Ethiop. J. Biol. Sci. 21(1): 1–16, 2022

ISSN: 1819-8678

RESEARCH ARTICLE

ASSESSMENT OF COFFEE BERRY BORER, *HYPOTHENEMUS HAMPEI* FERRARI (COLEOPTERA, CURCULIONIDAE) USING LOCALLY MADE BAITING TRAP IN MAJOR COFFEE PRODUCING AREAS OF ETHIOPIA

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ABSTRACT: Coffee represents the major source of revenue for foreign exchange and income source for households of large number of families in Ethiopia. However, coffee is facing a great challenge by coffee berry borer (CBB) [*Hypothenemus hampei* Ferrari (Coleoptera, Curculionidae)]. The attention given to control this insect-pest is very low compared with other African countries. Controlling the coffee berry borer using conventional chemical method is difficult due to its cryptic nature in its life cycle. Mass trapping of the insect using baiting trap method is the most promising and relevant one. This study were conducted in selected and representative coffee producing areas of Tepi, Limu Goma and Mizan-Aman. A total of 32 red color local baiting trap was prepared and lured with Ethanol:Methanol (E:M) mixture (1:1, 1:2, 1:3 and control) and releasing rate of 509.9 ± 0.06, 577.3 ± 0.02 and 580.3 ± 0.02 mg day^{-1}, respectively. Traps were attached to wood stakes branches in a completely randomized block design (CRBD), 12 m within the raw, 15 m between blocks and 1.20 m from the ground. The efficiency of the attractant (E:M) mixtures at Tepi-Baya II, Jimma zone (Limu-Goma II) and Mizan-Aman showed no significant difference, but all were significantly different from the control ($p<0.001$). The percentage of captured CBB with E:M (1:1, 1:2 and 1:3) were 427 (93%), 413 (98.6%) and 416 (95.2%) at Tepi-Baya II; 97 (89%), 115 (100%) and 90 (93.8%) at Limu-Goma II, and 137 (86.7%), 122 (97.6%) and 98 (94.2%) at Mizan-Aman, respectively. Non-target coffee berry borer (NCBB) were not preferably attracted by 1:1 and 1:3 than 1:2 E:M mixture across the localities. None of the controls captured the NCBB beetles at any of the localities. The study indicated that this trap can be used in different localities for trapping of the female CBB as a tool to reduce the population level of CBB.

Key words/phrases: Baiting trap, Ethanol: Methanol, *Hypothenemus hampei*, Semiochemical.

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INTRODUCTION

Coffee is one of the major commodities that is a significant source of income for more than 80 countries in the international agricultural trade (Belay Abate, 2021). Ethiopia, which supplies coffee beans to the rest of the world, is believed to be the birthplace and diversity of Arabica coffee (*Coffea arabica*). Coffee is vital to the economy of Ethiopia, providing a major source of foreign exchange earnings and, as a cash crop, supporting the livelihoods of millions of people involved in cultivation, processing, marketing, and export industry. This cash crop occupies the first place among the export crops in Ethiopia. However, the coffee berry borer (*Hypothenemus hampei* Ferrari), which causes direct damage to the coffee beans, poses a significant threat to the business (Yonas Chekol and Tesfaye Alemu, 2017).

Coffee is mainly cultivated in western, southern, northern and eastern parts of Ethiopia. One of the major challenges to coffee production across the world is the damage caused by the coffee berry borer (CBB), *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae). These small beetles are found in central and eastern African countries (Le Pelley, 1968) and cause severe losses and damages to coffee beans in coffee producing areas in Ethiopia (Esayas Mendesil *et al*., 2004; Belay Abate, 2021). Adult females bore a hole in the coffee berry and lay their eggs in internal galleries, with larvae feeding on the coffee bean (Benavides *et al*., 2012). The female insect is responsible for drilling the coffee fruit, green fruit, ripe and over-mature fruit, usually in the crown region. Inside the fruit, the insect forms galleries where it lays its eggs.

The feeding of an insect on coffee beans damages the beans and reduces the yields, lowers the quality of the seed, and can result in abscission of the berry. The quality of the beans at the end of processing influences the price achieved when sold on the market and therefore, defects in coffee beans are undesired because they decrease the coffee production and quality (Ruiz-Diaz and Rodrigues, 2021). The female to male ratio of the insect in the berry is in the order of 10.1 inside the bean (Bergamin, 1943). Once the insects moult into adults inside the berry, mating occurs between the siblings. As a result, the emerging females are inseminated and are ready to search for a berry in which they start ovipositing (Vega *et al*., 2009). Thus, most of its life cycle takes place inside coffee berries, making this cryptic insect quite difficult to control by applying chemical as well as non-chemical strategies.

CBB is regarded the most prevalent and important insect pest of coffee in Ethiopia posing a major challenge to the coffee production. Some authors (Esayas Mendesil *et al.* 2004; Yonas Chekol and Tesfaye Alemu, 2017) have addressed the challenge posed by the insect pest in Ethiopia and recommended control measures that principally relied on cultural methods such as picking left-over and fallen cherries. These methods are inadequate and cumbersome for farmers/producers to apply. In addition to these cultural methods the capturing of the beetle using baiting trap is also practical and promising. For example, Ruiz-Diaz and Rodrigues (2021) trapped the insect pest using Ethanol (E), Methanol (M) with a 2 mm hole in the vial dispenser to capture CBB lured with E:M mixtures (1:1, 1:2, 1:3) and caught considerable number of CBB. Our study was designed to prepare a coffee berry borer trap from local materials and lured with Ethanol: Methanol (E:M) mixtures. We also checked the efficiency of the trap for future mass trapping approach to reduce the population of female CBB. The CBB were caught from different localities of coffee producing areas of Ethiopia.

MATERIALS AND METHODS

Study areas

Coffee berry borer (CBB) were caught and assessed in three different localities known as coffee producing areas in south western part of Ethiopia (Fig. 1). These localities were selected as a representative sample of potentially coffee producing areas, namely Tepi coffee plantation area at “Baya II” (7°10′36″N, 35°24′50″E and 1,206 m.a.s.l.) sampled on 20-29-01-2013, Jimma zone (Limu Goma II) (7°57′47″N, 36°41′9″E and 1,409 m.a.s.l.) sampled on 15-24-03-2014 and Mizan-Aman (7°00′10″ N, 35°34′56″ E and 1,325 m.a.s.l.) sampled on 15-24-11-2015 (Table 1). The ecological and environmental conditions of these three localities are favourable for coffee production but different in climatic and weather conditions. Due to these conditions, the flowering, fruiting and maturation of coffee production at these localities occur at different times. The harvesting of ripe red cherries at Tepi-Baya II, Mizan-Aman and Limu-Goma II areas takes place from late August to late October, late September to late November and from late October to late December, respectively. The data were collected at Tepi-Baya II during a winter season with moderate rain, while at Mizan-Aman data were collected during a spring season with an unexpected intense rain fall making coffee harvesting and drying process very difficult. The weather condition at Jimma zone Limu-Goma II was extremely dry condition.

Table 1. Geographical location, altitudes and description of coffee berry borer (*Hypothenemus hampei*, Ferrari) mass trapping sites from the three coffee producing localities of South Nations, Nationalities Region of People (SNNRP) and Jimma zone, Oromia.

Sites	Date data collection	Long/Lat location	Altitude	Description
Tepi-Baya II	20–30 January 2013	7° 10′36″N, 35°24′50″E	1,206	Flowering stage
Limu-Goma II	15–25 March 2014	7°57′47″N, 36°41′9″E	1,409	Dried condition
Mizan-Aman	15–25 November 2015	7°00′10″N, 35°34′56″E	1,325	Harvesting, rain

The type of coffee variety from the three coffee plantation areas is almost the common variety comprising varieties of 7440, Catmir, F59, Gesha and 7454. These varieties are all susceptible to insect pests including CBB that infects the coffee beans of different coffee types. Each coffee producing sites was planted with *C. arabica* with different coffee varieties of 7440, Catmir, F59, Gesha and 7454 grown under shade canopies (except Limu). Annual agricultural upkeep was ensured with moderate management, characterized by moderate coffee tree pruning and shade regulation. During data collection there was no control or protection measure carried out on the target CBB insect pest in any of coffee production localities.

Surveying and capturing of CBB, at Tepi-Baya II was carried out from 20-29-01-2013 after the end of the coffee harvesting season when the coffee plants were at the flowering stage. By that time, the future colonizing CBB females would survive in the unpicked left over residual and fallen fruits (Esayas Mendesil *et al*., 2004). The coffee plants were about 1.6–2 m high, unless otherwise stated. At Limu-Goma II, the capturing was carried out from 15-24-03-2014. It was a dry condition and the coffee plants were at vegetative stage (no flower and cherry fruit) and their height was ca 1.6–2 m, unless otherwise stated. Dry unpicked and fallen coffee cherries were common but the farm was in good sanitation compared with the farms in the other two localities. At Mizan-Aman, trapping was carried out from 15-24-11-2015 in the farms of volunteer farmers at a harvesting time and the coffee plants were 1.5–2 m high unless otherwise stated. The coffee plants were planted 2 m apart in rows and 1.5 m apart within the row at Tepi-Baya II and Limu-Goma II, but at Mizan-Aman some were planted in the row and others in random. At Mizan the coffee farm also produces other plants such as yam, maize and vegetables for household consumption.

Trap preparation

Traps were prepared and assembled using metal sheet, plastic funnel and cylindrical screw cupped container. The metal sheet was sketched, designed, assembled and painted with red colour except for the plastic container. The trap was designed to mimic the evolutionary adaptation of the CBB insect's biology that is attracted by coffee color and the volatile aroma of coffee cherry (Mendoza-Mora, 1991; Mathieu *et al*., 1997). The colour and the powerful attractant of the different concentrations of Ethanol Methanol (E:M) to the CBB was used according to Mathieu *et al*. (2001). Mendoza-Mora (1991) and Mathieu (1995) have demonstrated that vision and/or olfaction play a role in the CBB's preference for ripe (red) versus immature (green) berries. Each piece of the designed parts of the trap was assembled to make a completed CBB trap and a total of 32 local baiting traps were prepared and a flexible wire was attached on the top of the trap for hanging it on coffee tree (Fig. 1).

Fig. 1. Locally made CBB baiting trap. The trap is made from metal sheet, funnel and plastic jar that are assembled with wire. The trap was lured with ethanol: methanol mixture.

Determination of lure releasing rate

The releasing rates of the semiochemical were determined in the laboratory before field application. Transparent 10 ml plastic vials closed by a screw cap were used as dispensers perforated with 2 mm diameters hole at the centre of the screw cap on top (da Silva *et al*., 2006). The reference mixture used in all the trials consisted of 99% ethanol and 100% methanol commercially available and the two alcohols were used undiluted in accordance with the methodology proposed by Mathieu *et al*. (1997). From each Ethanol:Methanol, E:M (1:1, 1:2 and 1:3) mixture 10 ml were injected into labelled vials in five replicates and the releasing rate of each mixture were recorded within 24 hours intervals for seven days. The mean ± SD of semiochemicals releasing rate were calculated using SPSS 20. The amount of releasing rate was within the accepted range to attract adult CBB (da Silva *et al*., 2006; Mathieu *et al*., 1997). Each E:M mixture (lure) releasing rate was calculated based on the difference between the initial weight (mg) (vial plus the mixture) minus the weight of vial dispenser (vial plus the mixture) (mg) after releasing of its content within 24 hours intervals and their mean ± SD releasing rate was considered as releasing rate of each mixture mg/day units (Table 2).

Table 2. Semiochemical release rates of lure (E:M) mixture and mean ranges of releasing rate of different E:M concentration measured in mg day^{-1}.

E:M	Mean range mg day^{-1}	Mean ± SD mg day^{-1}
1:1	430.50–593.10	509.9 ± 0.06
1:2	559.06–587.66	577.3 ± 0.02
1:3	570.98–591.52	580.3 ± 0.02

Trap installation

Placing of traps in the coffee plantation area was carried out in a completely randomized block design (CRBD) with a factorial arrangement. The factors were the lure E:M mixtures (1:1, 1:2 and 1:3), the control and the two plots A and B were randomly selected from the coffee farm. From each study localities a total of 32 traps were placed for capturing of CBB which comprised 24 semiochemicals (E:M) baiting trap and eight controls. The traps installation at each study site was 12 m within the raw and 15 m between the blocks (da Silva *et al*., 2006). Based on this placing distance, CRBD arrangement four in rows and four in blocks (16 traps) were used and 1,620 m^2 areas were covered from each plot and a total of 3,240 m^2 (0.324 hectare) from each locality. This ensured that the effect of the lure was approximately the same within the range (Messing, 2012). The vial that contained the semiochemicals (E:M) mixture was kept at the centre in upright position to make sure that the releasing of the lure was not blocked by barrier. Each trap was attached to wood stakes branch so that the holes (dispenser) was located around 1.20 m from the ground (da Silva *et al*. 2006). The colour combination of the trap was red except for the semiochemical dispenser and the container. The female CBB entering the trap automatically fell into the container where they were drowned and collected in the sterile vial.

Data collection of CBB

After the traps were placed in the coffee plantation in the CRBD design the captured CBB were collected within 24 hours' intervals for 10 days. From each trap, caught beetles were collected in different sterile vials. Other *Hypothenemus* beetles, non-target insects (NCBB) were also found in the trap and they were sorted out and inspected using hand lens (10x) to differentiate them from the non-CBB *Hypothenemus* beetles (Messing, 2012). The differentiated CBB in each vials were counted and pooled into the rectangular transparent box and kept at room temperature until transported to the laboratory. In the laboratory each beetle was also further inspected and examined individually under a dissecting microscope using identification key of Andrew (2014).

Data analyses

Basic statistics such as mean ± SD, one way ANOVA and Tukey HSD were done using SPSS 20.

RESULTS

The releasing rate of semiochemicals were determined in the laboratory and all of the E:M mix volatility resulted in reduction of the initial weight. The calculated weight loss was directly proportional to the released rate of the each semiochemical, E:M. The weight loss in mean ± SD mg day^{-1} from each of E:M mix was calculated and resulted in 509.9 ± 0.06, 577.3 ± 0.02 and 580.3 ± 0.02 from E:M, 1:1, 1:2 and 1:3 mix, respectively (Table 2).

The mean number of captured CBB from Tepi-Baya II using different mixture of E:M on different days of data collection is given in Table 3. From (20-29)-01-2013, the mean number of CBB captured was relatively higher (ca.11–16 CBB/trap/day) and irrespective of the E:M mixture differences, the capture per trap per day showed relatively reduction in the last two days (Table 3). The mean capture of CBB from Tepi-Baya II on each days of data collection and attraction of 1:1 and 1:2 E:M mix showed no statistically significant difference in their efficiency in attracting of CBB. However, there was a statistically significant difference in the mean number of CBB captured per day per trap at E:M mixture of 1:3 (Table 3). The level of significance for each collected CBB with each bating traps was further checked at lower probabilities: $p<0.001$, $F = 4.923$, and $p = 0.003$ for 1:1; $F = 2.860$, $p = 0.038$ for 1:2 $F = 9.785$, and $p = 0.000$ for 1:3).

Table 3. Mean ± SD number of captured CBB with different E:M mixture per trap per day at Tepi-Baya II.

Date	1:1	1:2	1:3	Control
22	11.88 ± 5.30a	14.25 ± 7.67a	16.13 ± 4.76b	0.00 ± 0.00a
24	12.00 ± 3.59a	11.38 ± 2.62a	11.00 ± 2.62ab	0.38 ± 0.74a
26	14.50 ± 5.04a	9.75 ± 2.92a	9.75 ± 4.83ab	0.63 ± 0.92a
28	7.38 ± 2.50a	9.38 ± 4.57a	9.75 ± 2.49ab	0.50 ± 0.76a
30	7.63 ± 2.13a	6.88 ± 2.95a	5.38 ± 1.19a	0.38 ± 0.52a

Trapping of CBB from Jimma zone Limu-Goma II coffee plantation using baiting trap of E:M mixture resulted in relatively less number of captures (Table 4). The mean number of CBB captured across all days using the three different E:M mixtures was almost the same and there was no statistically significant difference in capturing of CBB per day per trap using the different E:M mixtures and the control at $p<0.001$, df = 4, $F(1, 32) = 2.643$, $p = 0.050$ for 1:1; df = 4, $F(1, 32) = 0.466$, $p = 0.233$ for 1:2 and df = 4, $F(1, 32) = 0.842$, $p = 0.508$ for 1:3.

Table 4. Mean ± SD number of captured CBB with different E:M mixture per trap per day at Limu-Goma.

Date	1:1	1:2	1:3	Control
17	3.38 ± 1.06a	3.63 ± 1.30a	2.25 ± 1.28a	0.00 ± 0.00a
19	3.00 ± 1.20a	2.00 ± 0.76a	2.88 ± 1.55a	0.00 ± 0.00a
21	1.88 ± 1.55a	2.88 ± 2.30a	2.00 ± 1.31a	0.00 ± 0.00a
23	2.13 ± 0.99a	3.13 ± 0.99a	1.75 ± 1.16a	0.00 ± 0.00a
25	1.75 ± 1.39a	2.75 ± 1.04a	2.38 ± 1.19a	0.00 ± 0.00a

Data on the mean capture of CBB from Mizan-Aman using baiting trap with different E:M mixtures is given in Table 5. The number of beetles captured with different E:M mixture on different days was small and similar. The mean capture was not significant with different E:M mixtures, both among the E:M mixtures and with the control ($p<0.001$, df = 4, $F(1, 32) = 1.103$, $p = 0.371$ for 1:1; df = 4, $F(1, 32) = 0.164$, $p = 0.955$ for 1:2 and df = 4, $F(1, 32) = 0.564$, $p = 0.690$ for 1:3 E:M mixture).

Table 5. Mean ± SD number of captured CBB with different E:M mixture per trap per day at Mizan-Aman.

Date	1:1	1:2	1:3	Control
17	4.00 ± 1.20a	3.25 ± 1.39a	2.38 ± 1.19a	0.00 ± 0.00a
19	3.63 ± 1.06a	3.00 ± 1.31a	2.88 ± 1.25a	0.00 ± 0.00a
21	3.25 ± 1.04a	2.75 ± 1.39a	2.13 ± 0.83a	0.00 ± 0.00a
23	3.00 ± 0.76a	3.25 ± 1.98a	2.25 ± 0.89a	0.00 ± 0.00a
25	3.25 ± 1.16a	3.00 ± 1.07a	2.63 ± 1.41a	0.13 ± 0.35a

The attraction potential of the different E:M mixture (1:1, 1:2 and 1:3) at the three different localities and the corresponding number of CBB captured per trap per day are shown in Table 6. The three different E:M mixtures at the Tepi-Baya II and Limu-Goma II had no significant difference in their potential for attraction of CBB into the trap but were significantly different from the control (Table 7). The attraction potential of the E:M mixture lured with 1:3 showed significant difference compared with 1:1 and 1:2 at Mizan-Aman per trap per day ($p<0.001$).

Table 6. Mean number of adult coffee berry borers captured per trap per day with local traps containing three different ratios of ethanol: methanol (E:M) for ten days.

Localities	**1st**	**2nd**	**3rd**	**4th**	**5th**
Tepi-Baya II	10.56 ± 8.09b	8.69 ± 5.48b	8.66 ± 6.26b	6.75 ± 4.68b	5.06 ± 3.41b
Limu-Goma II	2.31 ± 1.77a	1.97 ± 1.58a	1.69 ± 1.80a	1.75 ± 1.44a	1.72 ± 1.46a
Mizan-Aman	2.41 ± 1.85a	2.38 ± 1.74a	2.03 ± 1.56a	2.13 ± 1.70a	2.25 ± 1.63a

Table 7. Mean ± SD of baiting trap efficiency of the different E:M mixture to attract CBB trap per day from the three localities.

E:M	**Tepi-Baya2**	**Limu-Goma**	**Mizan-Aman**
1:1	10.68 ± 4.65b	2.43 ± 1.36b	3.43 ± 1.06c
1:2	10.33 ± 4.97b	2.88 ± 1.42b	3.05 ± 1.40bc
1:3	10.40 ± 4.80b	2.25 ± 1.30b	2.45 ± 1.11b
Control	0.38 ± 0.67a	0.00 ± 0.00a	0.03 ± 0.16a

The number and percentage of CBB and the NCBB beetles collected from Tepi-Baya II, Limu-Goma II and Mizan-Aman using baiting trap with different E:M mixtures are indicated in Table 8. The number of NCBB captured at Tepi-Baya II using 1:1, 1:2 and 1:3 mixture of E:M were 31, 6 and 21, respectively but more than 410 CBB were captured by all the E:M mix and also showed the highest proportion (Table 8). The number and the percentage of CBB captured at Limu-Goma II using 1:1, 1:2 and 1:3 E:M mixture were 97 (89%), 115 (100%) and 90 (93.8%), respectively but very low number of NCBB. The number of NCBB captured at Mizan-Aman showed relatively higher number, 21 (13.3%) lured with 1:1 E:M mixture than the other E:M mixture, but the captured CBB were 137 (86.7%), 122 (97.6%) and 98 (94.2%) with E:M mixture of 1:1, 1:2 and 1:3, respectively. From the overall collection of Curculionidae beetles, the highest proportion of percentage were CBB from all localities. The percentage of NCBB captured from Limu-Goma II and Mizan-Aman localities were relatively higher as compared with Tepi-Baya II. The NCBB showed preferably attracted by 1:1 and 1:3 than 1:2 E:M mixture across the localities. None of the control captured the NCBB beetles at any of the localities (Table 8).

Table 8. Percentage of captured NCBB and CBB collected from different localities of coffee producing area containing different concentrations of E:M.

E:M	Tepi-Baya 2				Limu-Goma 2				Mizan-Aman			
	NCBB	%	CBB	%	NCBB	%	CBB	%	NCBB	%	CBB	%
1:1	31	6.77	427	93.23	12	11.01	97	88.99	21	13.33	137	86.71
1:2	6	1.43	413	98.57	-	-	115	100	3	2.46	122	97.6
1:3	21	4.81	416	95.19	6	6.25	90	93.75	6	5.77	98	94.23
Control	-	-	15	100	-	-	-	-	-	-	1	100

The total number of beetles captured from Tepi-Baya II coffee plantation were 458, 419 and 437 beetles using 1:1, 1:2 and 1:3 E:M mixture of baiting trap, respectively (Table 9). The three mixture of baiting trap at Limu-Goma II, Mizan-Aman and Tepi-Baya II captured relatively the same number of beetles. However, the total captured beetles from Tepi-Baya II (1,329 beetles), Limu-Goma II (320 beetles) and Mizan-Aman (388 beetles) varied significantly.

Table 9. Total captured beetles (NCBB) and CBB from different localities of coffee producing area within ten days per trap per day using baiting local trap with different E:M mixture.

	Total beetles captured		
E:M ratio	Tepi-Baya II	Limu-Goma II	Mizan-Aman
1:1	458	109	158
1:2	419	115	125
1:3	437	96	104
Control	15	-	1
Total	1329	320	388

DISCUSSION

The present study indicated that the infestation level of CBB was high in the study area of coffee plantation, south western Ethiopia. The coffee berry borer (*Hypothenemus hampei*) is considered the most important insect pest and the greatest economic threat to coffee industry (Soto-Pinto *et al*., 2002). Davidson (1968) reported the first incidence of coffee berry borer in Ethiopia. Survey conducted in some coffee growing areas showed mean percentage infestation of 13.3% to 61% on dry leftover coffee berries (EARO, 2000). This indicates that the pest is also predominant in coffee growing plantations of organic coffee farmers. None of the organizations or farmers applied any measures towards the control of coffee berry borer despite the fact that there were reports on CBB infestation in the region for almost the last 50 years.

Surveying and mass trapping of this beetle is considered to be a good practice strategy to suppress the population and reduce its impact. The mean (± SD) of the releasing rate of the three E:M mixture (1:1,1: 2 and 1:3) that was used at the three localities were potentially effective in attracting the CBB into the traps. The mean (± SD) of E:M mixture 1:1, 1:2 and 1:3 releasing rate (mg day^{-1}) were 509.9 ± 0.06, 577.3 ± 0.02 and 580.3 ± 0.02, respectively. Da Silva *et al*. (2006) used (1:1) lured with E:M at releasing range of 342, 400, 428 and 710 mg day^{-1} and caught similar numbers of insects irrespective of the releasing rate. Mathieu *et al*. (1997) applied the three doses tested (0.5, 1.5, and 20 g/day) lured with 1:2 and 1:3 E:M and the traps with lowest emissions (500 mg/day) showed the best capture. From this result, it is possible to suggest that the attraction potential of these E:M mixture releasing rate in mg day^{-1} did not affect capture of the female CBB in the three localities and also it is clearly observed the live female CBB was successfully captured for the first time using locally prepared baiting traps in Ethiopia. The current results also showed that using different E:M mixture did not affect the mean number of captured CBB at different localities. Mendoza-Mora (1991) observed the effectiveness of the E:M mixture in attracting CBB using the trapping study. De Silva *et al*. (2006) used Ethanol (E), Methanol (M) with a 2 mm hole in the vial dispenser to capture CBB lured with E:M mixtures (1:1, 1:2 and 1:3) and they caught similar and higher number of insects than the control. Similarly, Mathieu *et al*. (1997) demonstrated that both ratios 1:1 and 1:3 (as well as a 1:2 ratio) perform equally well in CBB field captures.

The attraction and the capturing efficiency of each baiting E: M concentration (1:1, 1:2 and 1:3) did not show significant difference from each locality. Similar results were obtained by da Silva *et al*. (2006) where traps lured with E:M mixtures (1:1, 1:2 and 1:3) caught similar and higher number of insects than the control. Also, Messing (2012) using baiting traps containing a 1:3 ratio of ethanol: methanol mixture reported that the captured female CBB were not significantly different from those caught in traps containing a 1:1 ratio of the mixture. However, the capture of CBB using baiting methods of E:M by different researchers was controversial and not consistent. In Brazil, da Silva *et al*. (2006) found nominally higher and similar CBB captures in traps using a 1:1, 1:2 and 1:3 ratio of E:M while in El Salvador, studies showed marginally higher catches with the 1:1 ratio. Agramont *et al*. (2010) used traps with a 1:3 ratio which significantly outperformed traps with a 1:1 ratio in Bolivia. Commercial CBB lures sold in the United States use a 1:3 ethanol: methanol ratio (AgBio, Westminster, CO, USA) (Messing, 2012). Mendoza-Mora (1991) and Mathieu *et al*. (1997) have also shown a decreasing capture of CBB with the increase of release rate of 1:3 E:M mixtures, while others presented an opposite effect

(Borbón *et al*., 2000).

With colour of the traps the same discrepancies were observed. Red traps captured more CBB than white traps under semi natural conditions (Mathieu *et al*., 1997) but the opposite occurred in another field study (Borbón *et al*., 2000). Despite their long and widespread use of baiting E:M lure traps, there are considerable discrepancies between different researches about optimal capture of CBB. It is probable that the conditions under which coffee is grown (climate, spacing, shade, cultivar, plant age, wind direction, speed, etc,) may affect trapping efficiency (da Silva *et al*., 2006). This can induce some discrepancy in results involving capture of CBB in response to semiochemicals, which may interact with other factors.

The times of data collection from the three localities were not the peak seasons to capture large number of CBB. Capturing of the CBB at Tepi-Baya II and Limu-Goma II took place three months after harvesting time and time of capturing did not coincide with the time of trapping large number of CBB and Mizan-Aman had an unexpectedly intense rain which hindered capture of the beetle. The mean (± SD) of CBB trapped from each locality (Tepi-Baya II, Limu-Goma II and Mizan-Aman) using locally prepared baiting trap should not be considered as low number. The mean number of female CBB captured using E:M 1:1, 1:2 and 1:3 mixtures from Tepi-Baya II were 10.68, 10.33 and 10.40, respectively, after three months of harvesting time. Higher number of CBB capture could be at the season when the long dry condition was followed by rain (especially immediately after the rains) and when the relative humidity and temperature had increased (Pereira *et al*., 2012). Mathieu *et al*. (1997) also noted that the highest seasonal trap captures were at the time when coffee fruit on the trees declines rapidly. During the off-season (i.e. following the harvest and before the next year's crop is sufficiently developed for infestation) low but persistent numbers of CBB were captured (some tens per trap per day) which indicate that the reservoir of adult beetles surviving in coffee berries dropped to the ground, or dried berries remained on the trees, and in nearby off-farm sources.

Even though the mean (± SD) of the captured CBB per trap/day was small from each locality, the total number of capture per trap within five days was considerably higher. Taking the reproduction potential of each trapped female to lay an average of 50 eggs, the number of CBB females would approximately be 66,450, 16,000 and 19,400 from Tepi-Baya II, Jima zone Limu Goma II and Mizan-Ama, respectively, also assuming the sex ratio of

CBB to be 10 females to one male, and eight generations per year (Baker *et al*., 1994). However, this number would be lower considering the natural mortality factors in the environment (Baker *et al*., 1994). This is supported by the results that the highest mean percent of infestation at Tepi was 60% and most of the damaged berries obtained showed high degree of damage by CBB (>50% damage) Esayas Mendesil *et al.* (2004).

Based on placement distance (12 m in a row and 15 m in the block) and CRBD arrangement 4 in rows and 4 traps in blocks, it was possible to estimates the area coverage. From each study plot and localities, a total of 1620 m^2 and 3240 m^2 (0.324 hectare) areas were covered, respectively. From this, it is possible to predict that the total number of CBB captured from each locality of Tepi-Baya II, Limu-Goma II and Mizan-Aman were 1,329, 320 and 388 per 0.324 hectare of coffee plantation. This implies that very large number of CBB/trap/day will be captured if more baiting traps were used per hectare. The experience from Columbia showed as many as 3 million beetles per acre (0.4047 hectare) were caught in coffee berries that were not removed before pruning (Dufour *et al*., 1999). The altitudinal coverage of the study ranged from 1,206–1,409 m.a.s.l., which was within the range of altitudes coverage of Esayas Mendesil *et al*. (2004) which ranged from 1,200–1,770 m.a.s.l.

All *Hypothenemus hampei* as well as other non-targeted insects, NCBB, found in the traps were collected and counted at each day of data collection. The discrimination process was not difficult for this study as compared with the total numbers of capture but it seems to be a lengthy, tedious, and difficult task when very large number of individuals are caught. The sum total of NCBB *Hypothenemus* beetles trapped at different E:M concentration from different localities were relatively lower as compared with the CBB trapped.

The relative attraction of E:M lure to NCBB was higher in 1:1 at Tepi-Baya II 31 (6.77%), followed by Mizan-Aman 21 (15.3%) and 12 (11%) at Jimma zone Limu-Goma II, coffee plantation area. The trapped number of NCBB lured with 1:3 was lower at Jima zone Limu-Goma II and Mizan-Aman and even lower using 1:2 E:M from the three localities. Messing (2012) captured roughly equivalent numbers of non-target insects with 1:3 and 1:1 ratios of ethanol:methanol, predominantly invasive tropical nut borers, (*Hypothenemus obscurus* and black twig borers (*Xylosandrus compactus*).

Some of the coffee plants in the study area were under the shade and some were surrounded by some native rainforest such as Tepi-Baya II and Mizan-

Aman. Some beetles might have migrated from the trees, shrubs, and Eucalyptus comprising the forest, to the coffee plantation areas. The relative higher number capture of NCBB at Tepi-Baya II and Mizan-Aman with baiting methods could be due to the reservoirs of tree that shade the coffee or from the surrounding trees or shrubs that could harbour the beetles. Pereira *et al*. (2012) also reported in their study that some scolytids migrated from the trees, pines, and Eucalyptus comprising the forest, to the coffee areas and some non-target beetles were also recovered in low numbers from these reservoirs.

CONCLUSION

From this study, it is possible to conclude that there is limited knowledge and awareness by farmers and some agricultural development workers about the distribution and the damage that is imposed by CBB on the coffee industry. The female CBB was successfully captured using this trap from the different coffee producing areas in different environmental conditions and seasons. This implies that this trap can be used in different localities for trapping of the female CBB as a tool to reduce the level populations of the pest. The mean (±SD) of the CBB captured from these different localities could be an alarm to check the economic injury level (EIL), the economic threshold or action threshold at different coffee producing localities for designing management aspects. Based on this study, it is possible to recommend that this method could also be used with other cultural and biological control methods to reduce its impact on production loss and quality of the coffee related to some fungi that produce fungal toxins such as Ochratoxin A associated with the beetle. Government, institutions, organizations, policy makers and others that are concerned about coffee production should give attention for this vital industry and the control of this insect pest.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Addis Ababa University for providing necessary facilities and funding to accomplish this study and also Mizan-Tepi University for providing study leave for YC. The authors also acknowledge Tepi Green Coffee Plantation PLC, Limmu coffee plantation, Ato Daniel Mulatu and Ato Mulatu Meno (Mizan-Aman), who allowed us to use their coffee farms to conduct the assessment and provided technical support.

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