Influence of Production System, Shade Level and Altitudinal Gradient on the Abundance of Urticating ant on Coffee in Southwestern Ethiopia

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Abstract

Urticating ant, also referred to as biting ant, *Tetramorium aculeatum* Mayr, is an important pest in coffee and becoming a constant problems for the farmers affecting farming activities in Southwestern Ethiopia. Urticating ants are not directly affecting coffee crop, but hindering the agronomic and ripe berry picking activities. As a result ripe coffee beans stay longer in the field and subjected to deterioration. This study assessed the influence of coffee production systems, shade level, and altitudes on the abundance of urticating ant in coffee farms among coffee-producing areas in Southwestern Ethiopia. The study was set as 3x3 factorial and replicated three times considering production system with shade level and again production system with altitude ranges as factors and farms as a replication. Twenty to forty coffee trees were randomly assessed in each farm. The results showed that varying numbers of urticating ant nests were observed on coffee trees among the three coffee production systems, shade coverage level and altitudinal gradients. Production systems in respect to shade levels had a highly significant influence ($p < 0.0001$) on the abundance of the urticating ant on coffee trees. Coffee trees in plantation production system with heavy shade level had significantly higher mean number of nests per coffee tree (17.25 ± 7.9) compared to the garden and semi-forest coffee in Southwestern Ethiopia. The present study also showed that coffee production system with altitudinal gradient had a highly significant ($p = 0.005$) effects on the abundance of nests on coffee trees. The urticating ant constructed the highest number of nests (20.10 ± 15.1) on coffee trees in plantation farms under lowland altitudes. Minimum temperature ($r = 0.61$*) and shade level ($r = 0.56$*) showed significantly positive correlations to infestation by urticating ant whereas altitude ($r = -0.57$*) is negatively correlated with ant abundance. In conclusion, this study revealed population of urticating ant nests varied among coffee production systems, shade levels and altitudinal gradients. In addition, it strongly suggests the abundance of urticating ant is dependent on microclimatic conditions of coffee agro-ecosystems. However, we recommend future study on the ecological role of urticating ant, ecological service or disservice provider to coffee ecosystem, and also this study calls up further studies on the bio-ecology and integrated management methods as it has implication on coffee yield loss.

Keywords: Ant nest, coffee tree, insect occurrence, coffee production system

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Introduction

Ethiopia is the largest producer of coffee in Africa and the fifth-largest coffee producer in the world next to Brazil, Vietnam, Colombia, and Indonesia [International Coffee Organization (ICO), 2017]. Coffee farming in Ethiopia takes place over a vast area, under varied production systems, and under different cultivation practices. The majority of coffee production is from the main coffee zone of the Southwest, followed by the Sidama and Yirgacheffe coffee areas in the Southeast coffee zone of the country [Environment & Coffee Forest Forum (ECFF), 2017].

In agricultural systems, particularly coffee, insects have significant impacts on plant productivity and can become constant problems for farmers (Vega *et al*., 2015). The coffee plant hosts a wide range of arthropod pests, many of which are found throughout the tropical and subtropical areas, either feeding on the plant or associated with other species as parasites or predators. Coffee is a perennial crop that remains in the field for many years and provides a stable and persistent environment for some insects to maintain an uninterrupted succession of generations without leaving the plant. Some insects may be permanently associated with coffee and have a narrow host range, but their populations increase to damaging levels under certain favorable conditions (Waller *et al*., 2007). The coffee leaf miner (*Leucoptera caffeina*), antestia bug (*Antestiopsis intricata*), coffee berry borer (*Hypothenemus hampei*), and urticating/biting ant (Tetramorium aculeatum)are important insect pests of coffee in Ethiopia which need priorities for management (Mendesil *et al*., 2008; Wakjira *et al*., 2015; Teshome *et al*., 2018; Mendesil, 2019; Kidanu *et al*., 2021). The urticating ant, *T. aculeatum*, synonym *Macromischoides aculeatus*, is an African ant feared by plantation laborers (Cammaerts and Dejean, 1993). Urticating ant does not cause direct damage to the coffee plant, but indirectly affects farm activities by stinging workers during coffee berry picking and pruning in ant-infested farms (Kidanu *et al*., 2021; McNutt, 1975; Hill, 2008).

In Ethiopia, four major coffee production systems are found (Woldetsadik and Kebede, 2000). These are 1) forest coffee which is sometimes referred to as “Wild” coffee, 2) semi-forest, 3) garden coffee sometime referred to as smallholder coffee which is produced in plots of varying sizes around dwellings, and 4) plantation coffee which is established on previously cleared land (Labouisse *et al*., 2008). Forest coffee systems may comprise forest coffee with or without human management while in semi-forest coffee the degree of management is relatively higher than in forest coffee. Coffee growers follow different management practices depending on the type of production systems they prefer to increase the production and productivity of their coffee.

One of the major constraints upon establishing effective integrated pest management approaches is the lack of adequate information about the microclimatic influence on urticating ant occurrence and distribution. It is important to assess the effect of different environmental factors including the influence of coffee production systems, shade levels, altitudes, and temperature to design sampling plans and formulate management strategies. Therefore, the objective of this study was to assess the influence of coffee production systems, shade coverage levels, and altitudes variables on the occurrence of urticating ant in Southwestern Ethiopia.

Materials and Methods

Description of the study areas

The study was conducted in 2017/18 at selected coffee producing districts of Bench Sheko (Previously known as Bench Maji) and Sheka zones of Southwest Ethiopia, and coffee is the primary cash crop in this areas. Bench Sheko Zone lies between 5°33' and 7°21' N latitude and 34°38'and 36°14' E longitude with an elevation ranging from 800 to 2500 meters above sea level (m.a.s.l.). The average annual rainfall ranges 1500-1800 mm per year and has 15-25 °C range of temperature annually. Sheka Zone lies between 7°24'and 7°52' N latitude and 35°13' and 35°35' E longitude with an altitudinal range of the areas in the zone falling between 900 and 2700 m.a.s.l. The zone covers about 2175.25 km^2, out of which 56, 24, and 20% is a highland, a mid-altitude, and lowland, respectively. It receives high amounts of rainfall, with an average of 1800 – 2200 mm per annum (CSA, 2013; Sualeh *et al*., 2021).

Treatments and Experimental design

The experiments were laid out in 3×3 factorial in Randomized Complete Block Design (RCBD). Factor A was production systems with three levels (plantation, garden, and semi-forest) based on (Woldetsadik and Kebede, 2000) and Factor B was shade levels with three levels (high, moderate and low) based on Jonsson *et al.* (2015). Again, the second experiment, factor A the three production systems (plantation, garden, and semi-forest) combined with three levels of altitudinal gradients as a factor B (highland, midland, and lowland) based on Tadesse (2017). Three farms in each district were used as replications. In the first stage six high coffee producing districts, three from Bench Sheko (South Bench, Guraferda, Sheko) and three from Sheka (Yeki, Anderacha, and Masha) zones, were selected using a purposive sampling technique based on potential of coffee production and availability of the three coffee production systems, shade level and altitude; here Masha and Anderacha were highland agro-ecology. These zones and districts are among the main coffee-growing areas in the country and hotspots for *T. aculeatum* (Abebe and Mormone, 1985; Damte *et al*., 2009; Wakjira *et al*., 2015).

Sampling procedures and data collections

In each farm, 20–40 coffee trees were randomly selected from different sampled farms using zigzag sampling pattern which were spaced at least 10 to 20 m apart. The canopy of each tree was divided into three approximately equal sections and labeled as upper, middle, and lower. The farms were situated 5 to 10 km from each other depending on coffee farm availability. The study areas were categorized into three altitudinal groups, Lowland 1000-1500; Midland 1500-1750; Highland above 1750 m.a.s.l. (Tadesse, 2017) and shade levels category (High > 50 trees per hectare, Moderate 21-50 trees per hectare, and Low 0-21 trees per hectare with a minor modification of Jonsson *et al*. (2015). The common signs of urticating ant are the nests on coffee trees constructed by binding a single, two, or more coffee live or dead leaves together. According to Helmut (2013), the urticating ant on coffee builds delicate nests (each containing a few hundred small brown ants) in the bushes. The association of various geo-climatic factors with urticating ant infestation and abundance was assessed using Pearson correlation analysis. Ten years of geo-climatic data on rainfall, maximum temperature, and minimum temperature were obtained from the Ethiopian National Meteorology Agency were used in the correlation analysis.

Data analysis

The data on the number of urticating ant nests under the factors of production systems with farm shade coverage level, and the other experiment, production systems with altitudinal gradients, were subjected to analysis of variance as both 3x3 arrangement and means were separated using a Tukey’s test for significant differences. The analysis of variance was performed using SAS Version 9.2. Pearson correlation between the geo-climatic factors; altitude, shade level and nest infestation; and abundance were analyzed using Minitab 17 software (Minitab, 2017).

Results and Discussions

Influence of production system and shade level interaction on urticating ant abundance

The results showed that production systems and shade levels had a highly significant influence ($p < 0.0001$) on the abundance of the urticating ant on coffee trees (Table 1). Coffee trees in plantation production system with heavy shade had significantly higher mean number of nests per coffee tree (17.25 ± 7.9) compared to the garden and semi-forest coffee in Southwestern Ethiopia. The mean number of urticating ant nests in the other two production systems under the study, garden and semi-forest under heavy shade coverage farms had 5.55 ± 3.8 and 1.88 ± 1.7 number of nests per coffee tree, respectively, but were not statistically different. This suggests that the optimum management rendered to coffee trees in the heavily shaded farms of plantation production system might be more suitable for the ants than the other production systems. In the garden and semi-forest coffee, the intensity of human management is low and there is little or no use of modern inputs such as fertilizers and pesticides, and very low uniformity of the coffee tress in terms of variety, age distribution, growth, etc. The low level of urticating ant infestations in the semi-forest production system might be attributed to low or no pesticide use that might enhance the activities of natural enemies. In contrast, a study conducted in Mexico reported that ant patchiness in coffee agro-ecology varied based on management intensity where coffee intensification negatively affects the occurrence of dominant ants species in coffee plants (Philpott, 2006). In Ethiopia, insect pests are more challenging in an intensive coffee plantation mainly due to changes in cultural practices associated with new varieties planted in the plantation (Abebe, 1987; Mendesil, 2019). This study also confirms earlier findings of Teshome *et al.* (2018) who observed more ant nests in shaded coffee compared to unshaded coffee trees. The authors also found ant infestations on *G. robusta*, *Ficus sur* and *Ekebergia capensis* which are coffee shade tree species. This indicates that increase in the intensification of coffee farm in plantation and shade canopy closure had impacts on the density of urticating ant nests on coffee trees. The more frequent abundance of urticating ants on heavily shade-covered coffee trees might be because their nests are less disturbed (destructed) by rain storms. Damte and Minase (2010) reported that the shade trees *Milletia ferruginea*, *Grevillea robusta*, and *Ficus* sp. harbor urticating ant, however, coffee trees under heavy shade had higher number of nests than under light shade which indicates that the intensity of shade is more important in determining coffee infestation.

On the other hand, garden and semi-forest production system with low shaded coffee farms had numerically less 0.55 ± 0.3 and 0.0 ± 0.0 ant nest density but were not significantly different from each other. Similarly, moderately shaded farms in garden and semi-forest production system showed a non-significant difference in the number of urticating ant nests (2.67 ± 1.5) and (0.30 ± 0.2), respectively (Table 1). Plantations coffee production system with moderately and low shaded farms had various number of nests than garden and semi-forest with moderate or low shaded farms which were not statistically different from each other (0.97 ± 0.41 and 0.08 ± 0.04, respectively). This implies that shade coverage level and production systems have significant effects on the density of ant nests in southwestern of Ethiopia, which highlights the importance of shade tree regulation to reduce ant population in coffee plantation.

Influence of production system and altitudinal gradient interaction on urticating ant abundance

The present study showed that coffee production system and altitude had a highly significant ($p = 0.005$) effects on the number of ant nests on coffee trees (Table 1). The urticating ant constructed the highest number of nests (20.10 ± 15.1) on coffee trees in plantation farms of lowland altitudes, while the lowest number of ant nests (0 ± 0) were observed on coffee trees under highland and midland of semi-forest as well as highland plantation production system (Table 1). Similarly, Wakjira *et al*. (2016) reported that the distribution of *T. aculeatum* was higher at a lower elevation (Bebeka 1100 m.a.s.l.) and lower at a higher elevation (Teppi 1200 m.a.s.l.) and the ant was not observed above the altitude of 1300 m.a.s.l. This study also showed that even though statistically non significant difference was observed, 4.76 ± 3.1 and 3.71 ± 3.6 ant nests were recorded on lower altitudes of garden and semi-forest production system, respectively. On the other hand, coffee trees grown under highland and midland of garden production system, highland and midland of semi-forest, as well as midland and highland plantation system were not significantly different ($p = 0.005$) in the of abundance of urticating ant nests per coffee tree in Southwestern of Ethiopia (Table 1).

Table 1. Influences of different production systems with shade level and altitudinal gradient on the abundance under different production systems in SW Ethiopia

Production systems	Farm shade levels			Altitudinal gradients		
	Highly shaded	Medium shaded	Low shaded	High Altitude	Medium altitude	Low Altitude
Garden	5.55 (2.33) ± 3.8[b]	2.67 (1.74) ± 1.5[b]	0.55 (0.96) ± 0.3[b]	0.16 (0.80) ±0.12[b]	0.16 (0.80) ±0.12[b]	4.76 (2.04) ± 3.1[b]
Semi-forest	1.88 (1.44) ± 1.7[b]	0.30 (0.88) ± 0.2[b]	0.0 (0.71) ± 0.0[b]	0.0 (0.71) ± 0.0[b]	0.0 (0.71) ± 0.0[b]	3.71 (1.86) ± 3.6[b]
Plantation	17.25 (4.14) ± 7.9[a]	0.97 (1.20) ± 0.41[b]	0.08 (0.76) ± 0.04[b]	0.0 (0.71) ± 0.0[b]	1.54 (1.27) ± 2.3[b]	20.10 (4.22) ± 15.1[a]
ANOVA						
P-value		< 0.0001			= 0.005	
Tukey(HSD)		8.77			15.78	

Values are taken as Mean ± SD, Figures in parenthesis are square root transformed value (√x+0.5). Means with the same letter(s) within a column are not significantly different at 5% level of probability (Tukey HSD). ** = highly significant (p < 0.01); * = Significant (P < 0.05); ns = non significant.

Pearson correlation analysis

Minimum temperature and shade level showed a significant and positive correlation to *T. aculeatum* infestation (R = 0.56) (Table 2). Beer *et al*. (1998) indicated that shade trees create hostile conditions for pests and harbor a variety of predatory insects. There were significant and negative correlations between *T. aculeatum* abundance and altitude (r = - 0.57). In addition, the percent infestation by the urticating ant was positively correlated with abundance of ant nests (r = 0.66) (Table 2).

Table 2. Pearson Correlation Coefficients among urticating ant with rainfall, temperature, different altitudes, and shade levels in the southwest of Ethiopia

	RF	MAXT	MINT	ALT	SHL	INF	ABU
RF	1.00	-0.35^{ns}	-0.17^{ns}	0.39^{ns}	0.01^{ns}	-0.01^{ns}	0.10^{ns}
MAXT		1.00	0.42^{ns}	-0.93*	0.17^{ns}	0.44^{ns}	0.39^{ns}
MINT			1.00	-0.52^{ns}	0.34^{ns}	0.61*	0.41^{ns}
ALT				1.00	-0.27^{ns}	-0.49^{ns}	-0.57*
SHL					1.00	0.56*	0.47^{ns}
INF						1.00	0.66*
ABU							1.00

* =Significant at P<0.05; **= significant at P<0.01; ns=non-significant; RF= Rainfall; MAXT=Maximum temperature; MINT= Minimum temperature; ALT = Altitude; SHL = Shade level; INF=Percent of infestation; ABU= Abundance of nests. Source of meteorological data = National Meteorology Agency, 2018.

Conclusion and Recommendation

The current study showed coffee production system, shade coverage level, and altitude had significant influences on the abundance of urticating ant. The abundance was high in plantation coffee productions system in heavily shaded coffee farms as compared to the others. Similarly higher number of ant nests was recorded at lower altitudes, especially on the lowland plantations of Southwestern Ethiopia. This indicates that coffee production systems in respect to farm shade level and altitudinal gradient are very important factors for the abundance of urticating ant. Thus, studies and management of this pest need to focus on lowland areas in plantation production system. The study also suggests that regulation of shade trees can contribute to the reduction of the ant population in coffee plantations. The current study contributes to our knowledge of the ecology and abundance of the urticating ant and also calls up to further studies on the bio-ecology and integrated management methods. Generally this study confirmed a significant influence of production systems with shade level and altitudes on ant abundances in coffee agroecology. However, future efforts should be ecological studies on the urticating ant including top-down and bottom-up interactions, coffee (management practices, variety, population, age, shade, etc) on its biotics, distribution, seasonality, and population dynamics. Future studies also need to look into the ecological role played by the urticating ant in coffee-producing areas across wide agro-ecologies.

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