Advances in Entomology, 2023, 11, 264-284
https://www.scirp.org/journal/ae
ISSN Online: 2331-2017
ISSN Print: 2331-1991

Pest Status of Antestia Bug, *Antestiopsis* spp. (Hemiptera: Pentatomidae) in Arabica Coffee Fields of Smallholder Farmers in Tanzania

Edmond Zani, Gration M. Rwegasira

Department of Crop Science and Horticulture, Sokoine University of Agriculture, Morogoro, Tanzania
Email: zannyy2022@gmail.com

How to cite this paper: Zani, E. and Rwegasira, G.M. (2023) Pest Status of Antestia Bug, *Antestiopsis* spp. (Hemiptera: Pentatomidae) in Arabica Coffee Fields of Smallholder Farmers in Tanzania. *Advances in Entomology*, **11**, 264-284.
https://doi.org/10.4236/ae.2023.114019

Received: July 5, 2023
Accepted: October 8, 2023
Published: October 11, 2023

Abstract

Coffee (*Coffea arabica* L.) is a crop of major economic significance in Tanzania with annual revenue estimated at 100 Million USD. The current mean annual production of the crop is 68,000 MT of clean coffee of which 90% is contributed by about 450,000 smallholder farmers and while large estate owners contribute the rest. Antestia bug (*Antestiopsis orbitalis* spp.), the pest known to attack all vegetative and fruiting parts of the coffee tree with substantial yield reduction of up to 45% has been reported to occur contemporary on Arabica coffee in Tanzania, particularly in Kilimanjaro Region. Despite the reported existence of Antestia bug and its damages that badly inflict on the productivity and quality of coffee, the pest status of the bug in Tanzania has never been established. The present study examined the incidence damage severity of Antestia bug in the Arabica coffee fields in major producing regions of Kilimanjaro, Ruvuma and Songwe. A stratified sampling of 360 coffee farms was done on which the Antestia bug incidence and severity were recorded. Results suggested that all regions were infested and the shade intensity influenced the pest incidences with the highest severity record in Kilimanjaro and the least affected was Songwe Region. Dense shade had the highest Antestia bug incidence than sparse shade canopy ($p < 0.001$). The current study sheds insights into understanding the pest status of Antestia bugs on Arabica coffee in Tanzania which could be used in designing effective management strategies.

Keywords

Antestiopsis orbitalis spp., Canopy Shade, Incidence, Severity, Pest Status, Tanzania

1. Introduction

The vast and varying landscape of Tanzania provides appropriate altitude, climate and suitable soils for the cultivation of good-quality coffee [1]. In Tanzania, coffee has been a prime mover of its economy since independence [2]. The country is the fourth coffee producer in Africa, with an annual production of 68,000 tons of clean coffee [3]. Coffee is Tanzania's second largest export commodity, accounting for 24% of the country's total foreign exchange earnings after Tobacco [4]. Close to 90% of Tanzania's coffee is produced by about 450,000 households operations on 265,000 hectares of land, and the rest is grown by estate owners [3].

Despite its significance to economic growth, the crop suffers great yield losses attributed to diseases and insect pests. The pests attack roots, stems, leaves, flowers and fruits [5]. Among these, Antestia bug is the most devastating coffee pest due to its lowest threshold of 2 bugs per tree, which can cause total yield quality loss [6]. Smallholder coffee farmers cultivate coffee farms on less than five hectares [7]. The majority of them practice coffee farming mixed with various shade trees. In Kilimanjaro, Chaggas practices the so-called "kihamba" (chaggas community home garden) agroforestry system. This traditional land use system is characterized by coffee fields intercropped with banana, fruit trees, timber trees as well as other annual plants, which affect the amount of light that penetrates the ground subsequently influencing the below canopy ecological composition. Elsewhere, [8] reported that the tendency of smallholder farmers practicing diversified multi-strata coffee has been a common cropping system since the beginning of agriculture. Smallholder farmers use agroforestry to reduce coffee production costs, diversify income and address livelihood needs. [9] reported that Antestia bug population can increase with shade intensity. The increase in Antestia bugs can subsequently lead to increased incidences and damage severity on the coffee crop. Nevertheless, [6] reported on the varied response of pests to shade intensity whereby the populations of some insect pests were depressed by dense shades while others were positively favored.

The major insect pest of coffee in different coffee plantations in Tanzania is mainly Antestia bugs [10]. A similar report has been made by [11] that Antestia bug is the number one insect pest damaging coffee in East Africa. The yield losses attributed to Antestia bug worldwide and in Africa are respectively 13% and 96% [6]. Antestia bug infestations are ubiquitous in coffee plantations, but occur in patchy distributions possibly due to the insects' semio-chemical mediated reproductive behavior [12]. Nymphs and adults Antestia bug feed on all vegetative and fruiting parts of the coffee tree leading to yield reduction and poor quality of coffee beans. As they feed, they inject saliva containing the spores of the Ashbya fungus that causes the taste defect in coffee beans [6] [13]. According to [14], the average coffee annual yield losses due to Antestia bug range from 35% to 54%. In Kenya, a study by [15] showed that 2 to 4 Antestia bugs per tree caused a crop loss between 15% and 27%, whereas in Uganda, between 36%

and 51% yield losses were attributed to densities of 1, and 2 bugs per coffee bush [15]. [16] established that a density of 2 to 5 bugs per tree in Burundi and Rwanda caused a yield loss of approximately 30%. The principal damage caused by Antestia bug is due to the bugs sucking the growing tips, and flowers, developing berries and producing spotted and pitted beans [13]. Feeding at the growing point of the coffee tree, results in leaves that are scarred and distorted [17]. When Antestia bugs feed on flower buds, they become black or brown, which impairs fruit setting [11]. [18] reported that Antestia bug causes a significant loss of flowers when it is present in coffee plantations during the onset of rains and severe infestations may prevent the tree from flowering. In the absence of berries, Antestia bugs attack young shoots and mat of short secondary and tertiary branches, which bear no crop. Loss of flowers of affected plants is a common symptom, which leads to loss of yield and quality of coffee [18]. Despite the vast knowledge of Antestia bug damage and subsequent yield losses elsewhere, the knowledge of the pest status in Arabica coffee-growing areas of Tanzania was scanty. Very little information existed on the geographical distribution, incidences and severity of the pest in Tanzania. The present study was conducted aiming at addressing the knowledge gaps on the pest status, specifically the distribution, abundance and inflicted damage severities caused by Antestia bugs in major Arabica coffee-growing regions of Kilimanjaro, Ruvuma and Songwe in Tanzania. The study findings will contribute to the advancement of concerted efforts to manage the pest in the country.

2. Materials and Methods

2.1. Site Selection

The study targeted the Arabica coffee smallholder farms in major growing regions, namely: Kilimanjaro, Ruvuma and Songwe. Purposeful sampling techniques were used. Two Districts in each of three regions were selected for the study. The basis for selection of farms to be studied was threefold: 1) the farm had to be owned by smallholding coffee family, 2) the farm had to be sufficiently large to permit presence of 64 plants/stands organized in 16 quadrats, 3) the minimum isolation distance between sampled farms had to be at least two kilometers to minimize chances for autocorrelation among farms as guided by [19].

2.2. Description of the Study Area and Duration

The diagnostic survey was conducted on monthly basis from September 2021 to August 2022 covering duration of 12 months (a year) in a total of 360 farmers' fields. The study locations were Mbinga district located (10˚15'0" to 11˚34'0"S and 34˚24'0" to 35˚28'0"E), Nyasa district located (10˚15'0" to 11˚34'0"S and 34˚24'0" to 35˚28'0"E) in Ruvuma Region, Mbozi district located (10˚15'0" to 11˚34'0"S and 34˚24'0" to 35˚28'0"E) and Ileje district located (9˚14'0" to 9˚37'0"S and 32˚80'0"E) in Songwe Region, Hai district located (2˚50'0" to 3˚29'0"S and 30˚30'0"E) as well as Moshi district located (2˚ to 5˚S and 37˚0' to 38˚0'E) in Kilimanjaro Region. The altitude of the surveyed farms ranged from 1224 to 2051 meters above sea level (m.a.s.l).

2.3. Antestia Bug Identification and Damage Signs

During the assessment in coffee fields, a meticulous methodology was employed. The study specifically focused on coffee fields that had not been treated with any pesticides for an entire season (one year). This selection criterion ensured that the obtained results were representative of the natural occurrence and impacts of Antestia bugs in untreated coffee fields. Prior to field surveillance, colored photo cards of Antestia bug species suspected to exist in the study areas were printed and displayed to targeted farmers to accustom them with the pest infesting their coffee crops. In addition, the photo cards (Figure 1) of the damage signs associated with Antestia bugs were shown to help them distinguish from damages caused by other causes.

2.4. Abundance of Antestia Bugs

Physical counts of Antestia bug on the coffee trees were carried out on monthly basis on the selected coffee plants for ultimate estimates of pest populations. Antestia bug is a relatively big insect that can be easily seen with naked eyes. According to [20], most Antestia bugs are sized between 4.5 mm to 4.8 mm making them morphologically distinguishable by eyes. On each farm and during each observation round 16 Arabica coffee trees were sampled making a total of 5760 coffee trees (Table 1). Each of selected trees was stratified into three canopy layer and one branch from each layer was randomly chosen for data collection. The sampled branches were tagged using conspicuous label to allow repeated data collection. The *Antestiopsis* spp. (nymph to adults) were counted and recorded irrespective of their life stages except the eggs that were not recorded. The assessment was made on different coffee fruit developments and fruiting phenologies.

2.5. Assessment of Antestia Bug Damage Incidences

To determine the damage incidences of Antestia bug, a comprehensive and

(a) (b) (c)

Figure 1. Antestia bugs damage signs: (a) Side shoot growth on coffee branches; (b) Desiccated inflorescence; (c) Round hole on coffee berry.

Table 1. Summary of the sampling protocol in the three regions surveyed.

Region	District	Village name	Number of surveyed farms	Number of trees inspected per farm
Kilimanjaro	Hai	Lya-Kati	20	16
		Lya-Sinde	20	16
		Lya-Kilanya	20	16
	Moshi	Nduoni	20	16
		Iwa	20	16
		Nganjoni	20	16
Ruvuma	Mbinga	Luwaita	20	16
		Myangayanga	20	16
		Ugano	20	16
	Nyasa	Kingerikiti	20	16
		Ukuli	20	16
		Lumecha	20	16
Songwe	Mbozi	Nsenga	20	16
		Mbimba	20	16
		Iyenga	20	16
	Ileje	Shikunga	20	16
		Kalembo	20	16
		Ibaba	20	16
			360	**5760**

robust approach of quantifying pest damage was adopted. Since Antestia bug damage causes apparent and distinctive sign and symptoms to the infested coffee tree (**Figure 1**), the pest incidence (I) was established based on the observable signs of the Antestia bug damage [21] on shoot, flowers and fruits. So the Antestia bug incidence in the coffee field was established based on the proportion of coffee trees with damage signs out of the 16 trees sampled multiplied by 100 to establish the percentage incidences (Equation (1)).

Damage incidence for each tree sampled was calculated as follows:

$$\text{Damage incidence}\left(\text{i}\right)=\sum\nolimits_{x=1}^{N}\frac{xi}{N}\times 100 \quad (1)$$

whereby, xi represented the number of damaged plants in a field, N represented the total number of the sampled plants in the coffee field [10]. We excluded those plants in the border lines during data collection [22].

2.6. Assessment of Antestia Bug Damage Severity

The pest severity rating is established as the degree of damage symptoms or infestation level observed per plant part assessed [21] was determined in each field visited. One primary branch of the selected tree was picked, from each on the top, middle and bottom among the chosen 16 trees. Border rows plant were excluded during data collection as per [22]. The descriptive visual diagnostic scale for Antestia bug damage proposed by [23] [24] were adopted during the survey with minor modification whereby 0% = 1, no damage, 1% - 5% = 2 small parts damaged 5% - 12% = 3 damage easily observable, 12% - 30% = 4 appreciable damage and 30% - 100% = 5 very severe damage (**Table 2**) followed by the computation as per [21] [25].

The Arabica coffee varieties considered in all surveyed fields were Bourbon and Kent. However, it is worth mentioning that these varieties have been used for very long time with lots of crossing such that their original identities have been lost hence regarded as local varieties used by smallholder coffee farmers. Thus, the inherent genetic characteristics of the varieties could not be considered as a factor for assessment of Antestia bug damages. The age of the sampled coffee trees ranged from 8 to 50 years. The location (coordinates) of a central point for each sampled coffee field was established using a global positioning system (GPS) and used later to generate maps.

Mean severity (S) was estimated based on the equation:

$$\text{Damage severity}(\text{S}) = \frac{\text{Area of tissue affected}}{\text{Total area of the tissue}} \quad (2)$$

Table 2. Description of visual diagnostic Antestia bug severity scores used in the current study.

Damage parameter	Plant part assessed	% damage severity	Severity score	Descriptions
Antestia bug damage incidence	Foliage	0%	1	None of the branch grow side shoots (fan branching) [4]
		1% - 5%	2	Very few branches grow side shoots
		5% - 30%	3	Appreciable number of branches grow side shoots
		30% - 50%	4	Half of the branches grow side shoots
		50% - 100%	5	Almost all of the branches grow side shoots
	Flower buds/flowers	0%	1	None of the flower bud/flower Blackened
		1% - 5%	2	Very few flower buds/Flowers show faint blackened
		5% - 30%	3	Appreciable number of flowers show blackened
		30% - 50%	4	Half of the flowers show blackened
		50% - 100%	5	Almost all flowers show blackened
	Fruits	0%	1	None of the coffee berry shrinks
		1% - 5%	2	Very few coffee berry shrinks
		5% - 12%	3	Appreciable number of coffee berry shrinks
		12% - 30%	4	Half of the coffee berry shrinks and slightly rot
		30% - 100%	5	Almost all coffee berry shrinks and rot

Source: [24] [25] with slight modifications.

2.7. Influence of the Shade Canopy

The influence of shade canopy on Antestia bug incidence and severity was assessed in consideration that the quantity of light penetrating the coffee field had influence on the Antestia bug infestation. In each village two farms were identified, one under dense canopy shades and the other under sparse canopy shades. According to [26], the light penetrating in the coffee field is subject to the types, quantity and mixture of shade trees present in the coffee field. [26] classified four groups of shade trees, namely fruit trees, banana trees, timber trees and services trees. In this study, we categorized the shade canopy in two classes as sparse shade and dense shade. The sparse shade qualified the coffee fields with no shade trees (open sun) while simple shades (coffee trees and service trees) and dense shades were coffee fields with various types of trees diversification.

2.8. Antenstia Bugs with Coffee Fruiting Phenology

To assess the tremendous variation of Antestia bugs population and allied incidence and severity linked with the fruit phenology we collected samples in different months with respect to the coffee fruit setting. The samples were collected from the time of bud formation, bud swelling, flowering, fruit initiation and fruit ripening as guided by [27] as detailed (**Figure 2**).

2.9. Statistical Analysis

Collected data were summarized and subjected to normality test using Shapiro-Wilk and thereafter analysis of variance (ANOVA) with subsequent mean separation by using Duncan's multiple range test (DMRT). Computed antestia bugs' incidence data were subjected to arcsine transformation to normalize their distribution. GenStat software (16th version, VSN International) was used in data transformation and analysis for correlation between Antestia bug population, damage incidence and severity with shade and fruit phenology were determined. Duncan's multiple range test (DMRT) at $p < 0.05$ in GenStat software (16th version, VSN International). The least significant difference among means was likewise established at 5%.

Figure 2. Coffee plant fruit phenology [27].

3. Results

3.1. Antestia Bug Population Density

Antestia bugs (*Antestiopsis orbitalis* spp.) were found in all the coffee-growing regions with high production of Arabica coffee in Tanzania surveyed. The population density of the bug was varied with location (regions), shade canopy structure and fruiting phenology (**Figure 3**). The mean population density generally ranged from the lowest 0.01 per tree in Ileje (Ruvuma) to 12.4 per tree in Hai (Kilimanjaro) with a mean density of 1.89 ± 0.16 (Mean ± SE) Antestia bugs per tree in densely shaded canopy and 1.36 ± 0.16 (Mean ± SE) in sparsely shaded canopy. Differences between locations with dense shades and with sparse shade in terms of Antestia bug density was significant ($p < 0.01$). The higher Antestia bugs density of 12.4, 2.65, and 0.23 was recorded in the dense shades at the fruiting phase for Kilimanjaro, Ruvuma and Songwe respectively compared to the densities of 7.75, 1.45, and 0.15 per tree respectively in sparsely shaded

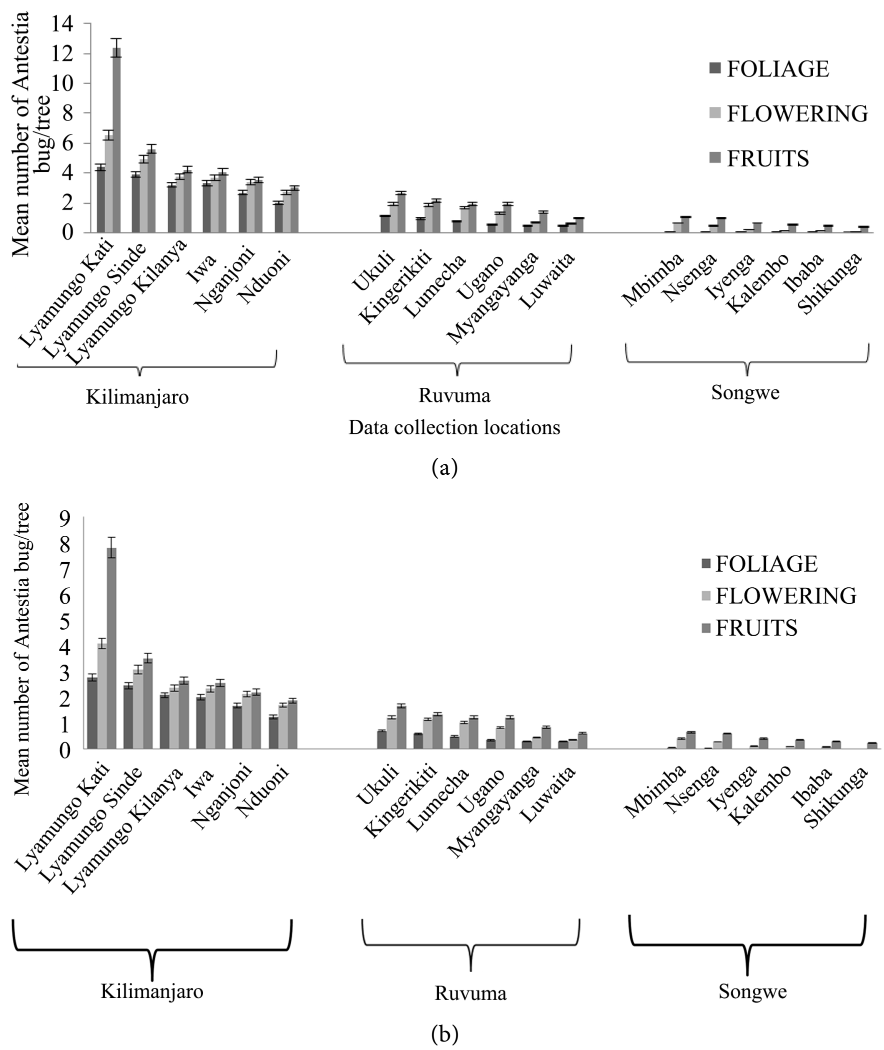

Figure 3. Abundance (mean number) of Antestia bug per tree in the study locations: (a) Dense shade canopies; (b) Sparse shade canopies.

areas. Considering the mean population density Kilimanjaro Region had the highest mean number of Antenstia bugs (5.43 ± 0.28) while Songwe had the lowest mean of 0.01 ± 0.12 bugs per tree.

3.2. Antestia Bug Damage Incidence

Antestia bugs were recorded in all 360 surveyed farms in the three regions, with average village incidences ranging from 0.16 to about 100% (**Figure 4**). The highest Antestia bug incidence data was recorded in Kilimanjaro with variation based on the assessed plant parts (**Figures 5-7**). Recorded incidences in dense shades canopies and sparse shades were respectively: 39.95% ± 0.28%, 31.3% ± 0.17% on foliage, 45.03% ± 0.44%, 33.1% ± 0.28% on flowers, and 56.78% ± 1.16%, 43.08% ± 0.73% on fruits. As such, incidences increased with advancement in fruiting phenology towards maturity of coffee berries. These incidence levels recorded in Kilimanjaro were significantly higher than the rest of Ruvuma and Songwe Regions. Incidence data for dense and sparse shaded canopies in Ruvuma were respectively established to be 17.29% ± 0.09%, 14.51% ± 0.06% on foliage, 18.04% ± 0.19%, 15.17% ± 0.12% on flowers and 23.07% ± 0.19%, 19.80% ± 0.1% on fruits. Songwe Region had the lowest Antestia bags incidences with recorded values in dense and sparse shade canopies as 2.35% ± 0.01%, 1.80% ± 0.01% on foliage, 3.66% ± 0.07%, 1.93% ± 0.05% on flowers and 4.77% ± 0.09%, 2.06% ± 0.06% on fruits. The antestia bug incidences were significantly ($p < 0.001$) different between the dense and sparse shaded canopies. Across the sites the incidence of Antestia bugs in coffee fruiting phase was the highest compared to other plant growth stages in all regions.

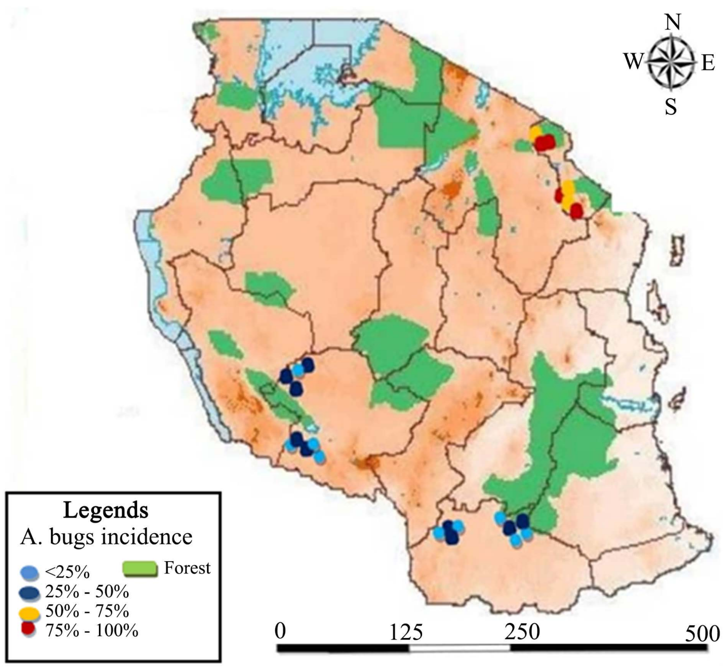

Figure 4. A map showing Antestia bugs incidences in major Arabica coffee-growing regions of Tanzania.

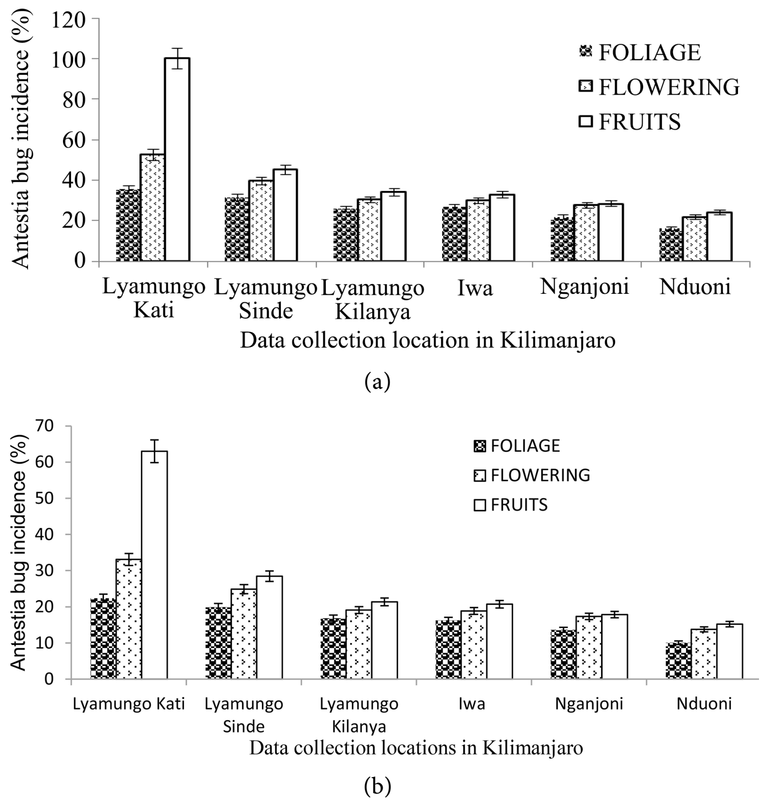

Figure 5. Antestia bug incidences (%) in study locations in Kilimanjaro Region: (a) dense shade canopies & (b) sparse shade canopies.

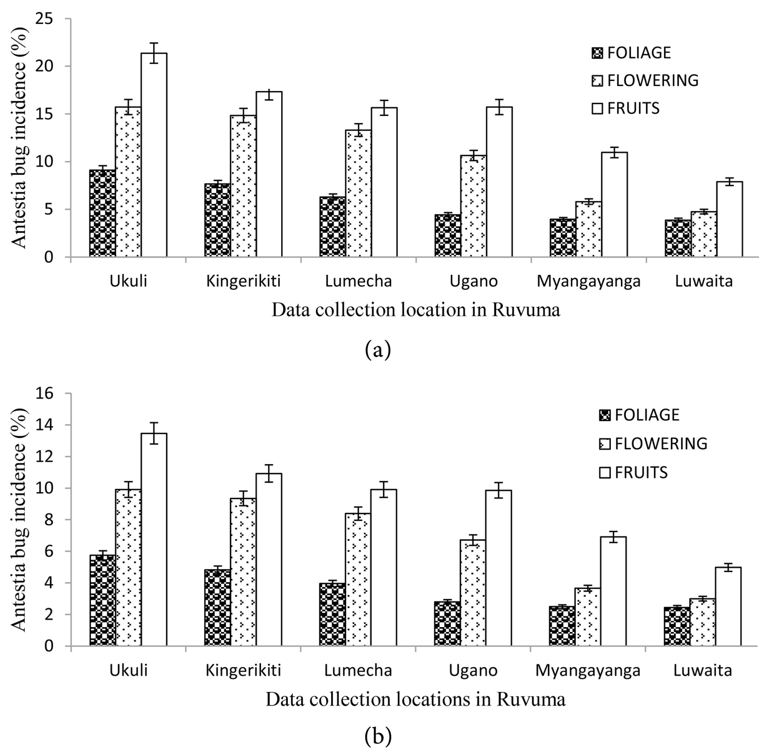

Figure 6. Antestia bug incidence (%) in study locations in Ruvuma Region: (a) Dense shade canopies; (b) Sparse shade canopies.

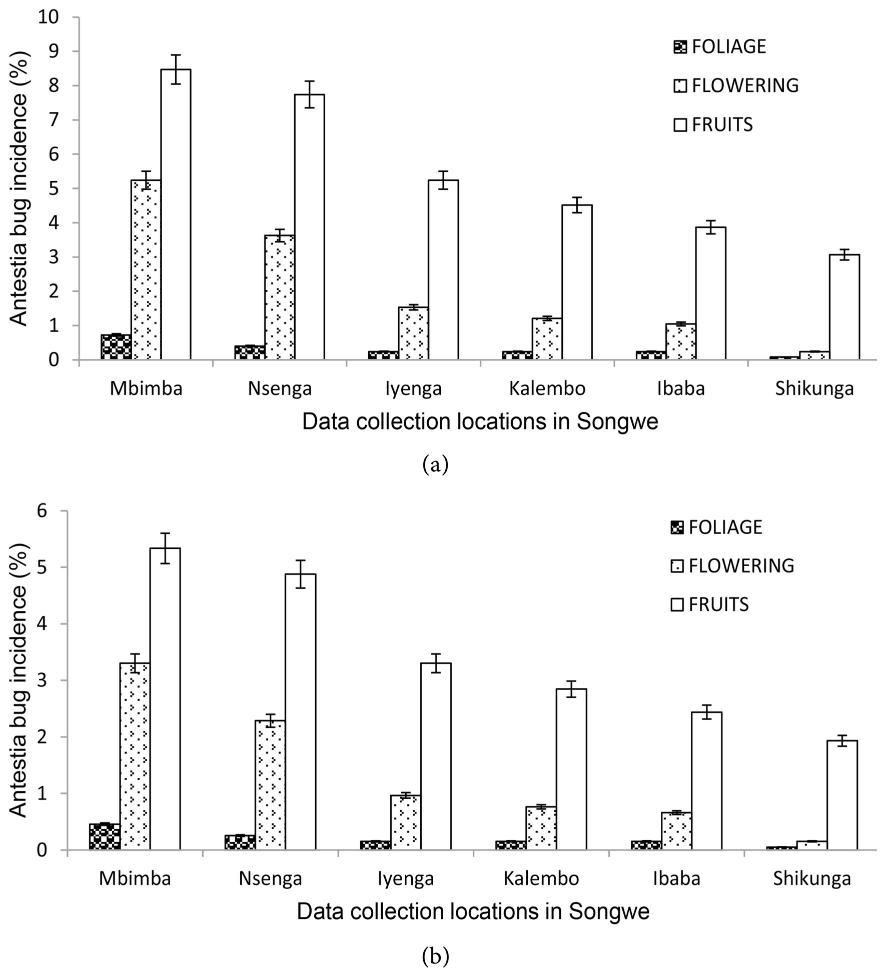

Figure 7. Antestia bug incidence (%) in study locations in Songwe Region: (a) Dense shade canopies; (b) Sparse shade canopies.

3.3. Antestia Bug Damage Severity

The magnitude of Antenstia bugs damage (mean severity score) on foliage, flowers and coffee berries (based on the established scale of 0 - 5) ranged from 0.02 to 5.0 (Figure 8). The damage severity data segregated on basis of canopy density *i.e.* dense and sparse canopy shades suggested severe damages in the former canopies than the latter. A wide variation in Antestia bugs mean damage severity was recorded in ranges of 0.04 - 1.77, 0.012 - 2.625, and 0.153 - 5.0 for the dense shade canopy, and 0.02 - 1.12, 0.08 - 1.65, and 0.016 - 3.15 for sparse shade canopies on foliage, flowers and fruits (berries) respectively. The highest pest damage severity scores of 5.0 & 3.15 for dense and sparse canopy shades were recorded at fruits/berries stage in Kilimanjaro Region in Hai District followed by Nyasa District in Ruvuma (1.07 & 0.67) and Mbozi district in Songwe had the least damage severity score (0.42 & 0.27). The severity of Antestia bugs significantly increased from foliage, flowering period and reaches the peak at berry formation (Table 3). Differences in damage scores between dense shades and sparse shade canopies were highly significant ($p < 0.001$).

Table 3. Relationship between canopy shade and Antestia bug damage severity score.

Region	Village	Dense shade (DS) location			Sparse shade (SS) location		
		Foliage season	Flowering season	Fruit season	Foliage season	Flowering season	Fruit season
Kilimanjaro	Lyamungo Kati	1.77a	2.63a	5.00a	1.12a	1.65a	3.15a
	Lyamungo Sinde	1.58a	1.98a	2.26a	0.99b	1.24a	1.42a
	Lyamungo Kilanya	1.29a	1.5a	1.69a	0.84bc	0.95b	1.07b
	Iwa	1.34a	1.50a	1.64a	0.81bc	0.94b	1.04b
	Nganjoni	1.08b	1.38a	1.42a	0.68c	0.86b	0.89bc
	Nduoni	0.80bc	1.09b	1.21a	0.50c	0.69bc	0.76bc
Ruvuma	Ukuli	0.46c	0.79bc	1.10b	0.29c	0.49c	0.67bc
	Kingerikiti	0.38c	0.74bc	0.87bc	0.24c	0.47c	0.55c
	Lumecha	0.31c	0.67bc	0.78bc	0.19c	0.42c	0.49c
	Ugano	0.22c	0.53c	0.79bc	0.14c	0.34c	0.49c
	Myangayanga	0.19c	0.29c	0.55c	0.12c	0.18c	0.35c
	Luwaita	0.20c	0.24c	0.39c	0.12c	0.15c	0.25c
Songwe	Mbimba	0.04c	0.26c	0.42c	0.02c	0.17c	0.27c
	Nsenga	0.02c	0.18c	0.39c	0.01c	0.11c	0.24c
	Iyenga	0.01c	0.08c	0.26c	0.01c	0.04c	0.17c
	Kalembo	0.01c	0.06c	0.23c	0.01c	0.04c	0.14c
	Ibaba	0.01c	0.05c	0.19c	0.01c	0.03c	0.12c
	Shikunga	0.00c	0.01c	0.15c	0.0c	0.0c	0.0c
	Grand mean	0.54	0.78	1.07	0.34	0.49	0.67
	LSD	0.33	0.37	0.43	0.28	0.31	0.34
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Means bearing same letter(s) in a column are not significantly different at $p < 0.05$.

3.4. Correlation among Antestia Bug Damage Parameters

Outcome of the Pearson's linear correlation analysis of Antestia bug damage indices was as shown (Table 4). The correlation suggested a positive relationship between dense shade canopy and Antestia bug damage incidences and severities on foliage, flowers and fruits. That is, the presence of dense shade led to increased incidences and severity of Antestia bugs' damages. Nevertheless, the correlation suggested negative relationships between pest abundance, incidences and severities with the sparse shade. Sparse shade canopy was associated with the decline in pest population and subsequent damages. The canopy shade intensity had positive correlation with advancement in fruiting that is, as the fruiting phenology transformed from flowering to fruit formation likewise the pest damage incidences and severities increased. The sparse shade canopy was negatively (−0.01) correlated with the dense shade canopies.

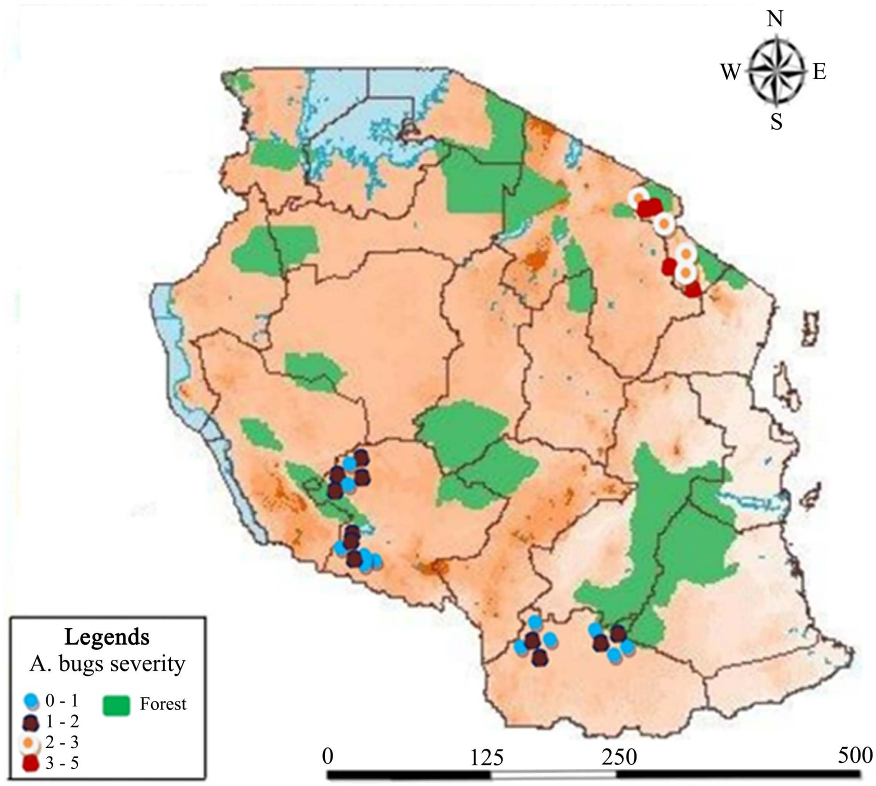

Figure 8. A map showing Antestia bugs mean damage severity scores in major Arabica coffee-growing regions of Tanzania.

Table 4. Correlation matrices between Antestia bug damage population, incidences (%), severities, the shade canopy and fruit phenology in sites covered during the survey.

Factor I	Factor II								
	A	B	C	D	E	F	G	H	I
A: Bug population	1.00								
B: Dense shade	0.89	1.00							
C: Sparse shade	−0.32	−0.01	1.00						
D: Foliage incid. (%)	0.73	0.65	−0.62	1.00					
E: Foliage severity	0.71	0.68	−0.54	0.75	1.00				
F: Flower incid. (%)	0.69	0.71	−0.45	−0.40	−0.12	1.00			
G: Flower severity	0.78	0.73	−0.06	−0.1	−0.32	0.46	1.00		
H: Fruit incid. (%)	0.84	0.78	−0.56	−0.34	−0.35	−0.25	−0.09	1.00	
I: Fruit severity	0.79	0.75	−0.32	−0.03	−0.16	−0.06	−0.02	−0.37	1.00

4. Discussion

It is apparent based on the finding from the current study that Antestia bug is omnipresent wherever Arabica coffee is grown particularly in the major growing areas of Kilimanjaro, Ruvuma and Songwe Regions. The pest abundance was at alarming levels beyond the minimum of 1 - 2 which was reported to inflict substantial economic damages [6]. Available reports [10] [27] deduced that Antestia bug induces injuries to the coffee trees which subsequently reduces yield in terms of quantity and quality. This information has for the first time been systematic and quantitative recorded in Tanzania in the current study. The ability to identify and gauge the damage caused by the pest is the basis for pest control [28]. [29] stated the adults and nymphs are the damaging stages of Antestia bug and they feed mostly on immature, green berries, from which they suck the sap, causing the fruits to shrink and fall. Also, [30] reported that adult and nymphs of Antestia bugs can feed on shoots and leaves of coffee plants but prefer to attack unripe coffee cherries. The attack of thus stages may not only causes physical damage to the coffee cherries but also facilitate fungal infection of the fruits, causing coffee bean rot and significant yield loss [5]. Several literatures have accentuated that the attack of the Antestia bugs on different parts of the plants does not only weaken the plant but also makes it susceptible to diseases. Due to the damage caused by both nymphs and adults feed on the berries, can result the young berries to drop and the production of soft or rotten beans by the bigger berries [5].

The prevalence of Antestia bugs in Arabica coffee fields threaten coffee production and the resultant yield quality. Antestia bug has been categorized as a major coffee pest in Tanzania [10]. Given the perennial nature of Arabica coffee, and the feeding habit of Antestia bugs [11], the pest is able to survive and multiply throughout the cropping season. The pest is always present on the coffee tree, although their populations and hence their extent of damage severity on the crop may vary with seasons of the year [10]. Observations on the population dynamics suggested that Antestia bugs population start to build up during flowering and attain peaks during the large berry formation. This is in line with the findings by [11] that Antestiopsis populations in East Africa build up around March and reaches peaks in May/June period. As the case in Tanzania, Arabica coffee flowering normally begin to appear October, and November, fruit starts to appear on January to march and fruit filling on May/June. During this period the Antestia bugs affect the crop differently depending on weather variation. [31] observed that climatic variables affect insect pests directly through modification of the physiological or behavioral systems or indirectly through modification of other factors such as the host plant and natural enemies. [11] observed that Antestia bugs are more prone to weather variables especially during wet season. [32] linked climatic variables such as temperature and rainfall to vary in time and space and dynamic effects on pests' density and associated damage.

The nature of the damage to the coffee plant is dependent on the type of pest involved [33]. Coffee berry infested by Antestia bug had lateral holes on the berries whereas those damaged by Coffee berry borer had galleries at the bottom of berries where eggs were mostly deposited [12]. Thus, the diagnostic signs of Antestia bug infestations differ according to the part of the plant affected as stated by [6] and [17]. Several authors have reported on the significance of antestia bugs on different coffee fruiting bodies. [6] reported Antestia bug damages to flowers cause flowers and flower buds to turn brown or black finally dropping off. Alternatively, the bud may completely fail to set flower. [34] indicated that the Antestia bugs attack flowers and green berries with resultant injection of saliva containing fungus spores which causes the taste defect. [35] reported feeding punctures that allow the Stigmatomycosis fungi and Nematospora to colonize the beans resulting in the rotting of endosperm. Despite the observed preferences, A. orbitalis feeds on green and red berries as well as shoots and flowers suggesting the ensured availability of food throughout the year [6]. Increased incidences and severity of Antestia bugs has been recent and is associated with several factors including the global warming and type of coffee farming practiced. Coffee crop grown under shaded ecology are more prone to the pest attack compared to those on open space or sparsely shaded areas. The contribution of climate change to Antestia bug incidences is supported with the report by intergovernmental panel on climate change [36] which estimated an increment in average global temperature from 1.4˚C to 5.8˚C by the end of this century, whereas areas around Kilimanjaro would be more affected. Temperature has been also mentioned by [35] as the most important environmental factor that affects insect distribution including Antestia bugs.

The incidence and severity of Antestia bugs in most of coffee fields in Tanzania ranged from low to high with fields in Kilimanjaro being severely affected. The study observed that the Arabica coffee fields with dense shades had more number of Antestia bugs, higher incidences and damage severities than those with sparse shades. According to [37], coffee in Tanzania is grown under shade trees and on open sun system. However, the canopy covers of shade in dense and sparse trees arrangements in different coffee fields vary according to regions [13]. Shades management has been observed as part of farming operations in coffee that contributes to pest incidences particularly the Antestia bugs. [37] reported that poor agronomic practices involving intensive intercropping of coffee with trees, other food crops like banana were among factors that reduces the coffee productivity and quality. [13] reported that some ecological traits of Antestia bug suggest that the bug prefers cool environments, populations are usually more abundant in bushy coffee trees and in dense shaded plantations, especially at medium and low elevation. Our present study revealed that areas in Kilimanjaro where the pest incidences and severities were high were characterized by agro systems known as Chagga home gardens, where vegetation usually develops in four layers of big trees for fruits, wood and dense shade, banana trees, coffee trees, and maize and/or vegetables at ground level [38]. Such complex systems lead to a wide range of dense shade, which may explain the variation observed in the bug density and damage severity in different regions as observed by other researchers [1]. Intensive intercropping has been linked with increased insect and disease attack, high nutrient mining and slow soil warming [37]. [13] reported that Antestia bugs' infestation levels have been reported to be higher in shaded coffee than in unshaded plantations, contrary to other coffee key pests such as coffee berry borer and thrips that thrive under full sunlight exposure. Shade tree regulation coupled with pruning of coffee trees are among the commonest cultural practices recommended for management of coffee insect pest including Antestia bug. The study observed that the low infestation and damage levels of Antestia bugs in Ruvuma and Songwe could be associated with not only the limited shading but also the presence of diverse natural enemies, which might keep the population of pests at low level.

The present study also indicated that coffee fruiting phenology influenced the Antestia bug damage incidence and severity. The combined average incidence of Antestia bug on foliar, flowers and fruits of Arabica coffee was 17.61%, 25.32% and 34.98%, and 0.89, 1.27 and 1.75 in dense and sparse shades respectively. Berries were the most vulnerable stage of the all components of fruiting phenology. The maximum number recorded for incidence was 100% during fruit phase and the minimum recorded was 0.05% and for severity, the highest was 5 out of 5 during fruit phase and the lowest was 0.003 and was during foliar phase. The varied pest preference of the different developmental stages of coffee was attributed to changing concentration of the bioactive compounds that occur in coffee as the crop develops to maturity. The Antestia bugs require different bioactive compounds found in the coffee tree to complete life cycle [39]. Antestia bug has incomplete metamorphosis development with six immature stages namely egg and five nymphal stages [6]. Each stage of development requires certain concentration of the bioactive compounds found in coffee growth to complete their life cycle. Although highest density of Antestia bugs was recorded on trees with large green berries the pest numbers declined as the berries ripened. On the other hand, available data suggest that the food source for different development stages of Antestia bugs could be highly varied and specialized such that different stages obtain suitable nutrients from specific coffee fruiting bodies [39]. [35] recorded high nymphs' mortality of up to 100% attributed to feeding only on coffee green berries. The mortality rate decreased when nymphs-rearing substrate was added with coffee leaves. [40] reported that the pre oviposition period (the time required by the female for ovary maturation and initiation of egg production) is known to be influenced by several factors acting during nymph development and sexual maturation such as food source. [39] observed that the olfactory system of the second instar nymphs of *Antestiopsis orbitalis* is adapted to locate suitable (unripe coffee berries) and avoid unsuitable (ripe coffee berries). It was concluded that Antestia bug populations are not only affected by the availability of food but the olfactory cues also play a key role in the host-finding. These attract or repel the Antestia bug in coffee farms with a high proportion of unripe berries and ripe berries. These facts by several authors concur with our findings that Antestia bug damage incidence and severity may rise with fruit maturity but subsequently decrease at the fruits ripening stage.

The correlation suggested a positive relationship between dense shade canopy and incidences and severities as well as Antestia bug damage on foliage, flowers and fruits. That is, the presence of dense shades led to increase in incidence and severity. Conversely, the correlation suggested negative relationship with the sparse shade. The presence of sparse shades was associated with the decrease in pest incidence and severity on foliage, flowers and fruits.

Antestia bugs have low economic thresholds of 1 - 2 Antestia bugs per tree that calls for an intervention with insecticide [15]. Limited investments in coffee pest management could have contributed to great abundance of the Antestia bugs. The fact that almost every tree had damage signs on the flowers, immature berries and young branches or the sight of eggs, nymphs and adult bugs as reported by [15] suggested the well-established populations of the bugs in the study areas. The study further established that most smallholder coffee farms are damaged by the bug infestation due to limited knowledge of correct pest identification and lack of financial support to properly manage the pest. Other workers [41] reported similar findings that pest and disease pressure were amplified by susceptible coffee cultivars and low use of agricultural inputs which contributed to low coffee yields in smallholding farms.

5. Conclusion

In all surveyed areas of Kilimanjaro, Ruvuma and Songwe, Antestia bugs were widely distributed varying in abundance and extent of damage incidence and severity levels. The variation in incidence and severity levels might be based on the shadiness of the coffee fields and the fruit phenology. The study possibly escalates attentiveness to the necessity to understand the effects of shade in the coffee field. The necessity to understand the critical time for intervention against Antestia bugs was proven paramount. Efforts to intensify control measures against the pest inclusive of cultural methods (pruning to minimize canopy shades), rational application of appropriate insecticides as well as integrated pest management (IPM) should be made to minimize damages inflicted by the Antestia bugs. Education to farmers to increase their awareness of the pests and empower them with proven control measures is imperative. Future studies should focus on the identification of locally existing natural enemies against Antestia bugs and the determination of their efficacy against the pest. Knowledge of the susceptibility or resistance of improved Arabica coffee varieties should also be of major focus in future research.

Acknowledgements

The authors are grateful to the Tanzania Coffee Board for funding the research work and providing material support during the study. Special thanks are due to the Tanzania Coffee Research Institute (TaCRI) staff at Lyamungo station (Kilimanjaro), Mbimba station (Songwe) and Ugano station (Ruvuma) for their support during data collection.

Funding

This research was partially funded by the Tanzania Coffee Board through study grants.

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author and can be made available upon reasonable request.

Conflicts of Interest

The authors declare that they have no competing interests.

References

[1] TCB (Tanzania Coffee Board) (2017) Tanzania Coffee Industry Development Strategy of 2011-2021. The Joint Stakeholders of Tanzania (2023), Kilimanjaro.

[2] Andrew, R. and Philip, D. (2014) Coffee Production in Kigoma Region, Tanzania: Profitability and Constraints; Development Studies Institute, Sokoine University of Agriculture. *Tanzania Journal of Agricultural Sciences*, **13**, 75-85.

[3] Tanzania National Coffee Sustainability Curriculum (TNCSC) (2023) Coffee Extension Materials. 2nd Edition, Joint Coffee Stakeholders of Tanzania, Kilimanjaro.

[4] National Bureau of Statistics (NBS) (2019) Statistical Abstract 2019. National Bureau of Statistics Ministry of Finance and Planning, Dar es Salaam.

[5] Aebissa, B. (2012) Developing Knowledge Based System for Coffee Disease Diagnosis and Treatment. Master's Thesis, Addis Ababa University, Addis Ababa.

[6] Alemu, A. (2016) Impact of Antestia Bug (*Antestiopsis* spp) on Coffee (*Coffea arabica* L.) Production and Quality. *Journal of Biology*, *Agriculture and Healthcare*, **6**, 18-22.

[7] Panhuysen, S. and Pierrot, J. (2020) Coffee Barometer 2020. Ethos Agriculture, Philadelphia.

[8] Pabro, S., Carlos, R. and Stavel, C. (2022) Smallholder Coffee in the Global Economy—A Framework to Explore Transformation Alternatives of Traditional Agroforestry for Greater Economics, Ecological and Livelihood Viability. *Frontiers in Sustainable Food System*, **6**, Article ID: 808207. https://doi.org/10.3389/fsufs.2022.808207

[9] Abedeta, C., Getu, E., Seyoum, E. and Hindorf, H. (2011) Coffee Berry Insect Pests and Their Parasitoids in the Afromontane Rainforests of Southwestern Ethiopia. *East African Journal of Science*, **5**, 41-50.

[10] Magina, F.L., Kilambo, D.L., Maerere, A.P. and Teri, J.M. (2016) Innovative Strategies for Control of Coffee Insect Pests in Tanzania: A Review. *Huria*: *Journal of the Open University of Tanzania*, **22**, 1-9.

[11] Bigirimana, J., Adams, C.G., Gatarayiha, C.M., Muhutu, J.C. and Gut, L.J. (2019) Occurrence of Potato Taste Defect in Coffee and Its Relations with Management

Practices in Rwanda. *Agriculture*, *Ecosystems and Environment*, **269**, 82-87. https://doi.org/10.1016/j.agee.2018.09.022

[12] Bigirimana, J., Gerard, A., Mota-Sanchez, D. and Gut, L.J. (2018) Options for Managing *Antestiopsis thunbergii* (Hemiptera: Pentatomidae) and the Relationship of Bug Density to the Occurrence of Potato Taste Defect in Coffee. *Florida Entomologist*, **101**, 580-586. https://doi.org/10.1653/024.101.0418

[13] Mugo, H.M., Kinemia, J.K. and Mwangi, J.M. (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.

[14] Chichaybelu, M. (2008) Seasonal Abundance and Importance of Antestia Bug (*Antestiopsis intricata*) in Southwest Ethiopia. 291-295.

[15] McPherson, J.E. (2018) Invasive Stink Bugs and Related Species (Pentatomoidea): Biology, Higher Systematics, Semiochemistry, and Management. CRC Press, Boca Raton, 465-493. https://doi.org/10.1201/9781315371221

[16] Feed the Future (2017) Control of Antestia/PTD and Improving Coffee Productivity in Burundi and Rwanda. 15*th Africa Fine Coffee Conference* (*AFCA*), Addis Ababa, 17 February 2017, 19-20.

[17] Abebe, M. (1987) Insect Pests of Coffee with Special Emphasis on Antestia, *Antestiopsis intricata*, in Ethiopa. *International Journal of Tropical Insect Science*, **8**, 977-980. https://doi.org/10.1017/S1742758400023274

[18] Waller, J.M., Bigger, M. and Hillocks, R.J. (2007) Coffee Pests, Diseases and Their Management. University of Rwanda, Kigali. https://doi.org/10.1079/9781845931292.0000

[19] Overmars, K.P., De Koning, G.H.J. and Veldkamp, A. (2003) Spatial Autocorrelation in Multi-Scale Land Use Models. *Ecological Modeling*, **164**, 257-270. https://doi.org/10.1016/S0304-3800(03)00070-X

[20] Azrag, A.G.A. (2019) Future Distribution and Life History Traits of Three Major Insect Pests of Arabica Coffee (*Coffea arabica* L.) in East Africa; Risk Assessment in Light of Global Warming. Ph.D. Thesis, University of Pretoria, Pretoria.

[21] Cardoso, J.E., Santos, A.A., Rossetti, A.G. and Vidal, J.C. (2004) Relationship between Incidence and Severity of Cashew Gummosis in Semiarid North-Eastern Brazil. *Plant Pathology*, **53**, 363-367. https://doi.org/10.1111/j.0032-0862.2004.01007.x

[22] Enikuomehin, O.A. and Peters, O.T. (2002) Evaluation of Crude Extracts from Some Nigerian Plants for the Control of Field Diseases of Sesame (*Sesamum indicum* L.). *Tropical Oilseeds Journal*, **7**, 84-93.

[23] Phiri, N.A., Hillocks, R.J. and Jeffries, P. (2000) Incidence and Severity of Coffee Diseases in Smallholder Plantations in Northern Malawi. *Crop Protection*, **20**, 325-332. https://doi.org/10.1016/S0261-2194(00)00161-7

[24] Joseph, B., Kiane, N., Daphrose, G. and Noah, A.P. (2012) Incidence and Severity of Coffee Leaf Rust and Other Coffee Pests and Diseases in Rwanda. *African Journal of Agricultural Research*, **7**, 3847-3852. https://doi.org/10.5897/AJAR11.955

[25] Anjorin, S.T., Jolaoso, M.A. and Golu, M.T. (2013) A Survey of Incidence and Severity of Pests and Diseases of Okra (*Abelmoschus esculentus* L. Moench) and Eggplant (*Solanum melongena* L.) in Abuja, Nigeria. Department of Crop Science, Faculty of Agriculture, University of Abuja, Abuja.

[26] Eugénie, C. (2015) Statistics Methods for the Assessment of Coffee Yield Losses Caused by Pests and Diseases under Different Production Situations. Mémoire de Fin d'Études: Institut National des Sciences Appliquées de Toulouse (INSA), Toulouse, 62 p. https://agritrop.cirad.fr/577252/

[27] Rolshausen, P.P. and Dzung, A. (2018) A Taste of Coffee. News from Subtropical Tree Crop Farm Advisors in California. Vol. 17, Springer, Berlin.

[28] Pallangyo, B., Mdily, K., Mkondo, C. and Kibola, A. (2019) Crop Pests, Control Measures and Potential Impacts in Kihansi Catchment Area. *Tanzania Journal of Science*, **45**, 650-660.

[29] Kimani, M., Little, T. and Vos, J.G.M. (2002) Introduction to Coffee Management through Discovery Learning. Farmer Participatory Training and Research Program. CABI Bioscience, Nairobi, 35-38.

[30] Matsuura, Y., Hosokawa, T., Serracin, M., Tulgetske, G.M., Miller, T.A. and Fukatsu, T. (2014) Bacterial Symbionts of a Devastating Coffee Pest, the Stinkbug *Antestiopsis thunbergii* (Hemiptera: Pentatomidae). *Applied and Environmental Microbiology*, **80**, 3769-3775. https://doi.org/10.1128/AEM.00554-14

[31] Bale, J.S., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K. and Good, J.E. (2002) Herbivory in Global Climate Change Research: Direct Effects of Rising 416 Temperatures on Insect Herbivores. *Global Change Biology*, **8**, 1-16. https://doi.org/10.1046/j.1365-2486.2002.00451.x

[32] Wallner, W.E. (1987) Factors Affecting Insect Population Dynamics: Differences between Outbreak and Non-Outbreak Species. *Annual Review of Entomology*, **32**, 317-340. https://doi.org/10.1146/annurev.en.32.010187.001533

[33] Mwangi, J.S. (2021) Coffee Entomology Pests, Kenya.

[34] Wangui, K.J. (2012) Effects of Climate Variability on Large Scale Coffee Production in Kigutha Coffee Estate in Kiambu County, Kenya. Master's Thesis, Kenyatta University, Nairobi, 85 p. https://ir-library.ku.ac.ke/bitstream/handle/123456789/11129/Effects%20of%20climate%20variability%20on%20large%20scale%20coffee%20production%20in%20Kigutha%20coffee%20estate%20in%20Kiambu%20County%2C%20Kenya.pdf?sequence=1&isAllowed=y

[35] Ahmed, A.G., Murungi, L.K. and Babin, R. (2016) Developmental Biology and Demographic Parameters of Antestia Bug *Antestiopsis thunbergii* (Hemiptera: Pentatomidae), on *Coffea arabica* (Rubiaceae) at Different Constant Temperatures. *International Journal of Tropical Insect Science*, **36**, 119-127. https://doi.org/10.1017/S1742758416000072

[36] IPCC (2014) AR5 Climate Change 2014: Impacts, Adaptation and Vulnerability. Summary for Policy Makers. https://www.ipcc.ch/report/ar5/wg2/

[37] Otieno, H.M., Alwenge, B.A. and Okumu, O.O. (2019) Coffee Production Challenges and Opportunities in Tanzania: The Case Study of Coffee Farmers in Iwindi, Msia and Lwati Villages in Mbeya Region. *Asian Journal of Agricultural and Horticultural Research*, **3**, 1-14. https://doi.org/10.9734/ajahr/2019/v3i229993

[38] Hemp, A. (2006) The Banana Forests of Kilimanjaro: Biodiversity and Conservation of the Chagga Home Gardens. *Biodiversity and Conservation*, **15**, 1193-1217. https://doi.org/10.1007/s10531-004-8230-8

[39] Njihia, T.N., Torto, B., Murungi, L.K., Irungu, J., Mwenda, D.M. and Babin, R. (2018) Ripe Coffee Berry Volatiles Repel Second Instar Nymphs of Antestia Bugs (Heteroptera: Pentatomidae: *Antestiopsis thunbergii*). *Chemoecology*, **28**, 91-100. https://doi.org/10.1007/s00049-018-0259-3

[40] Ruberson, J.R., Tauber, J.M. and Tauber, C.A. (1986) Plant Feeding by *Podisus maculiventris* (Heteroptera: Pentatomidae): Effect on Survival, Development, and Preoviposition Period. *Environmental Entomology*, **15**, 894-897. https://doi.org/10.1093/ee/15.4.894

[41] Bravo-Monroy, L., Potts, S.G. and Tzanopoulos, J. (2016) Drivers Influencing Farmer Decisions for Adopting Organic or Conventional Coffee Management Practices. *Food Policy*, **58**, 49-61. https://doi.org/10.1016/j.foodpol.2015.11.003