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Research Article

Evaluation of Coffee Cultivars to Coffee Berry Borer (*Hypothenemus hampei* (Ferrari)) Infestation in Southwestern Ethiopia

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Abstract

Background and Objectives: Coffee berry borer is one of the insect pests that causes damage on the coffee berry in Ethiopia. However, little information is available about the response of released coffee berry disease resistant cultivars to the target pest. Thus, this study was initiated to determine the current status of coffee berry borer infestation across coffee producing areas in southwestern part of Ethiopia and variation in susceptibility of coffee berry disease resistant cultivars to target insect pest. **Materials and Methods:** Coffee berry borer assessment were conducted for 2 years (2012/13 and 2013/14) across 37 sites in the major coffee growing areas of the country. Two hundred dried coffee berries were collected from randomly selected 30 coffee trees from each site and examined for their damage. The collected data were subjected to Analysis of variance using General Linear Model of SAS software. **Results:** Coffee berry borer was observed in all surveyed areas. The analysis of variance for the mean incidence of coffee berry borer showed a significant difference ($p<0.05$) among study areas. The highest incidence was recorded from Bebeka site; characterized by low land coffee producing agro-ecosystems. Similarly, significant difference was observed among coffee cultivars for coffee berry borer infestation at different sites in both years. At Bebeka, the highest incidence (85.76%) was recorded from cultivar 744 while the lowest (61.25%) was recorded from local varieties. **Conclusion:** The present research results suggest that there is high chance to exploit host plant resistance for the management of coffee berry borer in Ethiopia. Furthermore, economic and quality loss assessment should be conducted in the future in order to investigate the importance of this insect on coffee industry.

Key words: Arabica coffee, location, host plant resistance, incidence

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Coffee (*Coffea arabica* L.) is the major foreign exchange earning crop in Ethiopia economy. It is the main source of income for an estimated number of 15 million people, who are directly or indirectly involved in coffee production, including over four million primarily smallholder farming household[1]. Despite the significant role coffee plays in the economy of the country, the crop suffers from many biotic and abiotic production constrains that resulted in a low average national yield (0.72 t ha^{-1})[1-2]. Insect pests are among the biotic factors limiting the production of coffee both in quality and quantity[3-6]. Forty-seven insect pests of coffee were reported so far in Ethiopia and coffee berry borer ranked 3rd with regard to the pest that causes damage inflicts[6].

In Ethiopia, coffee berry borer (*Hypothenemus hampei*) was first reported by Davidson[7] who observed damaged berries and live beetles on both drying trays and coffee beans near Mizan Teferi and on processed coffee in Jimma and Shashamane areas. First, Abebe[4] reported this pest, known to be a low altitude pest. Latter it was indicated that, the borer is found at all altitudes from below 1000 to over 1900 masl in the major coffee growing areas in the southwestern Ethiopia with a relatively higher infestation at low altitudes[8]. Mendesil *et al.*[9] also reported that *H. hampei* covered a wide range of altitudes infesting large-scale coffee plantations, coffee in the research plots and garden coffee with considerable variations in the level of damage. The yield loss assessment conducted at various coffee growing areas of southwestern part of the country showed the borer inflicted from 60-73% yield loss[8-9]. In contrast to reports from other counties where *H. hampei* heavily attacks green, ripen and dry berries[10], the pest rarely attacks green berries in Ethiopia[9].

So far no meaningful attempts have been made towards developing *H. hampei* resistant varieties in Ethiopia. However, the outbreak of coffee berry disease (CBD) in 1971 and its subsequent rapid spread to all major coffee producing areas prompted the whole coffee research program to largely divert towards the development of CBD resistant cultivars. As a result, about 40 Arabica coffee cultivars, both selections and hybrids, have been released and most of them are under production throughout[11-12] the country since 1980. The response of those released CBD resistant cultivars to coffee berry borer has not been documented. So, it is imperative to assess whether CBD resistant cultivars are susceptible to this devastating pest or not, so that appropriate integrated CBB management practices could be developed via host plant resistance. Therefore, the study was initiated with 2 objectives: (i) To determine the current status of the *H. hampei* infestation across the major coffee producing districts in southwestern Ethiopia and (ii) To assess infestation levels of *H. hampei* among CBD resistant coffee cultivars in southwestern of Ethiopia.

MATERIALS AND METHODS

Description of the study site: The study was conducted in 2 major coffee producing regions of Ethiopia (Oromia and Southern Nation, Nationality Peoples Regional (SNNPR) States)[1] (Fig. 1). The study was conducted in four zones of the two regions (three zones from SNNPs: Kaffa, Benchi Maji and Sheka and one zone from Oromia: Illubabor) in the month of January, 2013 and 2014 production years. From each zone, one district was selected (Gimbo from Kaffa, Gurafereda from Benchi Maji, Tepi from Sheka and Metu Zuria from Illubabor) to make the assessment of the pest (Table 1). The selected study districts represents the different agro-ecologies of coffee production areas in southwestern Ethiopia, with elevations ranging from 995-1904 masl (Table 1). From each district, pest data were collected from different sites (farms), resulting in 37 sites in total (four, thirteen, twelve and eight sites from Gimbo, Gurafereda, Tepi and Metu Zuria districts, respectively (Table 1). Co-ordinates of each farms (sites) were recorded using Geographic Positioning System (GPS).

Experimental materials: In January 2013, a total of 19 coffee berry disease resistant cultivars (744, 741, 74112, 7454, 74140, 7440, 74165, 74110, Catimor, 75227, Gesha, F59, Ababuna, J19, Angafa, J21, 74158, 74154 and Dessu) and one local landrace were used for the assessment of coffee berry borer incidence

Table 1: Number of study sites/farms and coffee varieties at each district over the 2 years of observation

Regions	Zones	Districts	Number of sites within district	Altitude (masl) range	Number of coffee cultivar used for study 2012/2013	2013/2014
SNNPR	Kaffa	Gimbo	4	1721-1904	1*	1*
SNNPR	Benchi Maji	Gurafereda	13	996-1045	14	5
SNNPR	Sheka	Tepi	12	1136-1197	10	NA
Oromia	Illubabor	Metu Zuria	8	1558-1576	7	5

*Local landrace, NA: Not available, data was not collected

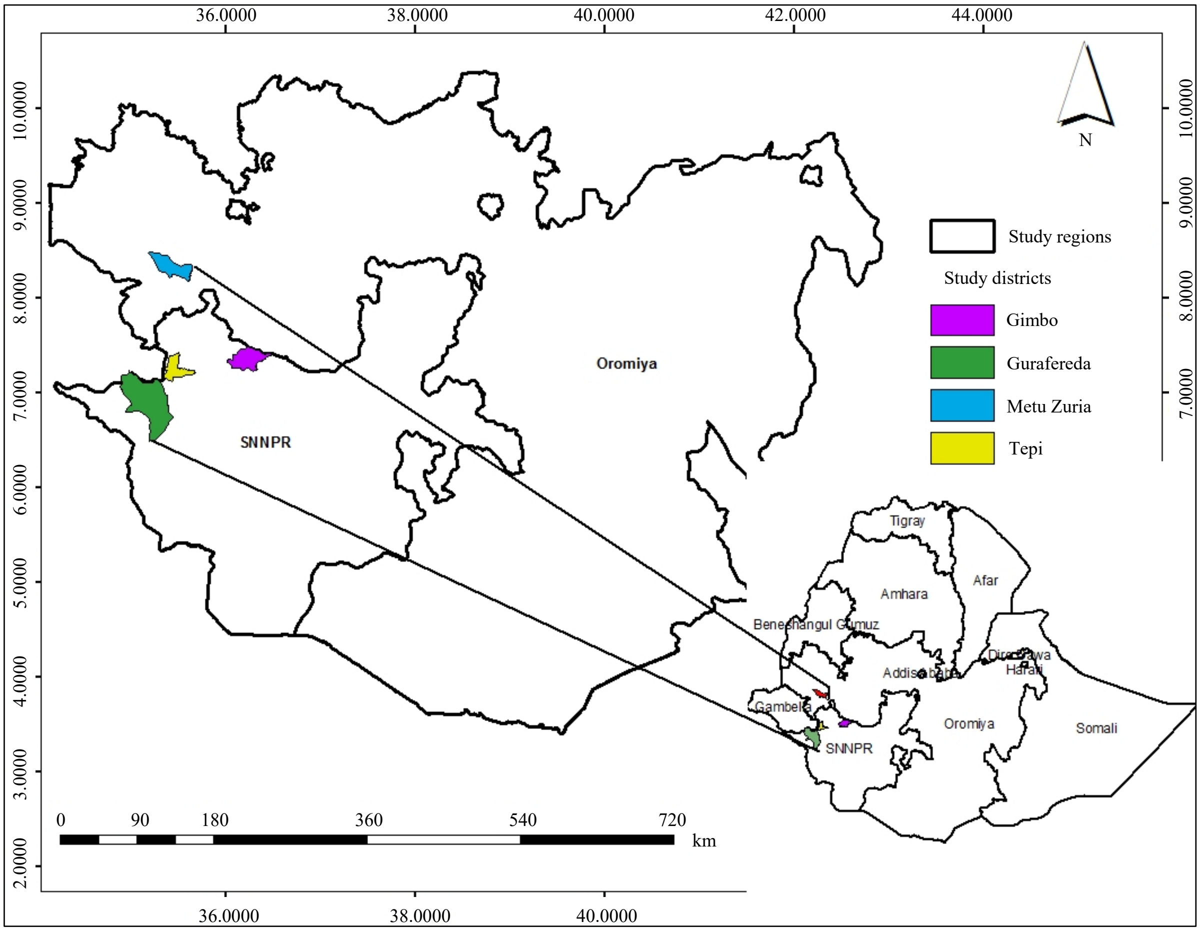

Fig. 1: Study regions and districts [SNNPR-Southern Nation, Nationality Peoples Region]
Source: Map constructed based on GPS points data collected during study period

across the study districts (Table 1). The number in Table 1 indicates the total coffee cultivars used (i.e., some of the cultivars assessed were the same at different districts) at each district. In January 2014, on the other hand, only 8 coffee berry disease resistant cultivars (744, 741, 7454, Catimor, 74112, 74140, 74165, 74158) (among 19 cultivars assessed in 2013) and one local landrace were used for the assessment of coffee berry borer damage. The assessment was superimposed on an existing coffee plantation at each site. Less number of coffee berry disease resistant cultivars was assessed in January 2014 as compared to 2013 due to very low berry production of some cultivars in 2014 as result of biennial bearing nature of cultivars (producing high yield in one year and followed by low yield in the following year). In both production years, data collections were made after the main coffee harvesting periods takes in the study area (October-December).

Sampling procedures: From each study site/farm 30 coffee trees were randomly selected to assess the damage level of coffee berry borer at each site. These 30 coffee trees were used as replication for each cultivar considered for the study site. Two hundred dried coffee berries were collected from the ten randomly selected coffee trees per site following Remond and Cilas[13] and Baker[10] methods to assess the damage level across the sites. Each coffee sample was labeled with a paper bag and brought to Jimma University, College of Agriculture and Veterinary Medicine, entomology laboratory for the assessment.

Data collections

Number of entrance holes/berry: All the collected berries were examined for the presence or absence of entrance hole at entomology laboratory of Jimma University College of Agriculture and Veterinary Medicine. Damaged berries with an entrance hole(s) were separately dissected with a surgical blade to confirm damaged by borer. Finally the percentage of the entrance hole/berry was calculated based on number of holes/berry and the result was presented as percentage frequency for holes.

Percentage of berry damage: Percentage of berry damage with *H. hampei* was computed as follow:

$$\text{DB (\%)} = \frac{\text{TB} - \text{HB}}{\text{TB}} \times 100$$

Where:

DB (%) = Damaged berries (%)
TB = Total berries assessed
HB = Total healthy berries

Percentage of berry damage was calculated for each district and coffee cultivars to compare damage level. All data collected across the sites of each district and cultivars were summarized as mean data and used for the subsequent analysis.

Statistical analysis: The percentage frequency of entrance hole/berry was calculated to determine the number of hole the damaged berry contains. Percentage damaged coffee berries data were tested for assumption of analysis of variance (ANOVA) using SAS software of Proc Univariate before running ANOVA analysis. The analysis indicated percentage damaged berry data violet the assumption of ANOVA. As a result square root transformation was employed to normalize the data and the transformed percentage damaged berry data were used for ANOVA analysis using General Linear Model (GLM) of the SAS 9.2. software[14]. However, the original mean data was used for the interpretation of the result.

One-way analysis of variance ($p<0.05$) was performed to determine the influence of districts (Gurafereda, Tepi and Metu Zuria) and coffee cultivars on the percentage berry damage of coffee berry borer. At Gimbo since the cultivar considered was only local landrace, comparison between varieties was not done. Tukey's Honestly significant difference (HSD) test at 5% probability level was used to identify the district with high *H. hampei* damage as well as the cultivars that were damaged more by *H. hampei* infestation within each district. The ANOVA analysis was done for each season separately as the variation in error variance between the 2 years was very high. Furthermore, a simple regression model was developed to determine the cause and effect relationship between district (i.e., altitude) and coffee berry borer damage.

RESULTS

Number of entrance hole/berry: The 2 years assessment result indicated that most of the damaged berries contain 1-2 entrance holes per berry while a few of them had 3 and 4 entrance holes per damaged berry (Fig. 2). Very rarely, 5 entrance holes/berry were observed. In 2013 assessment year, 34.08, 44.76, 17.68, 3.06, 0.4 and 0.02% of the sampled berries had 0, 1, 2, 3, 4 and 5 numbers of holes/berry, respectively. In 2014 assessment year, the percent frequency for 0, 1, 2, 3, 4 and 5 holes/berry assessed were 14.24, 41.51, 33.05, 10.20, 0.93 and 0.06%, respectively.

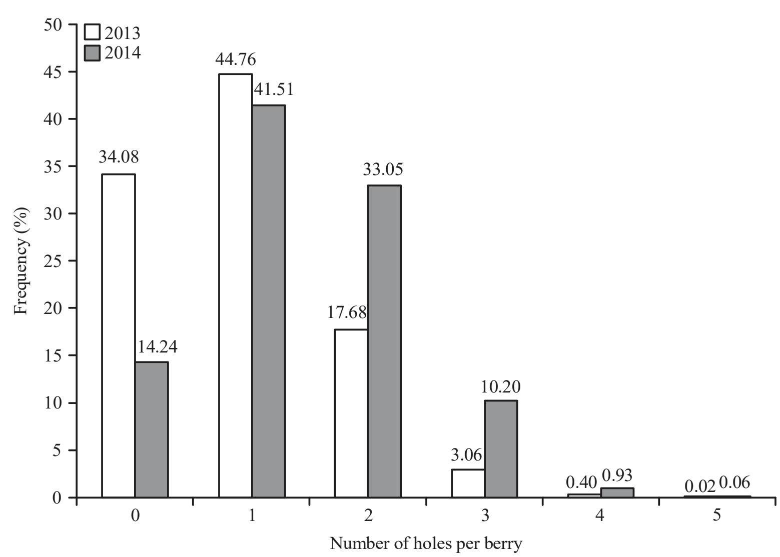

Fig. 2: Number of entrance holes/berry in 2013 and 2014 in southwest Ethiopia

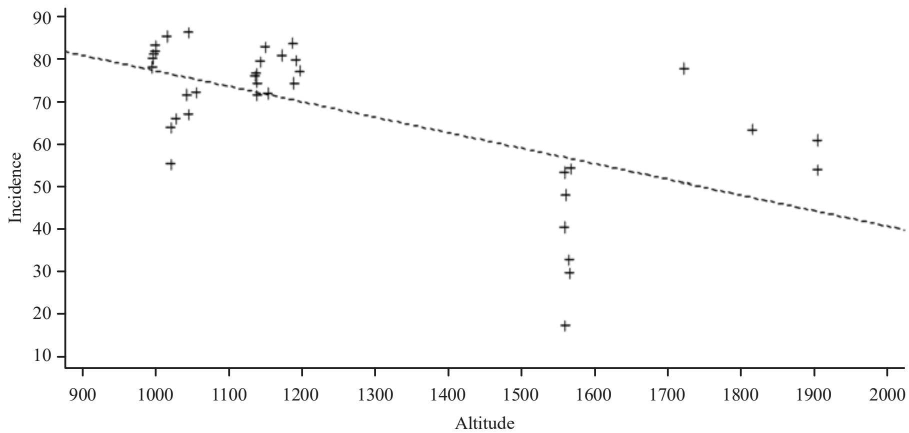

Fig. 3: Regression between altitude of the study site and *H. hampei* damage across study sites
Berry damage (%): 114.1-0.0366 altitude, R^2: 38.9%

Table 2: Mean percentage of berry damage by *H. hampei* across 4 districts of southwest Ethiopia in 2013 and 2014

	Assessment year	
Districts	2013	2014
Gurafereda	77.82[a]	93.55[a]
Gimbo	65.34[b]	75.55[b]
Metu Zuria	39.72[c]	74.79[b]
Tepi	73.07[a]	87.98[a]
p-value	0.0001	0.0015

Means followed by the same letter(s) within a column are not statistically significant at 5% LSD, Tukey's honestly significant difference (HSD) test

Coffee berry borer damage across districts: The result indicated that the mean percentage of berry damage by *H. hampei* was significantly ($p<0.05$) affected by the districts (Table 2). The mean percentage of berry damage ranged between 39.72-77.82 for 2013 assessment year, while 75.55-93.55% during 2014. In both study years, the highest mean percentage berry damage was recorded at Gurafereda and Tepi districts while the least percentage damage was observed in the Metu Zuria district. The simple regression analysis also indicated that the percentage berry damage by *H. hampei* was negatively regressed with the altitudes of the study districts. As the altitude of the study district increased the percentage berry damage by the *H. hampei* was decreased (Fig. 3).

Percentage of berry damage among coffee cultivars

Percentage of berry damage at Gurafereda: The analysis of variance result indicated that there was a significant difference ($p<0.05$) among the cultivars assessed to percentage berry damage due to coffee berry borer at both assessment years. The highest percentage of berry damage was recorded from cultivar 744 (85.76%), although it was statistically similar to some cultivars and the lowest was recorded from local landrace (61.25%) (Fig. 4). Similarly, during 2014, from the 4 CBD resistant cultivars and one local landrace assessed the highest percentage of berry damage was recorded from cultivar 744 (Fig. 4).

Percentage of berry damage at Tepi: The analysis of variance result indicated that there was a significant ($p<0.05$) difference among coffee cultivars in mean percentage of berry damage due to coffee berry borer at Tepi district in 2013 assessment year. The highest mean percentage of berry damage was recorded from cultivars 74140, F-59 and local landrace (Fig. 5). The lowest berry damage was recorded from 7440 and J21 cultivars. The result of 2014 is not included here due to very few berry productions for this cropping season in this area; no data was taken in 2014 assessment year at Tepi district.

Percentage of berry damage at Metu Zuria: The analysis of variance result also indicated that there was a significant difference ($p<0.05$) among coffee cultivars assessed in mean percentage berry damage both in 2013 and 2014 assessment years (Fig. 6). During 2013 assessment year, the highest mean percentage berry damage was recorded from local landrace, 74158 and 74165 while the lowest was recorded from 74112 cultivar (17.59%) (Fig. 6). Similarly, the highest mean percentage berry damage was recorded from local landrace, 74158 and 74140 while the least damage was recorded from cultivar 74112 in 2014.

DISCUSSION

The mean percentage berry damage caused by *H. hampei* across the study districts was very high. Most of the damaged berries had one or two entrance hole except few

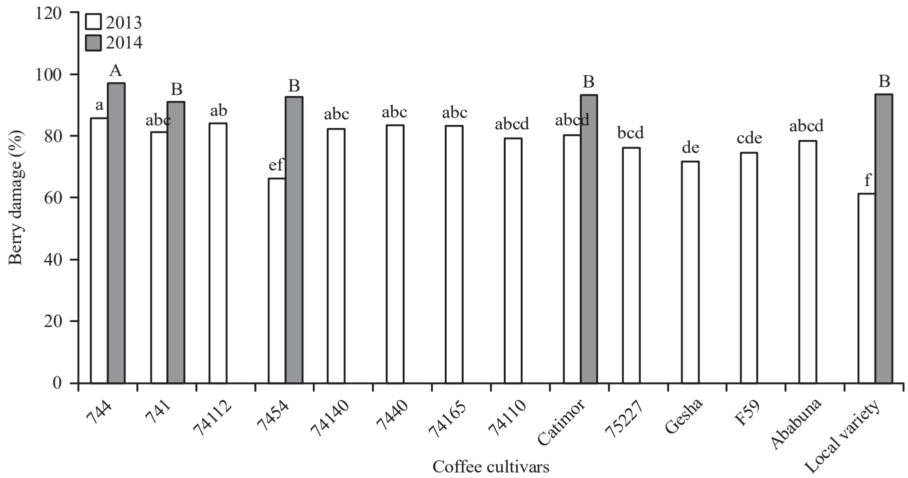

Fig. 4: Mean percentage of berry damage among CBD resistant cultivars and local landrace at Gurafereda district in 2013 and 2014

Means followed by the same letter(s) within a 2013 assessment year (lower case) and within a 2014 assessment year (upper case) are not statistically significant at 5%, Tukey's Honestly significant different (HSD) test

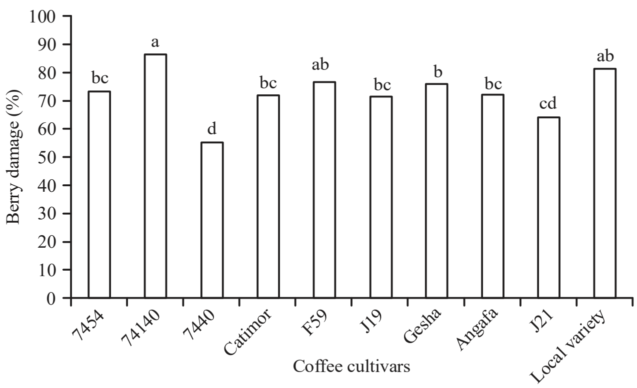

Fig. 5: Mean percentage of berry damage among CBD resistant cultivars and one local variety at Tepi district in 2013

Means followed by the same letter(s) are not statistically significant at 5%, Tukey's Honestly significant different (HSD) test

berries which had 3 and 4 entrance hole per damaged berry. There were variations in the level of berry damage caused by *H. hampei* among assessed CBD resistant cultivars. The variation in mean berry damage observed among the study districts could be associated with the difference in environmental condition, particularly temperature as Gurafereda and Tepi are located in low altitude areas as compared to Gimbo and Metu Zuria, which are located in the mid altitude area. This result can be used as a clue for the seriousness of the pest in the future due to climate change. In Jimma area, Platts *et al.*[15] reported that the mean annual temperature was projected to increase by 3°C using Representative Concentration Pathways (RCP8.5).

Significant differences in mean percentage berry damage were also observed among data collected from different districts of Ethiopia. High mean *H. hampei* percent infestation from 60-73% has been reported at Tepi, southwestern Ethiopia[8-9]. Similarly, high *H. hampei* infestation was recorded from large scale coffee plantation farms close to Tepi areas such as Yeki and Godere. On the other hand, less than 10% mean infestation of *H. hampei* was reported from afromontane rainforest of the coffee ecosystems located in the southwestern part of Ethiopia[16]. Likewise, different and very high *H. hampei* infestation was reported from different countries. In Kenya (80%)[17], up to 80% of the berries being attacked in Uganda, Ivory Coast and Brazil, 90% in Malaysia, 96% in Congo and Tanzania[18] and in New Caledonia up to 87% berry infestation was reported[19].

The occurrence of more than one hole within a single berry can be an indication of the level of infestation or severity of the damage. The high infestation of *H. hampei* in 2014 can be explained by the high number of holes/berry observed as compared to the 2013 assessment year. Different literature also indicated that, during the period of intense infestation more than one female bore and enters into a single berry, each female with its own entrance[20]. Similarly, study conducted in Southwestern part of Ethiopia showed *H. hampei* causes mean perforation per damaged berries[9] of 2.6.

The currently recommended coffee berry disease resistant cultivars in Ethiopian can be also used as a starting materials for the development of host plant resistance to coffee berry

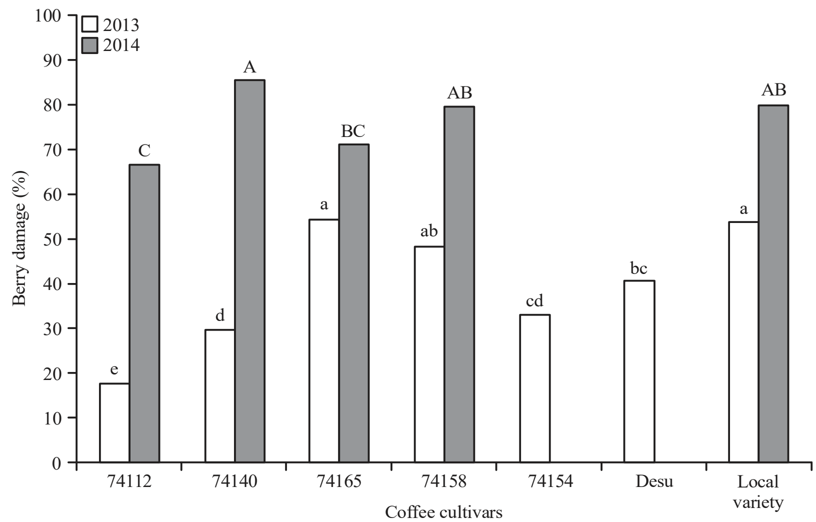

Fig. 6: Mean percentage of berry damage among CBD resistant cultivars and local variety at Metu Zuria district in 2013 and 2014
Means followed by the same letter(s) within a 2013 assessment year (lower case) and within 2014 assessment year (upper case) are not statistically significant at 5%, Tukey's Honestly significant different (HSD) test

borer threat in coffee industry. Further evaluation including other materials should be continued as the incidence of the pest is predicted to increase in Ethiopia due to climate change[21]. The report indicated that climate change brings increased temperature which also increases the pressure of coffee pest like coffee berry borer in east Africa. This pest is projected to increase, reducing yield and quality of coffee. Similar result was observed in an experiment conducted in Brazil for the evaluation of coffee genotypes resistance under controlled experiment. And, *Coffea kapakata*, *Psilanthus bengalensis*, *C. eugenioides* and genotypes with *C. eugenioides* genes were resistant by presenting low frequency of bored grains[22]. However, this study report focused only on percentage berry damage and no economic loss assessment have been made. Therefore, further study should be carried out to investigate the importance and economic loss of *H. hampei* on the coffee yield and quality in the country. Furthermore, the impact of climate change, particularly temperature on *H. hampei* has to be addressed in relation to coffee production in Ethiopia as most models predicted temperature will increase in the future.

CONCLUSION

The mean percentage berry damage caused by *H. hampei* across the study districts was very high. Most of the damaged berries had one or two entrance hole except few berries which had three and four entrance hole per damaged berry. Generally, the incidence of *H. hampei* decreases as altitude increase along the study districts. There were variations in the level of berry damage caused by *H. hampei* among assessed CBD resistant cultivars suggesting the possibility of developing host plant resistance as one control option of integrated pest management of CBB.

SIGNIFICANCE STATEMENT

This study will help the researchers to uncover the variations in the level of infestation among assessed coffee berry diseases (CBD) resistant cultivars, which can be used as starting materials for the development of host plant resistance/tolerant to the *H. hampei* threat in Ethiopia.

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