Status of Antestia Bugs (*Antestiopsis intricata*: Pentatomidae, Hemimptera) in southwestern Ethiopia

Belay Abate[1], Mulatu Wakgari[2] and Waktole Sori[3]
[1]*Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center*
P.O .Box 192, Jimma, Ethiopia
[2]*Plant Science, College of Agriculture and Environmental Science, Haramaya University, Haramaya, Ethiopia*
[3]*Ethiopian Horticulture Producer Exporters Association, Addis Ababa, Ethiopia*

Abstract

Coffee is a major cash crop for Ethiopia, but coffee productivity in Ethiopia is low compared to many coffee-producing countries and damage by pests and diseases are among the main constraints, which reduce coffee yield. Antestia bug is one of the major coffee pests affecting coffee productions in Ethiopia. The current study assessed the status of antestia bugs in 12 districts of the Oromia and Southern Nations, Nationalities and People's Regions (SNNPR) in the southwestern Ethiopia in 2017/2018 cropping year. The sample sizes were thirty coffee trees per farmer, five farmers per Farmers' Association and three Farmers Associations in each district. The antestia bugs were counted in each tree and hundred ripe berries were sampled from each tree and sorted to beans with darkening and clean beans. Three stage nested designs and correlation analyses were used for data analyses. Infestations were higher at districts of Ale (0.87 bugs/tree), Shabe Sombo (0.82 bugs/tree) and Mettu (0.41 bugs/tree), low at Sheko (0.03 bugs/tree), while no record was made at Gurra Farda, Debub Bench. Similarly, the highest percent number of bean damage was recorded at Ale district (1.20%), followed by Shabe Sombo (0.86%) and Mettu (0.62%). The study showed that antestia bugs infestation and coffee bean damage increased with altitude ($y = 0.005x - 0.428$, $r = 0.358$), level of coffee shade. Forest and plantation coffee production systems had the lowest antestia bug infestations and bean damages, while garden and semi-forest coffee had the highest. Local coffee varieties had higher antestia bug infestation and bean damage than the improved varieties, which are usually grown under better agronomic practices, including shade and canopy management and protection of pests with pesticides. The population of antestia (0 - 0.87 per tree) in most of the study area was below the economic threshold level of one to two bugs per tree. Studies are suggested on the seasonal abundance, effect of microclimate, natural enemies and management practices on the population dynamics of the pest, and the economics of antestia bugs in the major coffee growing areas of the country.

Keywords: Altitude, antestia bugs, *Antestiopsis intricata*, *Coffea arabica*, coffee bean damage, infestations.

Introduction

Coffee (*Coffea arabica*) is one of the five most important commodities in the world market (Ibrahim and Zailani 2010). Waller et al. (2007) indicated that it is a primary export of many developing countries, and as many as 25 million farmers depend on coffee for their livelihood and it provides significant foreign exchange earnings. In Ethiopia, coffee contributes 25 to 30% of the country's foreign exchange earnings, which is 6% of the gross domestic product (GDP), 12% of the agricultural sector output and 20% of the government revenues (Berhanu 2012; FDREMoT 2012).

In Ethiopia, coffee yields remain low at around 0.7 - 0.8 metric tons per hectare, while in Brazil, which is the largest producer of Arabica coffee, productivity is nearly double with 1.5 metric tons per hectare (Abu 2016). The low coffee yield could be attributed to a number of biotic and abiotic factors, including the damage by insect pests and plant diseases. Insect pests cause up to 20% of a crop loss and reduce the coffee value by 30 to 40% (Pablo et al. 2012). Besides, the International marketing policies do not allow coffee for exportations that have more than 1.5% damage caused by insects (Duque and Baker, 2003).

In Ethiopia, over 49 species of insect pests have been recorded on coffee (Chemeda et al. 2015), among which the antestia bugs (*Antestiopsis intricata* and *A. facetoides*) are the major ones inflicting considerable damage (Million 1987). Antestia bug causes 9% yield loss and 48% coffee bean darkening (Million 1988). Antestia bug is the most common bug found in all coffee growing areas of Ethiopia (Esayas et al.2009). Both the adults and nymphs of antestia bug feed mostly on immature, green berries by sucking the sap that causes the fruits to shrink (Kimani et al. 2002). Antestia also feeds on shoots and leaves of coffee plants but prefer to attack unripe coffee berries (Matsuura et al. 2014). The feeding by both nymphs and adults force the young berries to drop and bigger berries to be soft or rot (Birhanu 2012). Although antestia is common pest of coffee in Ethiopia there is no sufficient and current information on the status of antestia bug in southwestern Ethiopia. Therefore, the study was initiated to assess the infestation and damages due to antestia bugs on coffee in the southwestern Ethiopia.

Materials and Methods

Assessment of the Antestia Bug

The study was conducted in Jimma and Ilu Ababora Zones of Oromia Region and Bench Maji and Sheka Zones of Southern Nations, Nationalities and People's Region (SNNPR) of Ethiopia in 2017/2018 cropping year. Three districts were selected in each zone and in three Farmers' Associations in each district (Figure 1 and Table 1). In each Farmer's Association, five farms were selected and antestia bugs were counted on 30 randomly taken trees. Data were collected in the morning from 6 to 10 a.m. and afternoon from 4 to 6 p.m. to widen the chance of catching of antestia bugs (Chemeda et al. 2011). The antestia bugs were collected by hand. The entire canopy of each sampled tree was carefully examined and both immature and adult antestia bugs were counted (Karungi et al. 2015). To assess the incidence of bean darkening, the symptoms of antestia attack

(Mugo 1994), 100 ripe cherries were randomly collected from coffee trees. Then, the sampled cherries were hand pulped and classified into damaged and undamaged categories to calculate the percent number of beans with darkening.

Five to seven years old coffee trees were considered in the sample. Also, the production systems, coffee variety grown (local and improved variety) and shade status of the fields were recorded. The production systems used in the study were classified into plantation, garden, semi forest and forest coffee production systems based on varying level of plants associated with coffee, nature of coffee tree regeneration and human intervention (Workafes and Kassu 2000). In addition, the coffee shade levels of the farms were categorized into low (70 - 99%), medium (40 - 69%) and high shade (< 39%) light penetration (Matovu et al. 2013).

Table 1: Agro-meteorological characteristics (means rainfall, relative humidity and temperatures) of the study areas in 2017/2018 cropping year

District	Altitude (m.a.s.l.)	Rainfall (mm)	Minimum temp (oC)	Maximum temp (oC)	Average temp (oC)	Relative humidity (%)
Ale	1737-1974	1740.00	24.48	14.10	19.29	74.62
Anderacha	1225-1816	1820.21	24.00	12.10	18.05	74.25
Debub Bench	985-1317	1617.72	27.69	1506	21.38	73.00
Gera	1910-1969	1628.99	24.76	10.37	17.56	75.10
Gomma	1586-1695	1591.25	28.59	11.28	19.93	67.00
GuraFarda	1083-1410	1568.88	28.28	15.2	21.74	70.28
Masha	1651-1776	2257.18	22.86	10.75	16.80	74.96
Mettu	1555-1760	1991.68	27.06	13.89	20.48	72.00
ShabeSombo	1550-1790	1416.38	26.21	14.21	20.21	74.00
Sheko	1076-1750	1535.40	31.40	13.80	17.60	71.03
Yayyo	1350-1527	1619.10	28.68	13.21	20.94	69.00
Yeki	1195-1209	1470.33	29.96	15.09	22.53	70.00

Source: Ethiopian Meteorological Agency (2018)

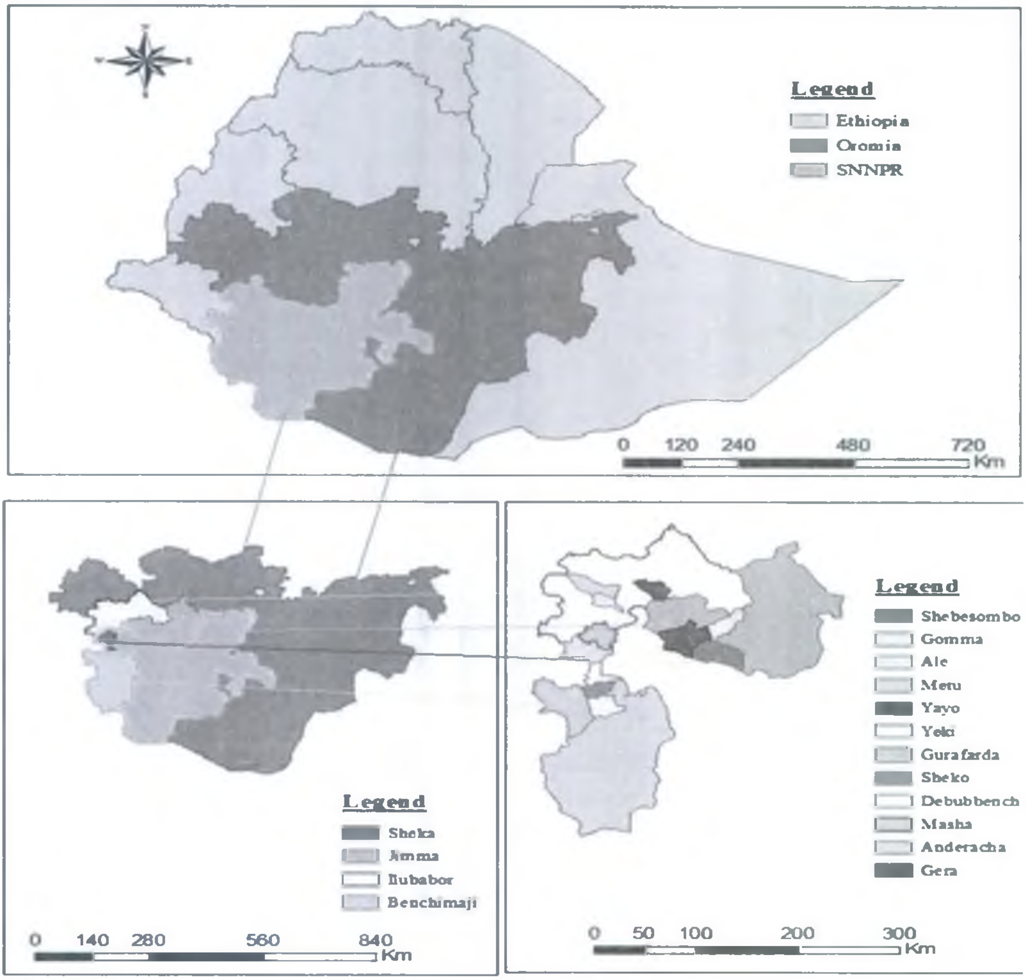

Figure 1: The study area map and assessed districts of southwestern Ethiopia.

Data analysis

The number of antestia bugs/tree and coffee beans damage were analyzed using three-stage nested design (Kumlachew et al. 2016). Data were subjected to analysis of variance (ANOVA) using SAS version 9.3 software package (SAS, 2012). Means were separated using Tukey's test. The relationship of infestations and bean damage by antestia bug with independent variables, *viz.* altitude, production systems, and coffee cultivars grown and level of shade were assessed using SPSS software program version 16.0. Determination of Pearson correlation was done using SPSS statistical software.

Results and Discussion

Infestation and coffee damage levels due to antestia bugs

The number of antestia bugs per tree were significantly ($p<0.05$) different among the assessed districts. The mean number of bugs per tree ranged from 0 - 0.87 per tree. The highest number of antestia bugs was recorded at Ale (0.87/tree), followed by Shabe Sombo (0.82/tree), Mettu (0.41/tree), Yayyo (0.37/tree) and Gomma (0.35/tree) districts. Antestia bugs were not recorded at Gurra Farda and Sheko districts (Table 2). Similarly, percent number of coffee beans damages with darkening due to antestia bugs were also significantly different among the surveyed districts ($p<0.05$). The mean damage levels ranged from 0.02 to 1.20%. The highest mean bean damage was recorded at Ale (1.20%), followed by Shabe Sombo (0.86%) and Mettu (0.62%) districts. The minimum or lowest bean damage was recorded at Sheko (0.02%), followed by Yeki (0.03) district (Table 2).

Table 2. Levels of antestia bugs infestations and damages on coffee in selected districts of southwestern Ethiopia

Region	Zone	District	Number of bugs/tree	Coffee bean damage (%)
Oromia	Ilu Ababora	Ale	0.87(1.15)[a]	1.20(1.28)[a]
		Mettu	0.41(0.95)[b]	0.62(1.05)[bc]
		Yayyo	0.37(0.93)[b]	0.46(0.97)[bcd]
	Jimma	Gera	0.09(0.76)[cd]	0.15(0.80)[ef]
		Gomma	0.35(0.92)[bc]	0.50(0.99)[bcd]
		Shabe Sombo	0.82(1.12)[a]	0.86(1.14)[ab]
SNNPR	Bench Maji	Debub Bench	0.07(0.75)[d]	0.21(0.84)[def]
		Gurra Farda	0(0.71)[d]	0.08(0.76)[f]
		Sheko	0(0.71)[d]	0.02(0.72)[f]
	Sheka	Anderacha	0.09(0.76)[cd]	0.26(0.87)[def]
		Masha	0.22(0.85)[bcd]	0.45(0.97)[cde]
		Yeki	0.03(0.73)[d]	0.03(0.80)[ef]
Tukey's (5%)			0.1496	0.1785
CV (%)			10.2	11.2

SNNPR = Southern Nations, Nationalities and People's Region (SNNPR). Values with the same letter(s) within the column are not significantly different according to Tukey's test ($p < 0.05$). Means in the parenthesis are square root transformed values.

The accessed four zones were significantly different in number of Antestia bugs and coffee bean damage ($p<0.05$). Ilu Ababora Zone had the highest number of antestia bugs (0.55/ tree) and bean damage (1.01%), followed by Jimma Zone with 0.4 bugs/tree and 0.49% coffee bean damage. Infestations and coffee bean damages were significantly lower at Sheko and Bench Maji zones.

The current study revealed that antestia bug is widely distributed across zones and districts of coffee production in southwestern Ethiopia. The study results agree with the findings of Tamiru et al. (2017) who reported antestia bug infestations that varied in Ilu Ababora and west Wollega Zones. Matsuura et al. (2014) indicated that antestia bugs are distributed and notorious pests of coffee plants in Africa. A study made by Mugo et al. (2011) in Kenya indicated that farmers consider antestia as the most common and widely distributed pest in all the coffee-growing agro-ecozones of Kenya. Antestia bugs are well distributed in all the coffee growing zones of Burundi and Rwanda and cause bean losses and affect the quality of coffee (Feed the Future, 2017).

Levels of infestations and damages to coffee beans varied across zones and districts of southwestern Ethiopia. However, antestia bug infestation in southwestern Ethiopia (0- 0.87 bugs/tree) was below the threshold levels [1-2 bugs/tree (CRF 1989)]. This is in line with the report of Tamiru *et al* (2017) who recorded 0.92, 0.85 and 0.76 bugs per tree in Mettu (Ilu Ababora), Hurumu (Ilu Ababora) and Ayira (Wollega), respectively. Bigirimana et al. (2012) did not record antestia bugs on coffee bushes in the eastern province and Kigali, but observed relatively low population in the northern, western and southern provinces of Rwanda. Earlier studies in Ethiopia indicated that antestia bug population densities were lower in Tepi than in Mettu (IAR, 1996, 1997). Wanjala (1979) reported 15-27% loss in total bean weight with infestation of 2 - 4 antestia bugs per tree. Another study indicated that the presence of 2-3 antestia bugs per tree in the field can cause about 45% crop loss (Global Knowledge Initiative, 2016). In Ethiopia, Mekasha (1993) reported that branches of coffee trees infested with four pairs of the bug caused the 1.2% coffee flower bud damage, 54.1% berry fall, 90.2% of bean damage, and low yield of 0.41 kg red cherries/tree.

Lower extent of infestations and damage by antestia bug in the southwestern Ethiopia might be due to presence of diverse natural enemies and genetic pools of Arabica coffee. Southwestern Ethiopia is believed to be the origin and diversity of Arabica coffee. Unlike to many countries of the world growing coffee, most of the insect pests of coffee are of minor importance in Ethiopia (Crowe and Tadesse 1984; Million and Bayissa 1986 and Million 2000). One of the possible reasons is the existence of diverse community of natural enemies, which keep the pest population at a low level mainly in the relatively undisturbed coffee ecosystems. Tsegaye et al. (2000) indicated that the genetic diversity of Arabica coffee coupled with cultural practices with minimum or no input used by subsistence farmers contributed to the low level of insect pests of coffee. But as Esayas et al. (2009) reported, adverse changes in agronomic/farm practices may affect the natural biological balance between pest and their natural enemies and minor pests could get a major status and pose a serious problem to coffee production.

The relationship between altitude, and number of antestia bugs and damage to berries

Altitude is positively related with number of antestia bugs per tree (y = 0.005x - 0.428, r=0.358) and coffee bean damage (y = 0.005x – 0.421, r=0.345) (Figure 3a and b; Table 3). Infestations and damage to beans were lower at lower altitude (<1350 m.a.s.l.) of Gurra Farda and Sheko districts, while the higher infestation and damage was recorded at an altitude > 1737 m.a.s.l. of Ale district.

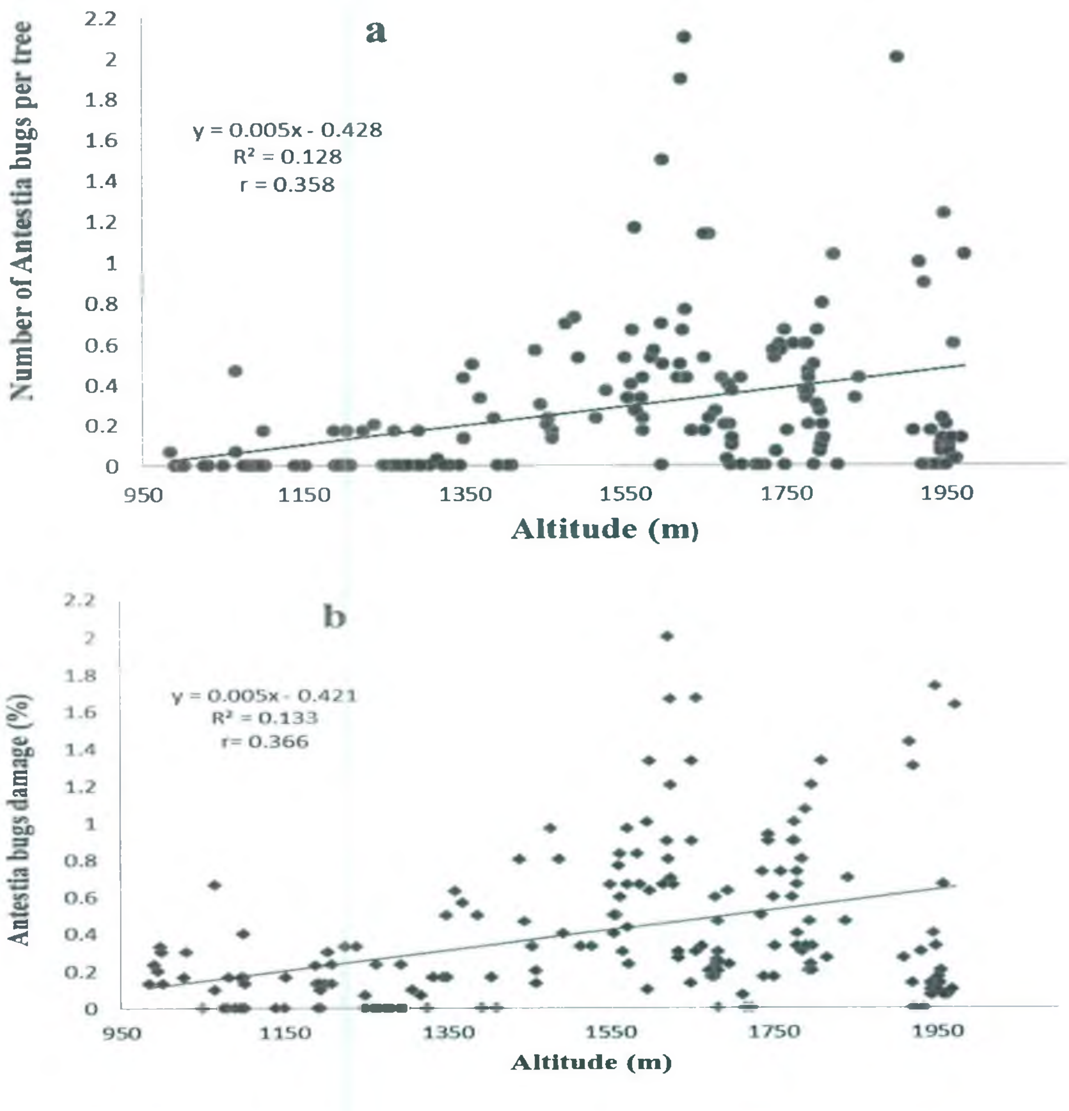

Figure 3.The relationship between antestia bugs mean number per tree (a) and damage per cent with altitude (m.a.s.l.) of the southwestern Ethiopia.

The study showed that the antestia bug infestations and damage increased along with increase in altitude. The finding is in line with the investigation by Ahmed et al. (2016) who reported that the population's density of antestia bugs linearly increased with increase in elevations. They recorded the lowest density of antestia bugs at 1100 and 1500 m.a.s.l., with means of 0.37 and 0.36 bugs/tree, respectively, while the highest population density at 1600 m.a.s.l., with mean of 1.03 bugs/tree.

Ahmed et al. (2016) indicated that elevation strongly influenced the population density of antestia bugs and may reach economic threshold level of one bug per tree at higher elevation. The risk maps derived from phenology models showed that the pest may shift to higher elevations of Kilimanjaro slopes, with an increase in the number of generations per year, leading to more damage in Arabica coffee of highest elevations (Ahmed et al., 2016). The increase in population density of antestia bugs could be due to the decrease in temperature. Based on intrinsic rate of increase obtained from laboratory study, Ahmed et al. (2016) indicated that the pest prefers low temperature. On the contrary, Murphy and Moore (1990) reported that coffee grown in low altitudes was severely affected than at higher elevations. Le Pelley (1968) reported occasionally severe attacks on coffee grown at low altitudes, resulting in the destruction of the entire crop.

Table 3. Correlation analysis between major factors (independent) and dependent (infestation and damage) variables of antestia bug in 2017/18 cropping year of southwestern Ethiopia

	Altitude (m)	Shade type	Coffee variety	Production systems	No. of bug per tree	Damaged bean
Altitude (m)	1	0.150*	-0.081	-0.040	0.358**	0.366**
Shade type		1	-0.160*	0.331**	0.074	0.012
Coffee variety			1	-0.767**	-0.214**	-0.183*
Production systems				1	0.203**	0.146
No. of bugs per tree					1	0.947**
Damaged bean						1

*. Correlation is significant at 0.05 level (2-tailed).

**. Correlation is highly significant at 0.01 level (2-tailed).

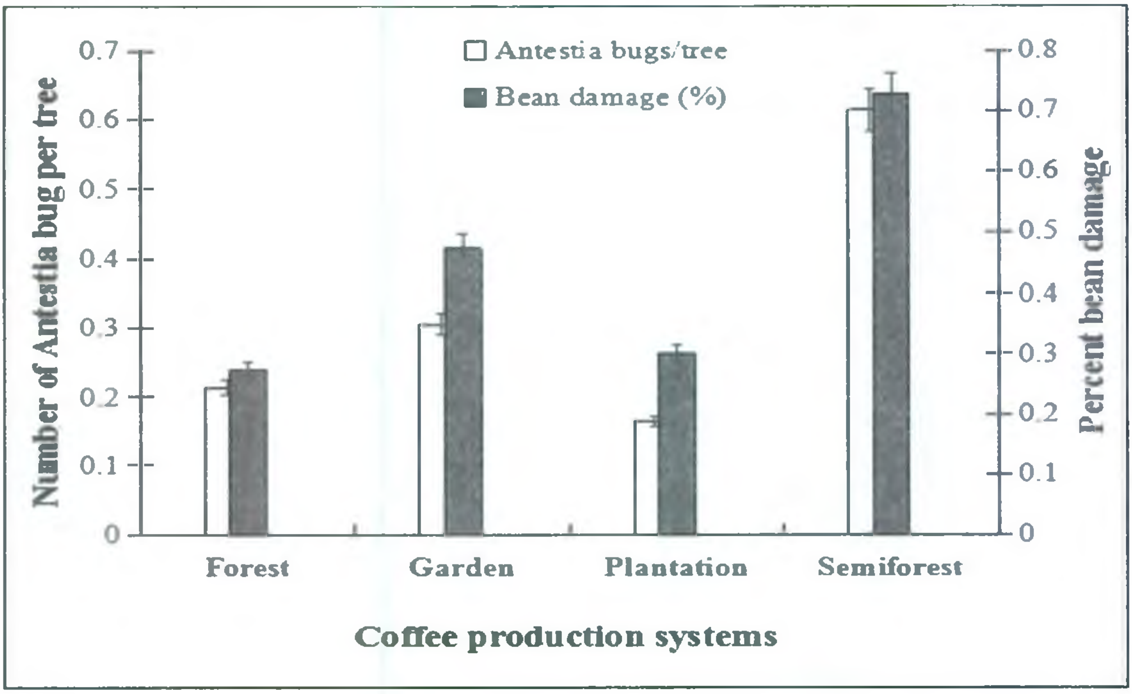

Figure 4.The relationship between antestia bug infestations and coffee bean damage and coffee production systems in southwestern Ethiopia. The error bar indicates standard error.

The relationship between antestia bugs and coffee production Systems

Mean infestation of antestia bugs per tree varied with coffee production systems. The highest antestia bugs infestations (0.61/tree) were recorded in semi-forest coffee production system, followed by garden coffee production system (0.31/tree). The lowest infestation (0.16/tree) was recorded in plantation coffee, followed by forest coffee (0.21/tree), while the highest and lowest bean damage was recorded in the semi-forest (0.73%) and forest coffee (0.27%), respectively.

Forest and plantation coffee production systems had the lowest antestia bug infestations and bean damages, while the highest were in the garden and semi-forest coffee. This may be because of pest management with the use of insecticides, shade management and improved coffee varieties in plantation coffee production system that might reduce the pest. The forest coffee production systems had little disturbance on natural enemies. In addition, the diversity in the coffee may contribute to low infestation and damage of coffee by antestia bug. The findings of this study are in line with the observation of Samnegård et al. (2014) who reported that the level of pest damage on coffee was lower in the continuous forest, which is the natural habitat of *C. arabica*. Bigirimana et al. (2012) also explained that in plantation coffee trees are regularly pruned that reduces the dense foliage, which creates favorable conditions for the bugs. The same authors further indicated that wide use of insecticides may be one of the reasons for low level of antestia bugs infestations in plantation coffee. Besides, pruning increases the efficacy of insecticides applied for the management of the antestia bugs (Esayas et al. 2009). Cultural practices, such as regulation of shade tree and pruning of coffee trees that are intensively practiced in plantation coffee, can reduce population of antestia bugs (Esayas *et al.*, 2008, 2009). But, the finding of the study disagrees with that of investigation of Million (1987) who reported that insect pest problems are more problematic in intensive coffee production system than garden and semi-forest coffee production systems. Such kind of pest problems may occur in plantation coffee due to failure in pest monitoring and application of proper pest management.

The relationship between antestia bugs and coffee variety

The local coffee varieties had higher antestia bugs infestation (0.33 bugs/tree) and bean damage (0.49%) (Figure 5) than the improved varieties with 0.28 bugs/tree infestation, 0.46% bean damage (Figure 5). This might be due to use of improved coffee varieties that are usually grown with better care and improved coffee management methods.

The relationship between antestia bugs and coffee shade levels

Coffee shade levels had varied effect on the infestation and coffee bean damage of coffee by the antestia bug (Figure 6). Higher infestations and damages by antestia bugs were recorded on coffee grown under high shade levels (Figure 6). Mugo et al. (2013) reported that coffee under the shade had significantly ($P < 0.05$) higher infestation by the antestia bugs than coffee in the open.

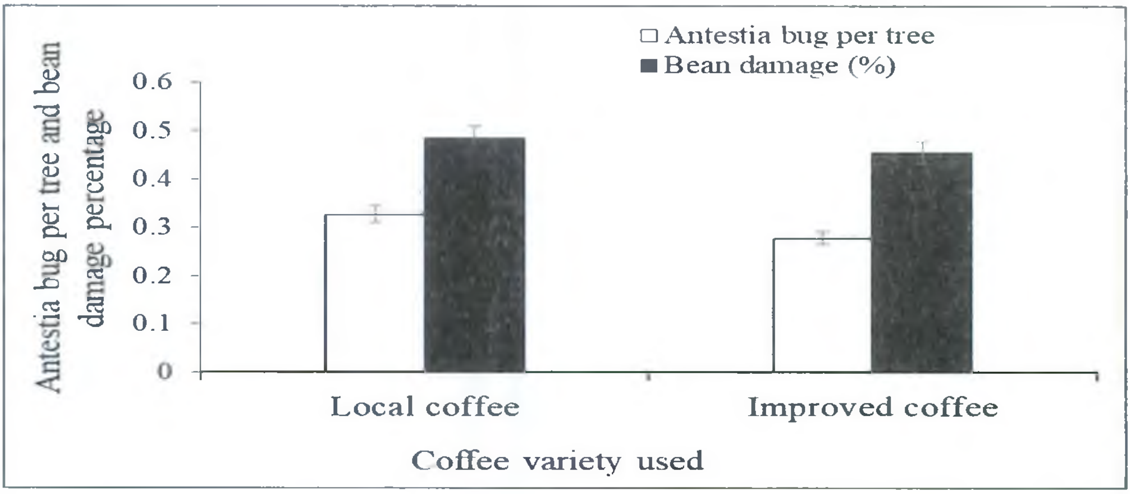

Figure 5. The relationship between antestia bug infestation and damage and coffee varieties grown in the southwestern Ethiopia. The error bar indicates standard error

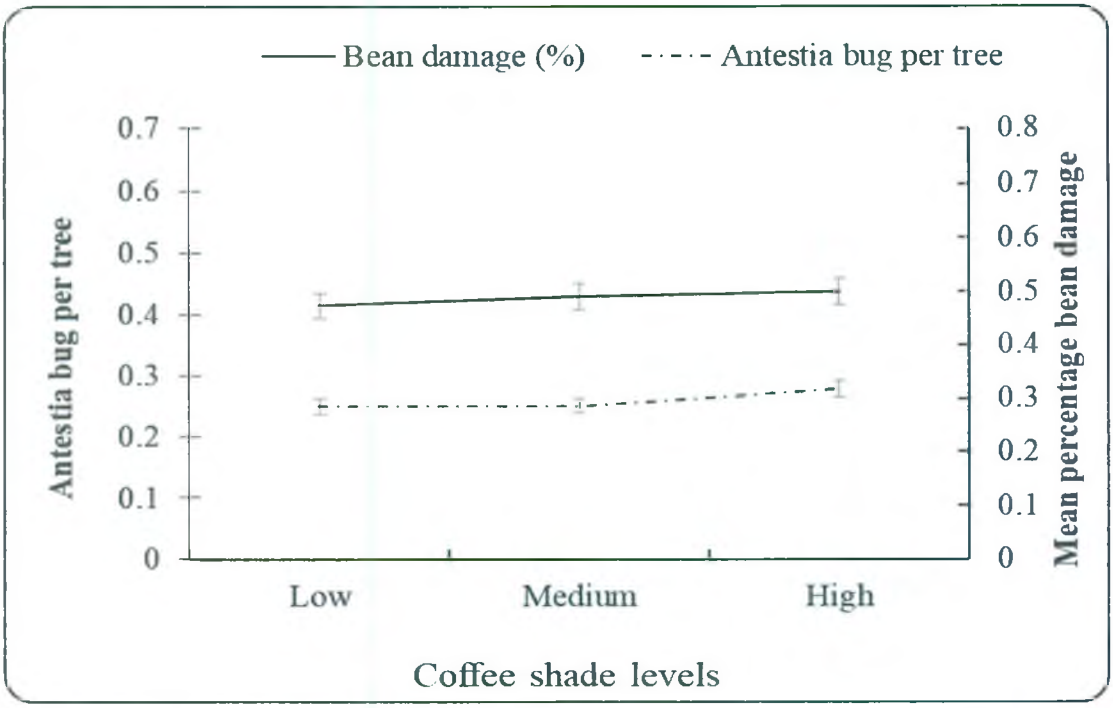

Figure 6. The relationship between antestia bugs infestations and damages and coffee shades in the southwestern Ethiopia. The error bar indicates standard error

The increase in antestia bugs with the increase inshade levels may be due to the influence of the shade on the natural enemies and microclimate of the pest. Several studies have reported that that shade trees increase coffee damage by coffee pests such as *A. intricata* by destabilizing the natural regulatory effects of their natural enemies (Oduor and Simons 2003; Chemeda *et al.* 2011; Jonsson*et al.* 2014). Ahmed (2015) also reported that agro-ecological and biological factors, such as shade, have a significant effect on the population density of antestia bugs. He predicted that antestia bugs may multiply more in shaded coffee plantations causing serious damage to coffee trees than non-shaded coffee trees. Crowe and Tadesse (1984) and IAR (1996) reported that cultural practices, such as pruning of coffee trees and shade tree regulation, can reduce the antestia bug populations by producing unfavorable conditions, since they prefer dense coffee foliage.

Coffee under shade and un-pruned coffee experience comparable micro-climate and habitat that promote rapid antestia bugs multiplication and low level of parasitism by natural enemies (Mugo *et al.*, 2013). Kenyan farmers in a pilot coffee IPM training project observed higher rates of parasitism of antestia bugs in pruned than un-pruned coffee trees (Davis *et al.*, 2001; Kimani*et al.*, 2002).

Pruning coffee can reduce antestia bugs infestations by half compared to the bug population in dark bushy canopy (Feed the

Future 2017). The open canopy of pruned coffee makes the habitat unsuitable for rapid multiplication of the pest but favorable for parasitoids (Mugo *et al*., 2013). In addition, pruning increases the vigor of the plant by cutting away unproductive vegetation and opening up the leaf canopy to allow more light to penetrate and air to circulate, thus reducing the humidity and temperature regimes (Kimani *et al*. 2002; Magina 2005). These conditions are less favorable to many insect pests and plant diseases, such as coffee berry disease and coffee antestia bugs (*Antestiopsis* spp.), while a favorable condition for natural enemies.

Conclusions

The antestia bug was distributed across the assessed districts of the southwestern Ethiopia. Infestation by antestia bug and damage to coffee berries were higher at Ale, Shabe Sombo and Mettu districts and lower in Gurra Farda, Debub Bench and Sheko districts. The pest infestation and damage to coffee beans were related to altitude, coffee shade levels, production systems and coffee variety. The study indicated that the antestia bug infestation and coffee bean damage was relatively higher at higher altitudes and higher levels of coffee shade. Populations of the antestia bug and damaged beans were lower in plantation coffee and on improved coffee production systems than on local coffee plantations.

In conclusion, antestia bug is still affecting coffee production in the southwestern Ethiopia. Future studies need to include major coffee-growing areas, like eastern and southern parts of Ethiopia. Similarly, study on the seasonal abundance, effect of microclimate, natural enemies and management practices on the population dynamics of the pest and the economics of antestia bugs should be focused.

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References

Abu Tefera. 2016. Ethiopia coffee annual report: Coffee production and exports remain steady. *Gain Report (Global Agricultural Information Network), USDA Foreign Agricultural Service.* Report Number: ET1615.

Ahmed AG, Murungi LK, Babin R. 2016. Developmental biology and demographic parameters of antestia bug, *Antestiopsis thunbergii* (Hemiptera: Pentatomidae), on *Coffea arabica* L. (Rubiaceae) at different constant temperatures. International Journal of Tropical Insect Science 36(3): 119-127.

Bigirimana J, Njoroge K, Gahakwa D, Phiri NA.2012. Incidence and severity of coffee leaf rust and other coffee pests and diseases in Rwanda. African Journal of Agricultural Research7: 3847-3852.

Birhanu Aebissa.2012. Developing knowledge based system for coffee disease diagnosis and treatment. MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia.

Chemeda Abdeta, Emana Getu, Emiru Seyoum, Hindorf H, Teshale Berhanu.2015. Coffee leaf damaging insects' occurrence in the forest coffee ecosystem of southwestern Ethiopia. African Journal of Plant Science 9(2): 75-81.

Chemeda Abedeta, Emana Getu, Emiru Seyoum, Hindorf H. 2011.Coffee Berry Insect Pests and their Parasitoids in the Afromontane Rainforests of Southwestern Ethiopia. East African Journal of Sciences 5(1): 41-50.

Coffee Research Foundation (CRF).1989. An Atlas of coffee pests and diseases. Pp. 256.Coffee Research Station, Ruiru, Kenya.

Esayas Mendesil, Million Abebe, Chemeda Abdeta. 2009. Review of research on coffee, tea and spices insect pests in Ethiopia. P. 117-125. *In* Abraham Tadesse (ed.), *Increasing Crop Production through Improved Plant Protection - II.* Plant Protection Society of Ethiopia (PPSE) and EIAR, Addis Ababa, Ethiopia.

Federal Democratic Republic of Ethiopia Ministry of Trade (FDREMoT). 2012. Coffee Opportunities in Ethiopia country profile. Addis Ababa, Ethiopia.

Feed the Future. 2017. Control of antestia/ PTD and improving coffee productivity in Burundi and Rwanda. 15th Africa Fine Coffee Conference (AFCA): Feed the Future Africa Great Lakes Coffee Program (AGLC). February 17, 2017. Addis Ababa, Ethiopia

Global Knowledge Initiative. 2016. Potato taste challenge prize winner identifies method to reduce potato taste defect in coffee. http://globalknowledgeinitiative.org/ Accessed on January 10, 2018

Ibrahim HW, Zailini. 2010. A review on the competitiveness of global supply chain in a coffee industry in Indonesia. International Business Management4(3): 105-115.

Jaramillo J, Muchugu E. Vega FE. Davis A, Borgemeister C, Chabi-Olaye A. 2011. Some like it hot: The influence and implications of climate change on coffee berry borer (*Hypothenemus hampei*) and coffee production in East Africa. Plos One 6(9): e24528.

Jassogne L, L€aderach P, van Asten P. 2013.The impact of climate change on coffee in Uganda: Lessons from a case study in the Rwenzori Mountains. Oxfam Research Reports.Pp.16.https://policy-practice.oxfam.org.uk/publications/the-impact-of-climate-change-on-coffee-in-uganda-lessons-from-a-case-study-in-t-277813.Accessed on May 10, 2018.

Karungi J, Nambi N, Ijala AR, Jonsson M, Kyamanywa S, Ekbom B. 2015. Relating shading levels and distance from natural vegetation with hemipteran pests and predators occurrence on coffee. Journal of Applied Entomology 139: 669-678.

Kumlachew Alemu, Girma Adugna, Fikre Lemessa, Diriba Muleta. 2016. Current status of coffee berry disease (*Colletotrichum kahawae* Waller and Bridge) in Ethiopia. Archives of Phytopathology and Plant Protection. DOI:10.1080/03235408.2016.1228736

Matovu RJ, Kangire A, Phiri NA, Hakiza GJ, Kagezi GH, Musoli PC. 2013. Ecological factors influencing incidence and severity of coffee leaf rust and coffee berry disease in major Arabica coffee growing districts of Uganda. Uganda Journal of Agricultural Sciences 14(1): 87 - 100.

Matsuura Y, Hosokawa T, Serracin M, Tulgetske GM, Thomas A, Fukatsu MT. 2014. Bacterial symbionts of a devastating coffee plant pest, the stinkbug *Antestiopsis thunbergii* (Hemiptera: Pentatomidae). Journal of Applied and Environmental Microbiology 80(12): 3769- 3775.

Moat J, Williams J, Baena S, Wilkinson T, Sebsebe Demissew, Zeleke Kebebew, Tadesse Woldemariam, Davis AP. 2017.Coffee Farming and Climate Change in Ethiopia: Impacts, Forecasts, Resilience and Opportunities - Summary. P. 37. The Strategic Climate Institutions Programme (SCIP). Royal Botanic Gardens, Kew, UK.

Mugo HM, Irungu LW, Ndegwa PN. 2011. The insect pests of coffee and their distribution in Kenya. International Journal of Science and Nature 2(3): 564-569.

Mugo HM, Kimemia JK, Mwangi JM. 2013. Severity of antestia bugs, *Antestiopsis* spp. and other key insect pests under shaded coffee in Kenya. International Journal of Science and Nature 4: 324-327.

National Agricultural Export Development Board (NAEB). 2017. Sustaining the growth in volume and value of Rwandan Coffee.http://naeb.gov.rw/index.php?id=1&L=1. Accessed on January 10, 2018

Pablo B, Carmenza G, Alex B. 2012. IPM program to control coffee berry borer *Hypothenemus hampei* with emphasis on highly pathogenic mixed strains of *Beauveria bassiana*, to overcome insecticide resistance in Colombia. P. 511-539. *In:* Farzana Perveen (ed.), Insecticides - Advances in Integrated Pest Management. In: Tech, Rijeka, Croatia.

Samnegård U, Hambäck PA, Nemomissa S, Hylander K. 2014. Local and regional variation in local frequency of multiple coffee pests across a mosaic landscape in *Coffea arabica*'s native range. Biotropica 46: 276-284.

Tamiru Shimalis, Sisay Kidanu, Belay Abate, Demelash Teferi. 2017. Survey on status of key coffee insect pests in major coffee growing areas of Ethiopia. International Journal of Research Studies in Science, Engineering and Technology 4(9): 17-21.