food availability and the suitability of environmental conditions for nesting. Ant diversity can be a bioindicator of agroecosystem health (Widhiono et al. 2017). The use of ants as bioindicators is often carried out in many fields (Lawes et al. 2017).

The influence of soil management on ant diversification is evident because the majority of ants and their nests are found in the soil. Organic farming practices without tillage demonstrate higher species richness (Gong et al. 2023; Leksono 2017). Plowing has been observed as a soil management practice with the greatest negative effect on ant species richness (Hevia et al. 2018). The abundance of ant species in a particular area is greatly influenced by environmental changes, and ants will respond when there are disturbances or changes in their environment or habitat (Supriati et al. 2019). Ants respond to land changes in predictable ways and their abundance and richness are associated with management factors, soil variables, and cultivation practices (Muhammad et al. 2022). This makes ants a potential biological indicator for assessing soil conditions and their management in sugarcane agroecosystems.

The sugarcane ecosystem at the research site consists of three ecosystems: (i) the Ratoon Cane (RC) ecosystem without soil tillage, (ii) the Replanting Ratoon Cane (PRC) ecosystem with soil tillage, and (iii) the Newly Cultivated Plant Cane (NPC) ecosystem with soil tillage. Among these three sugarcane ecosystems, the most commonly practiced by farmers is the RC ecosystem. It is possible that these three sugarcane ecosystems will cause differences in the diversity and abundance of ground surface ants. This information has not been reported before. The aim of this study is to evaluate the stability level of the three sugarcane cultivation ecosystems using ants as indicators.

MATERIALS AND METHODS

Study area

The study was conducted in a sugarcane plantation in Ngembul Village, Binangun Sub-District, Blitar District, East Java, Indonesia (-8.17154° S, 112.34253° E, 188 m above sea level, Figure 1). The average monthly temperature in Blitar Regency ranges from 26.5°C to 28.4°C. The average humidity ranges from 71.5% to 82.4% (BPS 2018). Meanwhile, the average monthly rainfall ranges from 11.3 mm to 577.6 mm. The research was carried out from August 2021 to February 2022. Sampling was carried out in three types of sugarcane plantation management: Ratoon Cane (RC) without soil tillage, Replanting Ratoon Cane (PRC) with soil tillage, and Newly Cultivated Plant Cane (NPC) with soil tillage.

Plot design

Sampling was carried out in three sugarcane plantations with a minimum plot size of each plantation was 37 m x 15 m (Figure 2). Plantation selection was carried out by survey in August 2021. Sugarcane plantation was selected with three predetermined criteria. First, the distance between sugarcane ecosystems was 100 m. Second, the land area is sufficient to make observation plots. Plots were made on each sugarcane ecosystem. In each plot, there were three subplots with a size of 10 m x 10 m. The distance between subplots was 1 m. While the distance between the subplot and the border was 2.5 m. Five pitfalls were systematically placed and replicated six times with two weeks interval. Third, the age of the plants in the observation plot must be uniform at 1 month.

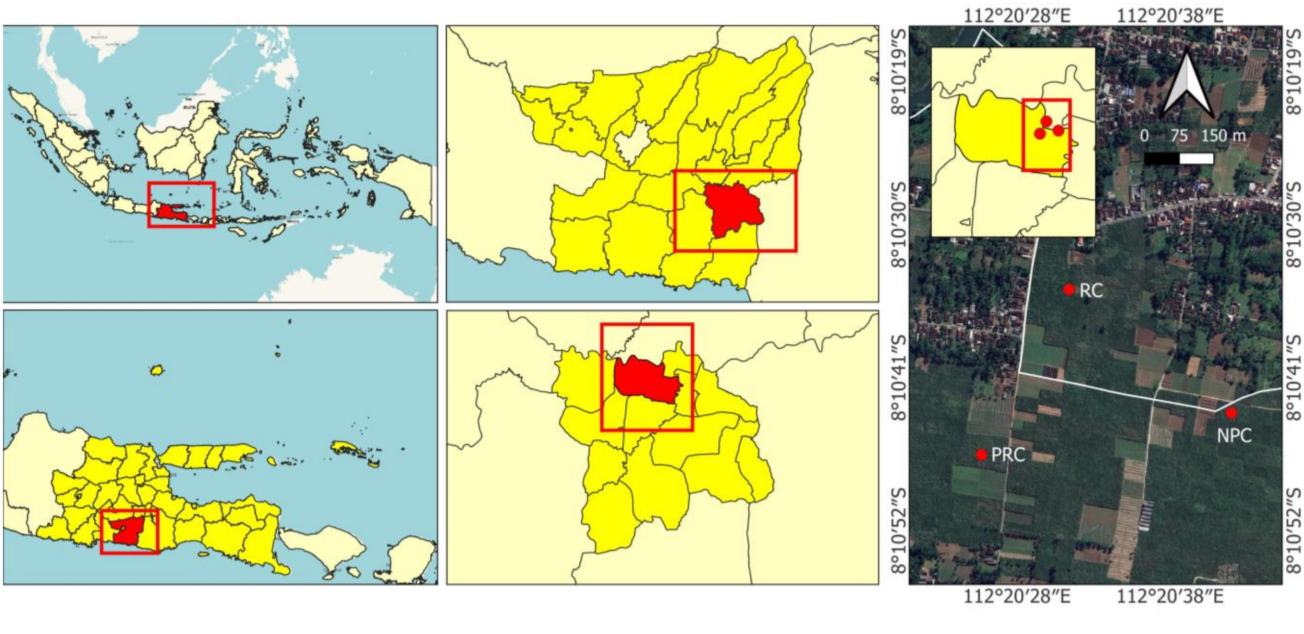

Figure 1. Research locations of three sugarcane plantations in Ngembul Village, Binangun Sub-District, Blitar District, East Java, Indonesia. RC: Ratoon Cane, PRC: Replanting Ratoon Cane, NPC: Newly Cultivated Plant Cane

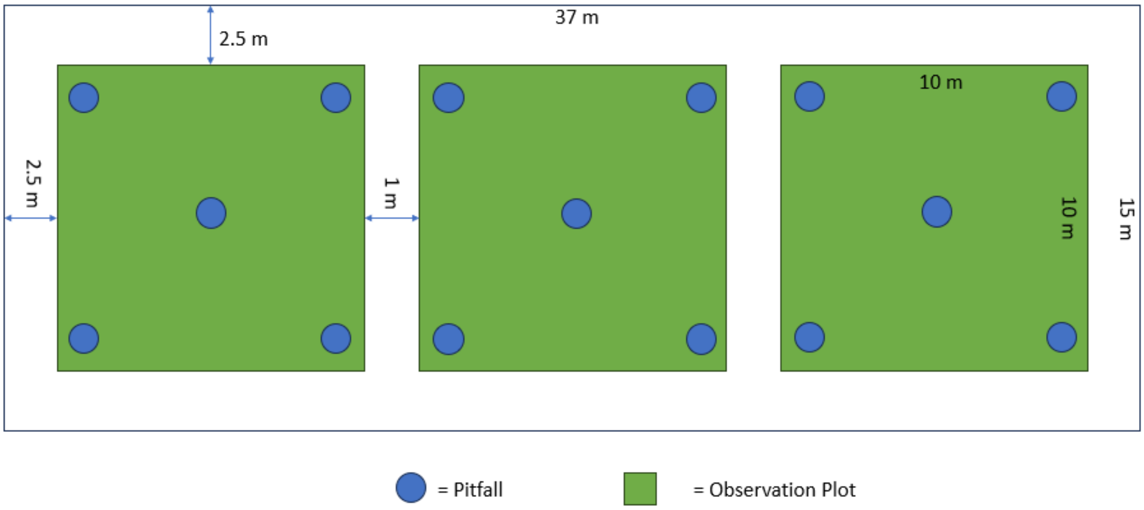

Figure 2. Plot design on each sugarcane ecosystem for observation

Ant sampling

Ant sampling was conducted from September until December 2021. Sampling was carried out using the pitfall trap method. The pitfall traps were made of plastic cups with a height of 10 cm and a diameter of 7 cm. The pitfall traps were buried in the ground, leveled with the soil surface. Each trap was filled with water mixed with 5% detergent to immobilize the trapped ants. Approximately one-third of the cup's height was filled with the water-detergent mixture, and a plastic cover was placed on top to prevent rainwater from entering. The traps were set every two weeks. The ants captured in each trap were collected after 24 hours, placed in separate plastic bags, and then brought to the laboratory to count the number of ants and categorize them. Subsequently, ant samples were preserved in bottles filled with 70% ethanol.

Identification

The identification of insects was conducted at the Entomology and Phytopathology Laboratory of the Research Institute for Sweeteners and Fibers and Plant Pest Laboratory at the Department of Plant Pests and Diseases, Faculty of Agriculture, Universitas Brawijaya. Morphological identification was performed using existing literature such as Bolton (1994) and Nazarreta et al. (2021). Identification was carried out using Olympus SZX7 stereo microscope provided by Plant Pest Laboratory. Identification was carried out down to the genus and morphospecies level (Lattke 2000). The population of ants was determined by counting the number of individuals per ecosystem plot.

Data analysis

The data analysis in this study involved analyzing the variances of all observed variables using ANOVA (Analysis of Variance). In the case of significant differences between treatments, further analysis was conducted using Duncan's multiple range test at a significance level of 5%. Shapiro-Wilk normality test was performed on species and abundance variable. If the data were not normally distributed, data were transformed using log(x+1). Ant fluctuations were analyzed using a line chart to determine the pattern of ant population growth in each ecosystem. To assess the similarity of ant species composition among each treatment, the ANOSIM test was employed, and the results were presented through Non-Metric Multidimensional Scaling (NMDS). The results of the ant similarity index with RC, PRC, and NPC ecosystems are depicted in the NMDS graph. The overlapping plots indicate the degree of similarity, particularly those with similar compositions. The entire statistical analysis was performed using R software version 4.1.0 (R Core Team 2022).

RESULTS AND DISCUSSION

Ant diversity in sugarcane ecosystems

The identification results of ants in three sugarcane ecosystems in Binangun, Blitar revealed the presence of 3 subfamilies, seven genera, and nine species and a total of 2,920 ant individuals. The Ratoon Cane (RC) ecosystem had 1,866 individuals, the Replanting Ratoon Cane (PRC) ecosystem had 485 individuals, and the Newly Cultivated Plant Cane (NPC) ecosystem had 629 individuals (Table 1). All nine species were found in RC and PRC ecosystem. While at NPC, there were only five species. *Crematogaster* sp.1 was the most abundant ant species (2,488 individuals) found followed by *Polyrachis* sp. (153 inds.) and *Nylanderia* sp. (149 inds.). *Crematogaster* sp.1 had more abundance in the RC than PRC and NPC ecosystem. While *Nylanderia* sp. and *Polyhrachis* sp. were more abundant in the PRC ecosystem. Among all species found, *Pheidole* sp. was the least abundance species.

ANOVA analysis showed that the highest species richness was found in the RC ecosystem, while the lowest was found in the NPC ecosystem ($F_{2,15}$=11.650; P=0.008; Figure 3A). The ant abundance in the RC ecosystem was significantly higher compared to the PRC and NPC ($F_{2,15}$=51.160; P=0.001; Figure 3B).

Fluctuations of ants in three sugarcane ecosystem

Fluctuations in ant populations were observed in three sugarcane ecosystems: NPC, RC, and PRC (Figure 4). The RC ecosystem exhibited rapid population growth, while the PRC and NPC ecosystems experienced slower fluctuations. During late-September or early observation, the ant population were growing continuously until late-October. During early-November, the ant populations in all agroecosystems exhibited a decline. High precipitation occurred during late-October.

Ant composition in three sugarcane ecosystems

The ANOSIM analysis showed significant differences in the ant species composition among each treatment and the composition of the sugarcane cultivation ecosystems (R ANOSIM=0.959, P=0.003, Figure 5). This finding elucidates how the utilization of distinct cultivation patterns influences ant species composition.

Table 1. Diversity and abundance of ants in three sugarcane ecosystems

Subfamily/morphospecies	RC	PRC	NPC
Formicinae			
Camponotus sp.	8	2	0
Nylanderia sp.	59	64	26
Polyrhachis sp.	27	96	30
Myrmicinae			
Crematogaster sp.1	1673	255	560
Crematogaster sp.2	1	38	0
Monomorium sp.1	60	1	0
Monomorium sp.2	31	3	2
Pheidole sp.	3	1	0
Dolichoderinae			
Tapinoma sp.	4	25	11
Grand total	1866	485	629

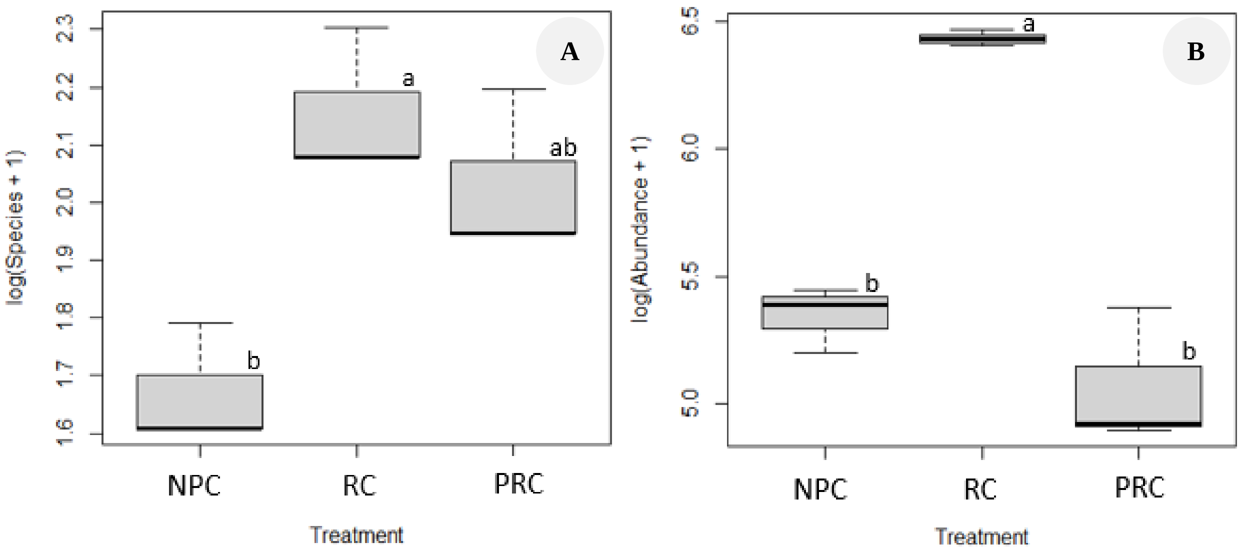

Figure 3. Boxplot of ant. A. Species richness, B. Abundance in the sugarcane ecosystems. NPC: Newly Cultivated Plant Cane, RC: Ratoon Cane, PRC: Replanting Ratton Cane. Boxplot followed by the same letters within each box are not significantly different at P<0.05 according to Duncan's multiple range test

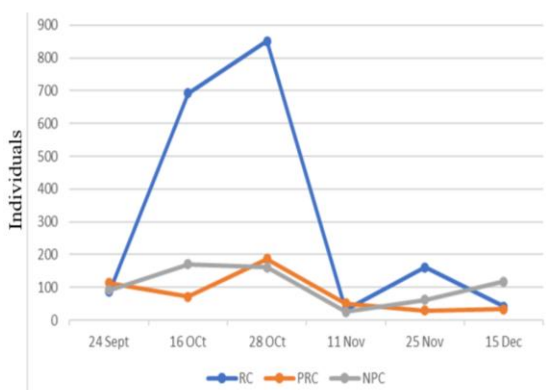

Figure 4. Fluctuations in ant population captured by pitfall traps in the Ratoon Treatment (RT), Unloading Ratoon (UR), and Newly Cultivated Sugarcane (NL) ecosystems

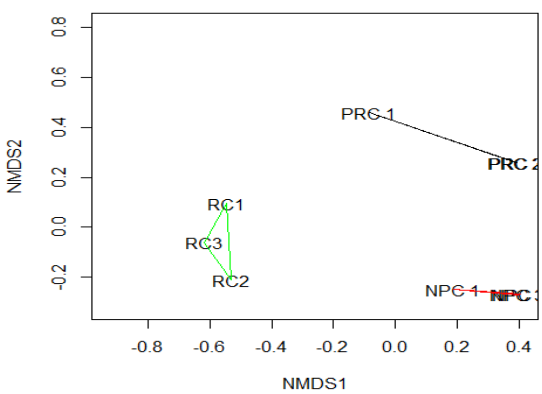

Figure 5. NMDS analysis to assess the differences or similarities of ants among RC, PRC, and NPC sugarcane ecosystem (Stress = 0.034)

Discussion

Based on the research, it can be seen that different land conditions affect the presence and diversity of ants in the sugarcane ecosystem. Yudiyanto et al. (2014) explained that the diversity of ants in a specific location is influenced by variations in land conditions. The abundance of ant species in a particular area is greatly affected by environmental changes, and ants respond to environmental disturbances or soil disruptions as they serve as their habitats (Andersen 2019). Sharley et al. (2008) further reported that soil tillage practices can have an impact on the diversity and population abundance of ants in dryland agriculture. Soil tillage can reduce the population of predators whose life cycles are in the soil (Rowen et al. 2020). In general, conventional farming practices result in significant changes in the composition and biodiversity of soil fauna. Agricultural management often leads to a reduction in species diversity and alters the structure of specific ant population (de Castro Solar et al. 2016). This can be attributed to soil tillage activities disrupting ant habitats and reduce food availability and nesting sites.

Intensive soil tillage has a significant negative impact on ant dynamics. Environmental changes and disturbances to the habitat can result in alterations to the composition of ant species, subsequently affecting trophic interactions and food webs within the ecosystems (Romarta et al. 2020). The effects of soil tillage on ant populations have garnered considerable attention from researchers in recent decades. Numerous studies have aimed to identify the specific ways in which soil tillage influences ant presence and activity in various ecosystems (Fernandes et al. 2018; Rowen et al. 2020; Rocher et al. 2022) Findings from these studies consistently indicate that soil tillage can negatively affect ant populations by disrupting soil structure and destroying ant nests. Consequently, ants struggle to thrive and reproduce in cultivated environments. RC had more species and abundance of ants compare with PRC and NPC. In the PRC plot, soil tillage was done in Early August to replace the old sugarcane plant. While in the NPC, the field was previously planted maize that needed intensive soil tillage. *Crematogaster* is a genus of ants that exhibits ecological diversity and can be found worldwide. These ants are mostly arboreal and exhibit predatory behavior, preying on other insects (Richard et al. 2001). *Crematogaster* can also exhibit dominant behavior (Dejean et al. 2019). *Crematogaster* has also been reported as the most abundant predator in sugarcane plantations (Ahmad et al. 2020). Their preferred habitat is in moist and dark environments, such as trees or under leaf litter (De Oliveria et al. 2012). The high number of *Crematogaster* in sugarcane fields is very beneficial because it can potentially control pests in sugarcane plantations. However, on the other hand, *Crematogaster* can be too aggressive in the disturbed ecosystem such as NPC (Richard et al. 2001). Dominant *Crematogaster* in NPC plot potentially reduces ant species richness due to their aggressiveness.

Of all the ants found, there are the genera *Nylanderia* and *Tapinoma* which some of their species are known to be tramp and invasive (Klimeš and Okrouhlík 2015; Williams and Lucky 2020; Seifert 2022). The presence of invasive species can adversely affect ecosystems (Williams and Lucky 2020). Invasive ants can monopolize existing resources in an ecosystem and can get rid of existing native species (Eyer et al. 2018). Tramp ants can adapt well to the environment inhabited by humans. Agricultural ecosystems are one example of an environment disturbed by humans. Feng et al. (2015) reported that the presence of *Tapinoma* ants may support mealybugs that attack plants by protecting them from parasitoids. One of the pests on sugar cane is the pink sugarcane mealybug *Saccharicoccus sacchari* (Cockerell, 1895) (Hemiptera: Pseudococcidae) (Monteiro et al. 2022). So the presence of tramp and invasive ants can increase mealybugs as pest in sugarcane plantations.

Chung and Maryati (1996) reported that human interventions in cultivation processes, such as land cultivation and plant maintenance, disrupt ant habitats and reduce ant diversity compared to undisturbed habitats. Andersen (1995) demonstrated that soil tillage reduces ant species diversity and alters community structures, primarily due to habitat damage, reduced food availability, and nesting site disruption. Reducing land tillage in cultivation practices with the ratoon system can increase existing biodiversity (Frøslev et al. 2022). Differences in the composition of ant species in each sugar cane management are caused by differences of ant preferences on specific habitat condition. Intensive land plowing is not desirable for ants establishment (Rocher et al. 2022).

Rainfall can affect ant populations by influencing nest conditions in the soil. Wet and humid nest environments reduce ant population growth, especially if the nests are not designed to withstand excess water. Consequently, ants may migrate in search of alternative food sources when their habitat becomes less fertile after rainfall. These dynamics directly impact the overall population trends of ants in the soil. The decrease in ant populations throughout the ecosystem in early-November was due to the transition to the rainy season. The results of research by Uhey et al. (2020) showed that the level of precipitation is negatively related to ant abundance. Indirectly, high precipitation can reduce abundance because the trophobiont insects that provide honeydew for ants also decrease (Parr and Bishop 2022).

The conclusion is that the application of ratoon to sugarcane is proven to be able to maintain the stability of agro-ecosystems. The application of ratoons minimizes soil disturbance support the diversity and abundance of ants in the soil. Higher diversity and abundance were found in ratoon sugarcane fields. The composition of ant species in all fields shows differences. In addition, the ratoon sugarcane ecosystem sustains diversity and abundance of ants more compared to the other two ecosystem.

ACKNOWLEDGEMENTS

Gratitude is due to the farmers in Ngembul Village who have allowed us to conduct research on their sugar cane fields. Gratitude is also due to Dennis Wibowo for reviewing our manuscript.

REFERENCES

Ahmad Z, Ghramh HA, Khan KA, Khan F, Shujauddin S. 2020. Short Communication: Impact of two attending ants, *Crematogaster subnuda* and *Camponotus compressus* (Hymenoptera: Formicidae), on the parasitism of sugarcane aphid *Melanaphis sacchari* (Zehnt.). Pak J Zool 52: 1-4. DOI: 10.17582/journal.pjz/20200309190337.

Andersen AN. 1995. A classification of australian ant communities, based on functional groups which parallel plant life-forms in relation to stress and disturbance. J Biogeogr 22: 15-29. DOI: 10.2307/2846070.

Andersen AN. 2019. Responses of ant communities to disturbance: Five principles for understanding the disturbance dynamics of a globally dominant faunal group. J Anim Ecol 88 (3): 350-362. DOI: 10.1111/1365-2656.12907.

Bolton B. 1994. Identification Guide to the Ant Genera of the World. Harvard University Press, Cambridge.

BPS [Badan Pusat Statistik]. 2018. Jumlah curah hujan (mm), 2016-2018. 2018. https://blitarkota.bps.go.id/indicator/151/126/1/jumlah-curah-hujan.html. [Indonesian]

BPS [Badan Pusat Statistik]. 2021. Statistik Tebu Indonesia 2020. Central Bureau of Statistics, Jakarta. [Indonesian]

Chung AYC, Maryati M. 1996. A comparative study of the ant fauna in primary and secondary forest in Sabah. In: Edward DS, Booth WE, Choy SC (eds). Malaysia Tropical Rainforest Research-Current Issues. Kluwer Academic, Dodrecht (NL).

Core Team R. 2022. A languange and environment for statistical computing. R Found Stat Comput Vienna R Found Stat. Comput.

de Castro Solar RR, Barlow J, Andersen AN, Schoereder JH, Berenguer E, Ferreira JN, Gardner TA. 2016. Biodiversity consequences of land-use change and forest disturbance in the amazon: A multi-scale assessment using ant communities. Biol Conserv 197: 98-107. DOI: 10.1016/j.biocon.2016.03.005.

De Oliveria RdF, De Almeida LC, De Souza DR, Munhae CB, Bueno OC, De Castro Morini MS. 2012. Ant diversity (Hymenoptera: Formicidae) and predation by ants on the different stages of the sugarcane borer life cycle *Diatraea saccharalis* (Lepidoptera: Crambidae). Eur J Entomol 109: 381-387. DOI: 10.14411/eje.2012.049.

Dejean A, Compin A, Delabie JHC, Azémar F, Corbara B, Leponce M. 2019. Biotic and abiotic determinants of the formation of ant mosaics in primary neotropical rainforests. Ecol Entomol 44 (4): 560-570. DOI: 10.1111/een.12735.

Diamé L, Rey JY, Vayssières JF, Grechi I, Chailleux A, Diarra K. 2018. Ants: Major functional elements in fruit agro-ecosystems and biological control agents. Sustainability 10 (1): 23. DOI: 10.3390/su10010023.

Eyer P-A, McDowell B, Johnson LNL, Calcaterra LA, Fernandez MB, Shoemaker D, Puckett RT, Vargo EL. 2018. Supercolonial structure of invasive populations of the tawny crazy ant nylanderia fulva in the us. BMC Evol Biol 18 (1): 209. DOI: 10.1186/s12862-018-1336-5.

Feng D-D, Michaud JP, Li P, Zhou Z-S, Xu Z-F. 2015. The native ant, *Tapinoma melanocephalum*, improves the survival of an invasive mealybug, phenacoccus solenopsis, by defending it from parasitoids. Sci Rep 5: 15691. DOI: 10.1038/srep15691.

Fernandes WD, Lange D, Pereira JM, Raizer J. 2018. Ant community in neotropical agrosystems: A four-year study in conventional and no-tillage systems. Sociobiology 65 (2): 130. DOI: 10.13102/sociobiology.v65i2.1204.

Frøslev TG, Nielsen IB, Santos SS, Barnes CJ, Bruun HH, Ejrnæs R. 2022. The biodiversity effect of reduced tillage on soil microbiota. Ambio 51 (4): 1022-1033. DOI: 10.1007/s13280-021-01611-0.

Gong S, Zhou X, Zhu X, Huo J, Faghihinia M, Li B, Zou Y. 2023. Organic rice cultivation enhances the diversity of above-ground arthropods but not below-ground soil eukaryotes. Agric Ecosyst Environ 347: 108390. DOI: 10.1016/j.agee.2023.108390.

Hevia V, Ortega J, Francisco M, Azcárate F, AL C, José A. 2018. Exploring the effect of soil management intensity on taxonomic and functional diversity of ants in mediterranean olive groves. Agric For Entomol 21 (1): 109-118. DOI: 10.1111/afe.12313.

Klimeš P, Okrouhlík J. 2015. Invasive ant *Tapinoma melanocephalum* (Hymenoptera: Formicidae): A rare guest or increasingly common indoor pest in Europe?. Eur J Entomol 112 (4): 705-712. DOI: 10.14411/eje.2015.089.

Lattke JE. 2000. Specimen processing: Building and curating an antcollection. In: Agosti D, De Majer J, Alonso L, Schultz T (eds). Ants: Standard Methods for Measuring and Monitoring Biodiversity. Smithsonian Institution Press, Washington DC.

Latumahina F, Musyafa, Sumardi, and Putra N. 2015. Respon semut terhadap kerusakan antropogenik dalam hutan lindung sirimau ambon. Jurnal Manusia dan Lingkungan 222: 169-178. DOI: 10.22146/jml.18739. [Indonesian]

Lawes MJ, Moore AM, Andersen AN, Preece ND, Franklin DC. 2017. Ants as ecological indicators of rainforest restoration: Community convergence and the development of an ant forest indicator index in the Australian wet tropics. Ecol Evol 7 (20): 8442-8455. DOI: 10.1002/ece3.2992.

Leksono AS. 2017. The effect of organic farming systems on species diversity. AIP Conf Proc 1908: 030001. DOI: 10.1063/1.5012701.

Monteiro GG, Peronti ALBG, Martinelli NM. 2022. Presence of pink sugarcane mealybug (Hemiptera: Pseudococcidae) increases probability of red rot on sugarcane. Sci Agric 79 (3): e20200373. DOI: 10.1590/1678-992x-2020-0373.

Moya-Raygoza G, Martinez AV. 2014. Ants (Hymenoptera: Formicidae) and trophobiont leafhopper nymphs (Hemiptera: Cicadellidae) become more abundant in shaded conditions: Implications for mutualism. Florida Entomol 97 (4): 1378-1385. DOI: 10.1653/024.097.0412.

Muhammad FN, Rizali A, Rahardjo BT. 2022. Diversity and species composition of antsat coffee agroforestry systems in East Java, Indonesia: Effect of habitat condition and landscape composition. Biodiversitas 23 (7): 3318-3326. DOI:10.13057/biodiv/d230702.

Nazarreta R, Bukhori D, Hashimoto Y, Hidayat P, Scheu S, Drascher J. 2021. A Guide to the Ants of Jambi (Sumatera, Indonesia). Identification Key to Ant Genera and Images of the EfforTS Collection. Penerbit BRIN, Jakarta. DOI: 10.55981/brin.273.

Parr CL, Bishop TR. 2022. The response of ants to climate change. Glob Chang Biol 28 (10): 3188-3205. DOI: 10.1111/gcb.16140.

Prabowo H, Rahardjo BT, Mudjiono G, Rizali A. 2021. Impact of habitat manipulation on the diversity and abundance of beneficial and pest arthropods in sugarcane ratoon. Biodiversitas 22 (9): 4002-4010. DOI: 10.13057/biodiv/d220948.

Prabowo H, Rahardjo BT, Mudjiono G, Rizali A. 2022. Stable isotope analysis to assess the trophic level of arthropod in sugarcane ratoon agroecosystem. Biodiversitas 23 (6): 2871-2881. DOI: 10.13057/biodiv/d230613.

Rahardjo BT, Muhammad FN, Setiawan Y, Febryadi A, Ihsan M, Wibowo D, Fernando I. 2023. Ant preference for different types of bait at sugarcane plantations in East Java, Indonesia. Biodiversitas 24 (4): 2099-2106. DOI: 10.13057/biodiv/d240420.

Richard F-J, Fabre A, Dejean A. 2001. Predatory behavior in dominant arboreal ant species: The case of *Crematogaster* sp. (Hymenoptera: Formicidae). J Insect Behav 14: 271-282. DOI: 10.1023/A:1007845929801.

Rizali A, Tscharntke T, Buchori D, Clough Y. 2018. Separating effects of species identity and species richness on predation, pathogen dissemination and resistance to invasive species in tropical ant communities. Agric For Entomol 20 (1): 122-130. DOI: 10.1111/afe.12236.

Rocher L, Blaya R, Blaise C, Bischoff A, Blight O. 2022. Species and functional responses of ants to inter-row tillage and vegetation in organic mediterranean vineyards. Basic Appl Ecol 65: 126-35. DOI: 10.1016/j.baae.2022.11.009.

Romarta R, Yaherwandi Y, Efendi S. 2020. Keanekaragaman semut musuh alami (Hymenoptera: Formicidae) pada perkebunan kelapa sawit rakyat di Kecamatan Timpeh, Kabupaten Dharmarasya. Jurnal Agrikultura 31: 42-51. DOI: 10.24198/agrikultura.v31i1.25622. [Indonesian]

Rowen EK, Regan KH, Barbercheck ME, Tooker JF. 2020. Is tillage beneficial or detrimental for insect and slug management? A meta-analysis. Agric Ecosyst Environ 294: 106849. DOI: 10.1016/j.agee.2020.106849.

Seifert B. 2022. The previous concept of the cosmopolitan pest ant *Tapinoma melanocephalum* (Fabricius, 1793) includes two species (Hymenoptera: Formicidae: Tapinoma). Osmia 10: 35-44. DOI: 10.47446/OSMIA10.4.

Sharley DJ, Hoffmann AA, Thomson LJ. 2008, The effects of soil tillage on beneficial invertebrates within the vineyard. Agric For Entomol 10: 233-243. DOI: 10.1111/j.1461-9563.2008.00376.x

Supriati R, Sari WP, Dianty N. 2019. Identifikasi jenis semut Famili Formicidae di kawasan taman wisata alam Pantai Panjang, Pulau

Balai Kota, Bengkulu. Jurnal Konservasi Hayati 10: 1-9. DOI: 10.33369/hayati.v15i1.10941. [Indonesian]
Uhey DA, Hofstetter RW, Remke M, Vissa S, Haubensak KA. 2020. Climate and vegetation structure shape ant communities along elevational gradients on the Colorado Plateau. Ecol Evol 10 (15): 8313-8322. DOI: 10.1002/ece3.6538.
Sulaiman A, Arsyad M, Amiruddin A, Teshome T, Nishanta B. 2023. New Trends of Sugarcane Cultivation Systems Toward Sugar Production on the Free Market: A Review. AGRIVITA J Agric Sci 45 (2): 395-406. DOI: 10.17503/agrivita.v45i2.4066.
Widhiono I, Pandhani RD, Darsono, Riwidiharso E, Santoso S, Prayoga L. 2017. Short Communication: Ant (Hymenoptera: Formicidae) diversity as bioindicator of agroecosystem health in northern slope of Mount Slamet, Central Java, Indonesia. Biodiversitas 18 (4): 1475-1480. DOI: 10.13057/biodiv/d180425.
Williams JL, Lucky A. 2020. Non-native and invasive *Nylanderia* crazy ants (Hymenoptera: Formicidae) of the world: Integrating genomics to enhance taxonomic preparedness. Ann Entomol Soc Am 113 (4): 318-336. DOI: 10.1093/aesa/saz039.
Yudiyanto, Qayim I, Munif A, Setiadi D, Rizali A. 2014. Keanekaragaman dan struktur komunitas semut pada perkebunan lada di Lampung. Jurnal Entomologi Indonesia 11 (2): 65-71. DOI: 10.5994/jci.11.2.65. [Indonesian]