ORIGINAL ARTICLES

Status and Management of Biting Ant, *Tetramorium aculeatum* (Formicidae: Hymenoptera) on Arabica Coffee at Bebeka, South western Ethiopia

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ABSTRACT

Ethiopia is the birthplace and the largest Arabica coffee producer in Sub-Saharan Africa. However production and productivity is low due to various reasons. In large scale coffee producing area like Bebeka and lower parts of Tepi, biting ants are becoming important pest in coffee production system. Biting ants are not directly affecting coffee crop growth but hindering the agronomic and ripe berry picking activities. As a result ripe coffee beans stay longer in the field subjected to deterioration. Therefore, this study was undertaken to assess the current status and management practices of the biting ant, *Tetramorium aculeatum,* at Bebeka Coffee Estate Share Company. To figure out current status of biting ants number of nests with colony was counted from ten sampled coffee trees replicated three times considering coffee plants under shade and without shade, compact and open canopy nature, and productive and less productive blocks. Five coffee varieties were considered to determine number of nests with colony and different ant growth stages per nest. Yield loss caused by biting ant was compared between infested and non infested coffee blocks. For the management of biting ant two round applications of Decis, Dan anticides, horticultural oil and manual ant nest destruction at fourteen days interval were tested to evaluate efficiency of each management options. The result showed yield loss was 29% higher in ant infested blocks. Number of ant nests with colony based on canopy nature was significantly ($P<0.0001$) higher than compact coffee variety. It was also higher on under recommended shade than non shaded coffee tree ($P=0.0035$). No significant difference ($P=0.5387$) result was observed between less productive and productive blocks. Ant management option results showed that manual ant nest destruction and immediately inserting in detergent solution had better ant management efficiency followed by spraying of Decis and Dan anticides. Spraying of horticultural oil was the least effective to manage the ant. Therefore, to reduce the population of the ant and its effect on hindering the agronomic and ripe berry picking activities manual ant nest destruction could be recommended. In the future ant population and infestation level at different seasons and other alternative integrated management options should be studied.

Key words: Ant status, coffee, IPM, management strategies, nest.

INTRODUCTION

Coffee (*Coffea arabica* L.) is the most valuable and widely traded tropical agricultural product in international market in terms of both volume and value (Fair trade and coffee, 2012). Ethiopia is the birthplace of Arabica coffee and the largest producer of coffee in Sub-Saharan Africa and is the fifth largest coffee producer in the world next to Brazil, Vietnam, Colombia, and Indonesia, contributing about 7 to 10% of total world coffee production. Coffee has economical, environmental as well as social significance to producer countries (USDA, 2013). Despite the fact that Ethiopia is the center of origin and diversity for Arabica coffee, production and productivity is very low. The national average yield of coffee is between 600-700 kg ha^{-1} as compared to the research result (production potential), which ranges from 1,800-2,500 kg ha^{-1} (Tesfu, 2012). Even in modern plantation like Bebeka, Limu and Tepi coffee plantations, productivity hardly exceeds 430 kg ha^{-1}. This is due to poor adaptability of most of the released coffee berry disease resistant varieties at low lands of Bebeka and Tepi, labor shortage, harvest losses and inadequate or improper crop management practices (Baye *et al*., 2008).

In addition, insect pests are also among the major factors considered to limit coffee production both in terms of quality and quantity in the country (Million and Bayissa, 1986; Million, 1987; 2000). Over forty seven species of insect pests are known to attack coffee in Ethiopia. The Antestia bug (*Antestiopsis intricata),* the blotch leaf-miner (*Leucoptera caffeine*) and the coffee berry borer (*Hypothenemus [=Stephanodores] hampei*) are among the most prevalent insect pests of coffee. Insect pest problem are more pronounced in intensive coffee production system (plantation) compared to garden and semi forest coffee production systems mainly due to changes in cultural practices associated with the newly planted cultivars (Million, 1987).

In coffee plantation like Bebeka and lower parts of Tepi, beside the major insect pests of coffee plants that attribute to low yield, biting ants have also indirect impact on coffee yield. Two arboreal ant species namely the biting ant, *Tetramorium aculeatum* (Mayer) and the weaver ant, *Oecophylla longinoda* intervening coffee production operations, were identified as an important indirect pest of coffee. The indirect losses attributable of *T. aculeatum* alone could reach 30% (Tebikew *et al*., 2010).

The urticating ant, *T. aculeatum* also known as *Macromischoides aculeatus,* is an African ant feared to plantation laborers. It makes papery nests between leaves, especially on small trees. Disturbance of the leaves causes ants to rush out of their nests, hurry along the branches, and reach the intruder on whom they climb and "sting" or "bite" (Wheeler, 1992). *T. aculeatum* is a nocturnal species and foragers, havening discovered a prey, emit an attractant for nearby nest mates (Owona, 1992). This ant is not saccharophilic and does not encourage infestation of scales and mealy bugs (Hill, 1983).

Although the direct and indirect effect of ant are great, there was no loss assessment and detail status mapping of biting ants carried out in the area. Hence, considering the increment of distribution areas, this research was initiated with the aim of investing the current status of the target insect pest and evaluating different management practices of biting ant on Arabica coffee at Bebeka coffee farm, southwest Ethiopia.

MATERIALS AND METHODS

Study site

Bebeka Coffee Estate Share Company (Fig. 1) is located at 595km to the South West of the capital city, Addis Ababa, Ethiopia. Its altitude is 1000-1368 meters above sea level (masl). The average annual rainfall of the area is 1742mm and the mean maximum and minimum temperature of the area is 35.6^{0}C and 17.2^{0}C, respectively.

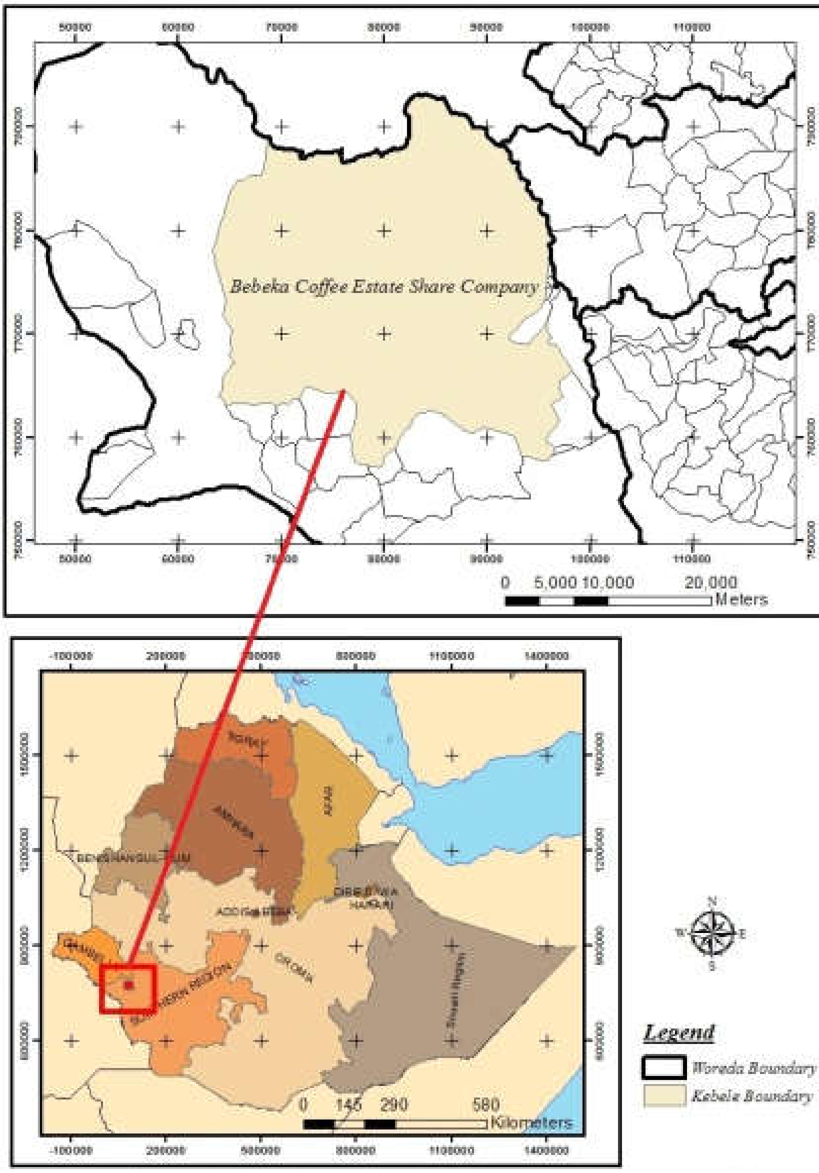

Figure 1. Bebeka location map

Yield loss assessment

Yield loss assessment was carried out for two consecutive production years (2013/14 and 2014/15) in the month of March to April when coffee harvesting is near to end. Number of coffee beans (dropped beans, beans left on the tree and germinated beans) were counted from randomly taken ten sample coffee trees of infested and non infested coffee blocks located in the same area at the end of harvesting season. To minimize biasness, similar in age, variety and shade tree nature of coffee blocks were used.

Effect of coffee varieties on ant stages and population

Dominantly cultivated coffee varieties in the plantation: Gesha, F-59, 7454, 7440 and Catimore, were considered for current study. From each variety, randomly ten coffee trees were selected for the experiment. It was replicated three times on similar location for nest with colony collection and number of eggs, larvae, pupae, workers, king and queens record. Killing the colony by tightening their nest with plastic bags and putting in deep refrigerator was done to get less disturbed nests that used for easy counting.

Effect of coffee plant canopy nature on number of ant nests

To know the effect of coffee canopy nature on the number of ant nests with colony, coffee varieties with canopy nature of open (F-59) and compact (Gesha) were used. From each category randomly ten sample coffee trees replicated three times located in similar location were used for nest with colony count.

Effect of coffee shade tree on number of ant nest

Shade levels vary from place to place in coffee production in Ethiopia. To know the effect of shade tree on the infestation level of ant, three shaded and relatively non shaded coffee blocks were selected for the study. The experiment was replicated three times for data collection. From each block, randomly ten sample coffee trees were taken to count numbers of nests with colony.

Effect of coffee age on number of ant nest

To understand the age of the coffee impact on the infestation of the ant, Gesha coffee variety with different age category of 5 years, 8-9 years and 13-14 years were used with three replication for the study. Randomly ten coffee trees were selected from each replication for ant nest with colony data collection.

Effect of productive and less productive coffee plants on number of ant nest

There were coffee blocks which gave less production (yield < 200 kg ha^{-1}) at least for five consecutive years. For these types of coffee blocks only two round hand weeding was accomplished and waiting either rejuvenation or uprooting period. In the contrary, for productive coffee blocks (yield > 400kg ha^{-1}) almost every activity required for coffee crops are accomplished. To know the relationships of coffee productivity on the infestation level of ant nest with colony, from productive and non productive coffee blocks numbers of nests with colony were counted. This was done on ten sampled coffee trees which was replicated three times.

Effects of different management options on biting ants

Five treatments were compared (tested) for the management of biting ant: Ants nest hand removal and immediate inserting in detergent solution, spraying of horticultural oil (a highly refined petroleum products) at a rate of 20ml/liter of water and spraying of Dan anticide (an organic extract) at a rate of 20ml/liter of water. Decis 2.5% EC (a synthetic pyrethroid pesticide) at a rate of 1ml/liter of water and control (untreated check) were used for comparison.

All treatments were applied on seven years age Gesha variety infested with ants that was weed free, handling and de-suckering was accomplished. Gesha variety was selected for treatment application as it showed more number of ants with colony during survey period. All spraying were made using separate OSATO knapsack sprayer with special insecticides spraying nozzle with swath width of 0.5 for each treatment. Shaking of the tree before spraying was made to create a chance of insecticide contact with the ants. Time of spraying was at 9:00 AM in the morning for maximum exposure. The experiment was repeated twice (two weeks interval). Randomized Complete Block Design (RCBD) with five treatments replicated three time was used. The total number of plot was 15 including the control and each with a size of 100 m^2 (10m x 10m). The spacing between blocks and between plots was 6m and 4m, respectively. Data on ant nests with colony were counted before applying treatments and after treatments application at 1^{st}, 3^{rd}, 7^{th} and 14^{th} day's post application. Numbers of sample coffee trees were ten for all treatments.

Data Analysis

A simple pair wise comparison of yield loss was made based on the data obtained from infested and non infested coffee blocks using t- test. Comparison of number of ant nest with colony based on coffee canopy nature, age of the coffee tree, shade and productivity were done. To compare the infestation level of ants by each survey variables ANOVA was used. The Fishers protected Least Significant difference (LSD) values were used ($P<0.05$) to separate means of different treatments. SAS version 9.2 for Windows (SAS, 2008) was utilized for data analysis. Before analyzing the data, raw data were transformed to percent means by abbot's treatment efficiency control formula (Abbott, 1925).

$$\text{i.e. Per cent control} = \frac{X-Y}{X}\, x\, 100$$

where X = % living in the untreated check sample and Y = % living in the treated sample

RESULTS AND DISCUSSION

Yield loss assessment

There was significant ($P<0.05$) difference in yield loss between ant infested and non-infested coffee blocks; more numbers of coffee beans were not harvested on ant infested coffee blocks which could be considered as a loss. About 55.19 of number of coffee bean was recorded on ant infested block and 39.21 for that of non-infested coffee blocks (Table 1). According to Teferi (2006) and Tebekew *et al* (2010) biting ant appeared more dominantly in Bebeka coffee plantation and cause a serious yield loss ranging from 15 - 30%.

Table 1: Number of intact coffee beans per tree in infested and non-infested blocks

Coffee blocks	Mean no. of beans per tree
Infested	55.19a
Non-infested	39.21b
Mean	47.60
P-Value	0.0132
LSD (5%)	12.46

Effect of coffee varieties on different biting ant stage and population

Number of different stage of biting ant (eggs, larvae, pupae, workers, winged male and queen) showed that workers were the highest in the ant colony on the different varieties.

There was no significant difference in terms of queen, winged male, eggs and larvae populations on the different coffee varieties. But, population of pupae and workers were statistically significantly (P<0.05) different. More number of ants population was found in compacted variety of Gesha and Catimor coffee than the other varieties (Table 2). According to Shattuck (1999) the number of ant stage differs based on coffee variety as they play active roles in ant colony searching for food, building, defending and cleaning the nest workers.

Table 2: Number of different ant growth stage per nest on five coffee varieties

Varieties	No. of different stages of the ant per nest on five coffee varieties					
	Queen	Winged male	Eggs	Larvae	Pupae	Workers
Gesha	2	2	141	48	136[a]	324[a]
Catimore	1.5	1	102	53	62[b]	278[a]
7454	2	3	121	17	114[a]	113[c]
7440	1.5	2	85	20	35[bc]	274[a]
F-59	1	3	94	38	22[c]	191[bc]
Mean	1.60	2.20	108.80	35.20	73.80	236.00
P-value	0.216	0.216	0.464	0.312	0.004	0.007
LSD (5%)	ns	ns	Ns	ns	24.77	47.26

Means followed by the same letter (s) within the column are non significantly different at P < 0.05; ns: non-significant.

Effect of coffee plant canopy nature on the number of ant

Statistically difference was observed in the number of ant nest between compact (Gesha) and open (F-59) coffee canopy nature. Relatively more mean number of ant nests with colony was recorded on coffee trees with compact canopy nature (Table 3). This might be due to the advantage of easy mobility of the ant to forage its food and less aeration in compact coffee type which is suitable for ants reproduction leading to more population. Ants choose trees with a dense or compact foliage as the habitat conditions are more favorable for nesting. There could be a chance of finding a suitable nesting site in a compact canopy, or they choose a compact canopy to provide nesting sites for seasonal migration (Vanderplank, 1960).

Table 3: Number of ant nest with colony per tree in compact and open coffee varieties

Canopy nature	Mean no. of nest with colony per tree
Open	6.07 [b]
Compact	10.23 [a]
Mean	8.15
P-Value	<0.0001
LSD (5%)	1.49

LSD: Least Significant Difference; Means followed by the same letter (s) within the column are non significantly different

Effect of coffee shade tree on number of ant nest with colony

Statistically there was significant difference ($P<0.0035$) in number of ant nest with colony per coffee tree under shade and without shade (Table 4). More number of ant nests with colony were found on coffee trees under shade when compared with without shade coffee trees. The possible reasons may be confined environment preference of this ant species and better chance of obtaining food under shade trees. In shaded coffee agro-ecosystems, numerically dominant arboreal ants most often nest and forage in coffee plants nearby (Vandermeer *et al.* 2002). During the survey period it was observed that some natural shade tree species such as *Gravillia robusta, Ficus sar forssk,* and *Ekebergina capensis* attract the ant and even itself infested by this ant sp. This might be again related with the advantage of easy mobility of the ant to forage its food and relatively less aeration is suitable for reproduction of ants (Vanderplank, 1960).

Table 4: Number of ant nest with colony per coffee tree under shade and un-shaded coffee trees

Shade status	Mean no of nest with colony per tree
Under shade	7.17 ^{a}
Without shade	4.7 ^{b}
Mean	5.94
P-value	0.0035
LSD (5%)	1.62

LSD: Least Significant Difference; Means followed by the same letter (s) within the column are non significantly different

Effect of coffee age on the number of ant nests

During survey period ant infestation on young coffee blocks with age less than five years was not observed. Average number of nest with colony on coffee tree with 5, 8-9 and 13-14 years age was 5.4, 7.93 and 9.2, respectively (Table 5).

This showed that more number of ant nest with colony was recorded on older coffee blocks. This might be because of the fact that as the age of coffee trees increases, more branches are interlocked with each other creating confined microclimate conducive to ant reproduction (Vanderplank, 1960).

Table 5.: Number of ant nest with colony at different age group of coffee trees

Age group	**Mean no. of nest with colony per tree**
5 year	5.4^{b}
8-9 years	7.93^{ab}
13-14 years	9.2^{a}
Mean	7.5
P-value	0.0356
LSD (5%)	2.59

LSD: Least Significant Difference; Means followed by the same letter (s) within the column are non significantly different

Table 6. Number of ant nest with colony per coffee tree in productive and less productive blocks

Coffee blocks	**Mean no. of nest with colony per tree**
Productive	9.50
Less productive	10.35
Mean	9.93
P-value	0.5387

Effect of productive and less productive coffee plants on ant nest with colony

The survey result showed that an average number of ants with colony on productive and less productive blocks were 9.5 and 10.35 per tree, respectively with statistically non significant difference (P > 0.5387, Table 6). This indicates that the number of ant nest with colony is not affected by productivity status of coffee tree.

Management biting ants

Different management tools for biting ant were compared for their efficacy. The tools were significantly different (P<0.05) in their efficacy at different days interval after application (Table 7). Manually ant nest harvesting and dipping in detergent solution had relatively high efficacy. Maximum efficiency was recorded one day after application (72.52%), followed by three days (66.37%), seven days (61.30%) and 14 days (53.39%) after application.

Application of Decis on ant nest colony was the second most effective but on par with Dan anticide. On the other hand, spraying of horticultural oil preformed the least in controlling ant colony. It was statically not significantly different from the control plot. In general as the number of days increases, mean percent ant control of all the treatments decreases calling for frequent application for effectiveness.

Similarly, there was a significant difference between the treatments for their ant control/ efficacy for the second round application (Table 8). Manually ant nest harvesting and dipping in detergent solution had the highest ant control with 63.52% (on day one), 63.21% (on day three), 57.30% (on day seven) and 65.39% (on day 14) followed by spraying of Decis and Dan anticide in that order. Least ant control was recorded by spraying of horticultural oil.

Table 7. Efficacy of management tools at different days interval after application (1st round)

SN	Treatments	PA	Efficacy (%) after application (days)			
			1 DAA	3 DAA	7 DAA	14 DAA
1	Manual ant nest with colony harvesting & dipping in detergent solution	13.60	72.52^{a}	66.37^{a}	61.30^{a}	53.39^{a}
2	Horticultural oil	12.23	15.40^{c}	6.42^{c}	4.35^{c}	1.08^{c}
3	Dan anticide	15.45	42.62^{b}	34.36^{b}	30.83^{b}	29.19^{b}
4	Decis	9.87	50.07^{b}	47.20^{b}	45.91^{ab}	40.98^{ab}
5	Control	10.27	3.91^{c}	4.23^{c}	5.54^{c}	4.90^{c}
	P- value		<.0001**	<.0001**	0.0001*	0.0005*
	Mean		36.90	31.72	29.58	25.90
	LSD (5%)		13.61	14.01	15.90	17.54

**Highly significant, *significant, DAA: day after application, PA: Pre-treatment application; Means with the same letter (s) with in the column are not significantly different at P < 0.05.

Table 8. Percentage efficacy of control tools at different days after application (2nd round**)**

SN	Treatments	PA	Efficacy (%) after application (Days)			
			1 DAA	3 DAA	7 DAA	14 DAA
1	Manual ant nest with colony harvesting & dipping in detergent solution	7.1	63.32a	63.21a	57.30a	65.39a
2	Horticultural oil	11.7	27.44c	27.59c	21.54b	17.91c
3	Dan anticide	12.1	38.88bc	35.02bc	30.75b	35.23b
4	Decis	5.9	53.70ab	44.55b	48.23a	51.69a
5	Control	10	3.38d	5.08d	5.71c	4.73c
	P- value		0.0005*	0.0003*	0.0002*	<.0001**
	Mean		37.35	35.08	32.71	34.99
	LSD (5%)		18.26	15.46	13.81	15.22

** Highly significant, * significant, DAap day after application PA: Pre-treatment application. Means with the same letter with in the column are not significant difference at P < 0.05.

Combined analysis of first and second round treatments effect (Table 9) showed that there were significant differences (P<0.0001) among treatments. Manually harvesting of ant nests and dipping in the detergent solution had the highest ant control efficiency. Maximum efficacy was obtained one day after application of this treatment (69.00%), followed by three (65.06%), seven (59.64%) and 14 days (58.09%) after application of the treatments on ant nest. In Zimbabwe, picking and killing adults of coffee white borer from infested plants are common management practices (Kutywayo, 2002) followed by spraying of Decis and Dan anticides. Spraying of horticultural oil had the least ant control efficiency which was statistically not different from the check. Selective manual nest harvesting had better effectiveness in reducing ant nests with colony.

Table 9: Combined analysis of the percentage efficacy of treatments at different days after application (Cumulative)

SN	Treatments	PA	Efficacy control (%)			
			1 DAA	3 DAA	7 DAA	14 DAA
1	Manual harvesting of ant nests with colony and dipping in detergent solution	10.35	69.00[a]	65.06[a]	59.64[a]	58.09[a]
2	Horticultural oil	11.95	21.33[c]	16.77[c]	12.73[c]	9.32[c]
3	Dan anticide	13.77	41.02[b]	34.67[b]	30.73[b]	31.94[b]
4	Decis 2.5 Ec	7.9	51.46[b]	46.02[b]	46.81[a]	45.09[ab]
5	Control	10.12	3.65[d]	4.64[c]	5.63[c]	4.82[c]
	P- value		<.0001	<.0001	<.0001	<.0001
	Mean		37.29	33.47	31.11	29.85
	LSD (5%)		13.47	13.86	13.58	13.54

DAA: Day after application, PA: Pre treatment application. Means with the same letter with in the column are not significant difference at $P < 0.05$.

CONCLUSIONS

The results of the ant survey showed that there was variations in number of ant nest with colony based on different factors such as coffee age, canopy nature, shaded and non-shaded coffee plants while no variation for productive and less productive blocks. Ant nests were dominantly appeared on older coffee trees as compared to younger coffee plants. Similarly coffee variety with dense canopy nature relatively holds more number of ant nests with colony compared with open canopy nature. More coffee yield loss was recorded on ant infested than non infested coffee blocks. There was difference between the number of pupae and workers per ant nest made on the leaves of different coffee varieties. In general more number of workers were recorded per ant nest among the different developmental stages.

Regarding ant management tools compared in this study, manual harvesting of the ant nest and dipping in detergent solution provided better control of ant when compared with other treatments. Therefore to reduce the population of the ant and its effect on hindering the agronomic and ripe berry picking activities manual ant nest harvesting could be recommended in Bebeka coffee estate Share Company and elsewhere with this species of ants challenge.

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