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Coffee leaf damaging insects' occurrence in the forest coffee ecosystem of southwestern Ethiopia

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Insects are diverse and abundant in forest ecosystems, but poorly documented in afromontane rainforests in Southwestern Ethiopia where *Coffea arabica* L. originated and is distributed worldwide. Therefore, the present study was initiated to study the occurrence of coffee leaf damaging insect pests in the afromontane rainforest of southwestern Ethiopia. Accordingly, surveys on insect pest of coffee were conducted to investigate pest status and; their damaging intensity in three (Yayu, Berhane-kontir and Bonga) forest coffee ecosystems. Based on general uniformity of forest coffee population, each forest coffee was stratified into three forest sites and 16 trees were systematically selected for leaf insect damage assessment. Survey and damage assessment results reveal that, coffee leaf damaging insect pests in afromontane rainforests of Southwestern Ethiopia include 12 insect families from five insect orders. Mean incidence data showed, significant different (P< 0.05) during different survey seasons within and between three forest coffee populations. Among the frequently occurred and damage causing insect pests were *Leucoplema doherthyi*, *Cryphiomystis aletreuta*, coffee giant looper and *Leucoptera* species and had 72.20 ± 1.42, 14.41 ± 5.15, 10.73 ± 4.30 and 2.63 ± 1.24 proportion damage across forest coffee populations, respectively. There is also high variation among major coffee leaf damaging insect during different seasons (rainy, rainy to dry transition, dry and dry to rainy season transition season). Generally, there were differences in insect pest incidence between and within forest coffee populations with regard to coffee leaf damaging insects and relatively low incidence observed compared to other coffee production systems. The present findings complement other research results meant for the conservation of remnant forest and its biodiversity especially to explore the natural enemies in these forest ecosystems.

Key words: *Coffea arabica* L., forest coffee, southwestern Ethiopia, insect pests, season.

INTRODUCTION

Coffee is an evergreen perennial crop grown in ecosystems, which favors insect pest to survive from year to year (Wrigley, 1988). According to Le Pelley (1968), one particular consequence for this reason is; it is not

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possible without coffee to employ the useful method of pest control applied for as annual crops particularly cultural control like “closed season” during which the crop is completely removed from the field. In general, succulent green shoots, leaves, flowers, and young fruits of coffee plant parts are attacked by different chewing and sucking insects (Wrigley, 1988; Mugo, 1994).

Despite the existence of suitable natural conditions for coffee production, the average national yield is very low in Ethiopia. Insect pests are among a number of factors that contribute to low yield (Mesfin, 1989; Million, 2000). Over 49 species of insect pests were recorded on coffee in Ethiopia, which were categorized as major, potential and minor pests (Million, 1987; Esayasl et al., 2006). Antestia bugs, *Antestiopsis intricata* (Ghesquiere and Carayon) and *Antestiopsis facetiodes* (Greathead) and coffee leaf miner, *Leucoptera caffeina* (Washbour) are considered as major insect pests of coffee particularly in large scale farms. Coffee berry borer, *Hypothenemus hampei* (Ferriere) is a potentially important insect pest of coffee in Ethiopia. Coffee insect pest status and category have been studied in plantation, garden and to some extent in semi-forest coffee production systems, but there is no single study so far conducted in forest coffee ecosystem, where coffee is grown as wild and used as organic product.

Furthermore, the diversity and the economic value of the Ethiopian coffee gene pool and its forest habitat as well as the institutional framework of forest users have been studied. The *in-situ* conservation of wild coffee offers an interesting approach in biodiversity conservation including both flora and fauna (Chemeda et al., 2011a, b; COCE, 2007). However, still the status of insect pest has not been assessed and described; and no reliable information exists in such genetically diversified ecosystems. In order to supplement *in-situ* conservation of the genetically diversified forest coffee plant and associated fauna for sustainable use, it is crucial to study the status of insect pests in different afromontane rainforest coffee populations and examine the extent of damage they inflict. Hence, the current study was initiated to obtain base line information on the status of forest coffee leaf damaging insect pests to contribute significantly to the overall conservation of forest coffee which is considered as source of organic coffee to the world market. Therefore, the study was initiated with the objective to investigate occurrence and incidence of coffee leaf damaging insect pests in afromontane rainforests of southwestern Ethiopia.

MATERIALS AND METHODS

Description of the study sites

The study sites were selected based on previous studies of joint project between the Center for Development Research (ZEF), Bonn University, Germany and the Ethiopian Institute of Agricultural Research (EIAR), Ethiopia, which focuses on “conservation and use of the wild populations of *C. arabica* in the montane rainforests of Ethiopia”. It was undertaken in Yayu (Gaba-dogi), Berhane-kontir and Bonga forest coffee populations, which are located 580, 620 and 420 km away from Addis Ababa to southwestern part of the country, respectively. Yayu forest coffee population is found in western part of Oromia Regional State, while Berhane-kontir and Bonga coffee populations are found in the Southern Nation Nationalities Peoples Regional state" (SNNPRs). The forest coffee populations are representatives of the different agro-ecologies for forest coffee production areas with elevations ranging from 1050 to 1900 m.a.s.l. and all exhibit tropical humid climate. From each forest coffee population, three representative sites of approximately one hectare was selected for the study. Plots were ecologically described including the slope, aspect (direction) and altitude within different gradient. Clinometer and compass were used to measure the slope and the aspect, respectively. Co-ordinates for the study sites were recorded using Geographic Positioning System (GPS) (Table 1).

In order to characterize shade structure (canopy coverage), forest inventories was made at each site. A 20 by 20 m plot replicated three times was used to describe the shade status for each site. Shade canopy coverage was visually estimated and classified into three classes: Low, medium and dense shade tree coverage which coincides with < 40, 40 - 60% and > 60% canopy coverage, respectively.

Experimental tree selection, insect specimen collection and damage assessment

A reconnaissance survey was carried to find out general information about each forest coffee populations, to select and tag experimental trees in each forest site. Based on general uniformity of coffee trees, shade status and elevation of forest coffee population, each population was classified into three forest sites (Table 1). Forest coffee population refers to three forest localities, while sites are strata in each population. Latter on from each site 16 trees were systematically selected employing the zigzag sampling method and tagged for leaf damage assessment. Furthermore, each tree was stratified into three-canopy layer and a pair of branch from each layer was selected for the assessment of leaf damaging insects.

Insect samples were collected during different coffee fruit phenological stages four times in all selected forest populations. Specimens were collected using different methods including hand collection, aspirator and sweep net. Collected insect samples were labeled with information including co-ordinates, altitudes, slopes, date of collection and developmental stage of the pest. All insect specimens were identified at the Biosystematics Department of the International Center for Insect Physiology and Ecology (ICIPE), Nairobi, Kenya.

Damage assessment was made by counting total and damaged leaves from lower, middle and upper canopy branch leaves in July, October, January and April 2007/08 cropping season, representing rainy, autumn (rainy to dry season transition), winter (dry season) and spring (dry to rainy season transition) of the year, respectively. The percentages of damaged leaves were computed from the cumulative number of damaged leaves to total number of leaves for each canopy branches.

Data processing and analysis

Forest coffee populations, sites, seasons (referring to data collected month) and percentage leaf damage were considered for statistical analysis. All measurements of count data of damaged leaves were tested for normality using SAS software Proc Univariate. Data violate the assumption of ANOVA or normality was square root

Table 1. Descriptions of forest coffee study sites.

Forest coffee Population	Forest site[1]	Shade status[2]	Elevation (m)	Co-ordinates		Slope (%)	Aspect or Direction
	PIVSI	Low	1493	N-08° 24' 11"	E-035° 47' 44"	10	East
Yayu	PIVSII	Medium	1491	N-08° 23' 98"	E-035° 47' 40"	16	West
	PIVSIII	Dense	1496	N-08° 23' 10"	E-035° 47' 62"	20	West
	PIIISI	Medium	1051	N-07° 07'43"	E-035° 26' 16"	15	North
Berhane-Koniter	PIIISII	Dense	1084	N-07° 07' 16"	E-035° 26' 29"	13	N-East
	PIIISIII	Low	1134	N-07° 06' 52"	E-035° 26' 33"	20	East
	PIISI	Medium	I744	N-07° 20' 01"	E-035° 13' 39"	5	East
Bonga	PIISII	Dense	1739	N-07° 20' 31"	E-035° 13' 32"	10	East
	PIISIII	Medium	1894	N-07° 19' 04"	'E-035° 03' 31"	8	N-West

[1]PII, PIII and PIV = Codes given to Bonga, Berhane-Kontir and Yayu forest populatins, while SI, SII and SIII are Site one, Site two and three, respectively. [2]Low = shade coverage < 40%, Medium= shade coverage 40% - 60%, and Dense = shade coverage > 60%.

Table 2. Coffee leaves damaging insects in the forest coffee ecosystem of southwestern Ethiopia.

Common name	Order	Family/species	Occurrence / status	Collected FCP*
Black thread scale	Homoptera	Diaspididae	Rare	2 and 3
Brown totrix	Lepidoptera	Tortricidae	Rare	2 and 3
Coffee aphid	Hemiptera	Aphididae	Rare	2 and 3
Coffee leaf miner	Lepidoptera	Lyonetiidae *Leucoptera spp.*	Frequent	1, 2 and 3
Coffee cushion scale	Homoptera	Stictococcidae	Rare	2 and 3
Coffee hawk moth	Lepidoptera	Sphingidae	Rare	2 and 3
Coffee thrips	Thysanoptera	Thripidae	Rare	1 and 2
Coffee leaf skeletonizer	Lepidoptera	Epiplemidae *Leucoplema doherthyi* Warren)	Frequent	1, 2 and 3
Dust brown beetle	Coleoptera	Tenebrionidae	Rare	1 and 3
Coffee giant looper	Lepidoptera	Geometridae	Frequent	1, 2 and 3
Helmet scale	Homoptera	Coccidae	Rare	2and3
Mussel scale	Homoptera	Diaspididae	Rare	2 and 3
Serpentine leaf minor	Lepidoptera	Gracillariidae *Cryphiomystis aletreuta (*Meyrick)	Frequent	1, 2 and 3
Stinging caterpillar	Lepidoptera	Limacodidae	Rare	2 and 3
Systates weevil	Coleoptera	Curculionidae	Rare	2 and 3

*[1]Yayu, [2]Berhane-Kontir and [3]Bonga forest coffee populations (FCP).

transformed to normalize the data and to meet assumption of ANOVA before executing statistical analysis. Transformed percentage damaged leaves were compared using the SAS package for windows-v8 (SAS Institute Inc. Cary NC, USA). One-way ANOVA with nested design was performed to analyze coffee plant-insect relations.

Nested design of SAS proc mixed was used to analysis variation in infestation across locations and data collection months (seasons). Wherever significant difference ANOVAs (F-ratios) was found for means at the 5% probably level, means were separated using Tukey's Honestly Significant Difference (HSD) test.

RESULTS

Level of damage by coffee leaf insect pests

Surveys result of coffee insect pests in afromontane rainforests of southwestern Ethiopia recorded 12 insect families from five insect orders (Table 2). Not all insect pests collected frequently occurred in all forest coffee ecosystems. Based on number of recorded site and

Table 3. Mean (± SE) damaged coffee leaves during different survey seasons and forest coffee populations in afromontane rainforests of southwestern Ethiopia.

Season during data collected	Forest coffee population			P- value
	Yayu	Berhane- Kontir	Bonga	
Rainy	35.73 ± 2.127bA	46.05 ± 1.611aA	17.40 ±1.053cA	<.0001
Transition (rainy to dry)	8.47 ± 0.579 C	8.82 ± 0.552D	9.16 ± 0.664C	0.7150
Dry	11.01± 0.903b B	13.40 ± 0.875abC	14.18 ± 1.241a B	0.0325
Transition (dry to rainy season)	10.04 ± 0.580cB	21.10 ± 0.741a B	16.83 ± 0.814b A	<.0001
P-value	<.0001	<.0001	<.0001	-

Means followed by the same letter(s) within a raw (lower case) and means followed by the same letter within a column (upper case) are not stastically significant at 5%, Tukey´s Honestly Significant Difference (HSD) test.

frequency of occurrence, insects in forest ecosystems of southwestern Ethiopia were categorized into two: rarely and frequently occurring insect pests of coffee. Generally rarely occurred insects were recorded once or twice in one and/two forest populations, however frequently occurring insect pests cause visible damage symptoms and recorded for more than two times in all forest coffee populations. Of the insect pests of coffee leaves, *L. doherthyi*, *C. aletreuta*, *Leucoptera* spp and Coffee giant looper, Geometridae were very common and causing visible damage on coffee leaves in all forest coffee forest surveyed in southwestern Ethiopia.

The mean incidence of coffee leaf damage varied between 10 and 56% with an average of 33% across the study coffee populations during rainy season. Of the total sites, 62% of them showed leaf damage incidence between 20 and 50%, 12% had more than 50% incidence and only 25% had less than 20% leaf damage with the lowest mean incidence of 10% recorded at Bonga forest coffee population. Analysis of Variance result showed a significant difference ($P < 0.05$) among forest coffee populations in level of coffee leaf damage insect pest with the highest mean recorded at Berhane-Kontir (46.05%) followed by Yayu (35.73%) and Bonga coffee population (17.40%) (Table 3). However, there is no significant difference ($P > 0.05$) among forest coffee populations in the level of leaf damage during rainy to dry season transaction survey period (Table 3). However, the mean incidence vary from 4-15% with the mean of 9% at Bonga, 8% at Berhane-Kontir and 8% at Yayu forest coffee populations. Similarly, dry season survey result revealed, there was significant difference ($P<0.05$) between Yayu and Bonga forest coffee populations. However, there was no significant difference between Berhane-Kontir and Yayu, and Berhane-Kontir and Bonga forest coffee population. But, variations in mean damages were observed across forest coffee populations (Table 3).

Data collected during dry to rainy season revealed that, 79% of the forest coffee populations showed more than 10% leaf infestation. However, there was a significant difference ($P < 0.05$) among forest coffee populations (Table 3).

Major coffee leaf damaging insects

Coffee leaf skeletonizer, Leucoplema doherthyi

It can be noticed that all the coffee tree under observation showed damage caused by insects. However, damage proportion caused varies among the major coffee leaf damaging insects at different seasons and forest coffee populations. Coffee leaf skeletonizer was among the most commonly occurring insect pests causing coffee leaf damage and showing the highest proportion of damage incidence (59%) out of 33% leaf damage incidence caused by the four most frequently occurring coffee leaf insect pest during rainy season data collected. Also, data collected three month later revealed, the pest showed the highest proportional damage incidence (70%) across forest coffee populations with and as high as 84 and 78% for data collected during dry and dry to rainy season transition, respectively (Table 4). Considering Yayu, Berhane-konter and Bonga forest coffee populations, coffee leaf skeletonizer shared about 71, 72 and 74% proportional damage, respectively to other three major coffee leaf damaging insects (Figure 1).

Serpentine leaf miner, Cryphiomystis aletreuta

Among all commonly occurring insect pests of coffee, coffee leaf skeletonizer ranked first followed by serpentine leaf miner with 72 and 14% proportion incidence throughout the study seasons and forest coffee populations, respectively. Coffee serpentine leaf miner showed 20, 14, 15 and 8% proportion incidence in rainy, rainy to dry, dry and dry to rainy seasons data collected time, respectively, compared to other coffee leaf

Table 4. Mean (± SE) proportion damage of coffee leaf by major insect pests coffee during different seasons in afromontane rainforest southwestern of Ethiopia.

Season	Serpentine leaf miner	Coffee leaf miner	Coffee leaf skeletonizer	Coffee gaint looper
Rainy	20.56 ± 1.09	9.12 ± 6.69	59.37 ± 8.90	10.95 ± 9.76
Transition (rainy to dry)	14.14 ± 14.10	1.09 ± 1.11	66.91 ± 11.04	17.93 ± 14.51
Dry	15.11 ± 12.89	0.08 ± 0.13	84.20 ± 12.31	0.62 ± 0.74
Transition (dry to rainy)	7.84 ± 5.64	0.25 ± 0.24	78.32 ± 8.09	5.25± 3.19

± = Mean plus or minus standard error of mean

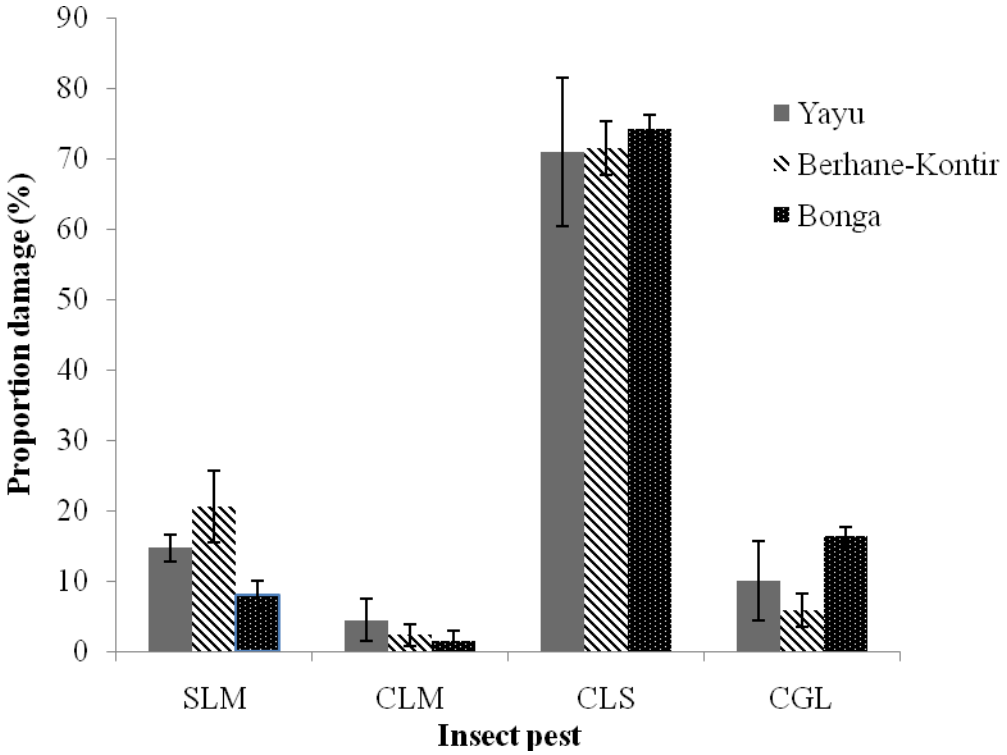

Figure 1. Mean (± SE) damage proportion by coffee leaf insect pests in three forest coffee ecosystems of southwestern Ethiopia. SLM= Serpentine Leaf Miner; CLM= Coffee Leaf Miner; CLS = Coffee Leaf Skeletonizer; CGL= Coffee Gaint Looper. Error bar (±) = Mean plus or minus standard error of mean

damaging insect pests (Table 4). However, 15% (Yayu), 21% (Berhane-konter) and 8% proportional damage were observed at Bonga forest coffee population compared to other leaf damaging insects (Figure 1)

Coffee gaint looper

Coffee gaint looper ranked third in terms of proportional incidence as it showed incidence of 10% (rainy), 18% (rainy to dry season transition), 0.20% (dry) and 13% (dry to rainy season transition) (Table 4). Also, 10%, 6% and 16% proportional damage were recorded at Yayu, Berhane-konter and Bonga forest coffee populations, respectively (Figure 1).

Coffee leaf miner, Leucoptera spp.

Among all commonly occurring insects pests of coffee leaf, coffee leaf miner ranked at last with the mean proportional incidence of 3% across seasons and forest coffee populations. Coffee leaf miner showed variation in terms of proportional incidence of 9% in rainy season and 0.08% in dry season compared to the other coffee leaf damaging insects (Table 4). The target pest showed about 5% damage as maximum at Yayu and 2% as lowest proportional damage at Bonga forest coffee popu-

lation compared to other leaf damaging insects (Figure 1).

DISCUSSION

Twelve (12) insect families from five insect orders of coffee leaf damaging insect were recorded in afromontane rainforests of southwestern Ethiopia. Afromontane rainforests in southwestern part of the country are characterized by complex ecosystems, in which many components including insect pests interact towards a prevailing equilibrium with natural enemies towards a steady state. As a result, occurrence and distribution of coffee insect pests was relatively low, probably due to the efficient role of natural enemies in stable ecosystems as there is minimum human intervention in these protected ecosystems. Different authors reported vegetation diversity play key role in insect pest management and their population response (Altier and Nicholls, 1999; Andow, 1991; Gibson and Jones, 1977).

Generally, data collected during different seasons highlights that there is variation within and between forest coffee populations in seasonal abundance and effects of coffee leaf insects pests. This result is in line with the hypothesis that, for tropical rainforests the rainy season is the most favorable period for the activities of leaf eating insects (Gombauld and Rankin-de-Merona, 1998), which totally agree with current study of coffee leaf damaging insects with highest incidence of 33.06%, when the amount of rain fall was very high compared to the other seasons. Furthermore, difference in genetic diversity of wild coffee populations as well as the intensity of cultural practices from one forest populations to another and within the same forest coffee ecosystem could be resulted in variations in the extent of insect incidence across forest coffee populations. Similarly, damage intensity by major coffee leaf damaging insects showed a great variation in their intensity across forest coffee populations.

Coffee leaf skeletonizer was observed in all forest coffee populations during all seasons varying and more abundantly compared to other leaf damaging insects. Million and Bayisa (1986) reported coffee leaf skeletonizer as potentially occurring insect pests of coffee in plantation and other production system; however the intensity was lower than coffee leaf miner. It reveals that different coffee production systems resulted with different level of occurrences/and damage level with the same insect pest in the country. Similarly, report from Kenya by Waikwa (1981) indicated that coffee leaf skeletonizer is a common pest of coffee in the lower and medium altitudes of coffee growing areas. However, Crowe (2004) reported that coffee leaf skeletonizer considered is a minor pest of coffee Arabica and Robusta in Kenya, Uganda and Democratic Republic of Congo without mentioning incidence can be inflected by the target pest.

Coffee serpentine miner comes after coffee leaf skeletonizer in importance in forest coffee populations of the study areas. However, there was no report on the incidence of coffee serpentine leaf miner from Ethiopia, but Million and Bayisa (1986) stated that the pest was very common in most coffee growing areas of Ethiopia though their population was highly suppressed by the natural enemies. The authors also reported, coffee serpentine miner can easily build its population and reach damaging level if its parasitoids are killed by pesticides as witnessed by the application of dieldrin to control ants in Mizan Teferi.

Coffee gaint looper ranked third in level of incidence in forest coffee populations with about 11% infestation among all major coffee leaf damaging insects. Waikwa (1981) also reported that Coffee gaint looper is most common and densely populated in areas of hot weather coffee growing areas in Kenya. Similarly, Crowe (2004) stated this insect pest became prominent in Kenya in 1961 following the spraying of parathion. However, coffee leaf miner, *Leucoptera* species showed relatively the lowest proportional incidence among major leaf damaging insects across forest coffee populations. However, study by Million and Bayisa (1986) and Million (1987, 2000) reported that coffee leaf miner comes next to Antestia bug in importance causing heavy defoliation when there is sever infestation in other coffee production systems other than forest. Studies conducted at Agaro Sub-Center, southwestern Ethiopia indicated that percentage leaf damage due to this insect pest ranged from 2.2 - 55% with an average of 13% infestation (IAR, 1986).

The result of this study indicated that there was no coffee tree free from insect pest attack. At least one insect pest species is associated with it. However, damage was mostly negligible and very low. And, generally incidence of forest coffee insect pests observed was relatively low compared to the other coffee production systems in the country and other coffee producing countries.

As the result, present research findings suggest that, these coffee stands may not urgently recommend additional control for leaf damaging insects, but it supplements other research findings to conserve remnant forest and its biodiversity in southwestern part of the country. Especially, it can serve as areas for exploration of different natural enemies for key and chronic pests of coffee production worldwide.

Conflict of interest

The authors have not declared any conflict of interest.

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