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Research Article

Coffee leaf miner ecosystem: Case study on Agro-ecological distribution and Socio-economic impact of coffee leaf miner *Leucoptera coffeella* (Guérin-ménèville) (Lepidoptera: Lyonetiidae)

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- Coffee agro-ecology
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- Coffee leaf miner

Abstract

Coffee is essential natural resource that plays a great role in social, cultural, economic and political values in the study area. However, it is under production constraint and challenge caused by different factors. One of the most challenging factors in coffee production is coffee leaf miner (*Leucoptera coffeella* L.). This research was aimed to assess Agro-ecological distribution and socio economic impact of the pest in the study areas so as to address the challenges of coffee production using pest management strategies of the pest. Both primary and secondary data were used and total of 147 sample household of coffee farms were used for the investigation. Data were analyzed using descriptive statistics like percentage, inferential statistics and frequency rank weight method. The study discovered that the spatial occurrence of the pest is higher in Woinadega followed by Dega and Kolla agro climate zone of study area respectively. Woinadega agro climate zone is suitable for severe distribution of pest. This is because of moist humid and warm tropical climatic conditions which is important for best proliferation or multiplication of pest. However, most of the populations in the area depend on coffee product; the pest reduces yield of coffee in relation to other factors. It is suggested that creating community awareness, strengthening the best traditional and community based management system, introducing improved coffee plant, encouraging local people to participate in the protection and management of the pest could be the possible alternatives to overcome problems caused by coffee pest.

INTRODUCTION

Historically, the origin of coffee (Coffea arabica L.) was the montane rainforests of Kaffa in South-Western Ethiopia [1]. Since then, early written testimonials and legendary thoughts depicted as that Kaffa Zone or area is not only the cradle of Coffea arabica/ Arabica coffee but also the name of coffee were transferred from the name of "Kaffa"clan living around and coffee user in line with other forest resources.

Complementary, according to [2], the origin and center of the genetic diversity of Coffee arabica lies in the south western region of Ethiopia, Kaffa kingdom, Decha Woreda Makira Kebele in which Buni village. Grandmother of coffee tree is alive today there in Buni village. Coffee is described as Buna in Amharic, native Ethiopian language in which the name was driven from the Buni village in Decha district of Kaffa Zone, where coffee was originated [3]. Kaffa is the origin land of coffee arabica. Overwhelmingly as a natural part of the ecosystem (naturally grown shrub) coffee was found in Kaffa and spread to different parts of Ethiopia as well as different parts of the world society [4] .

Coffee is one of the highly preferred international beverages and the most important traded commodities in the world next to petroleum [5]. Ethiopia contributes a total of 7 to 10% coffee induction to the world [6]. It is the most important export commodity for Ethiopia and it accounts for about 34% of value of all exports [7]. In Ethiopia, the coffee is important to the economy of the country which is used as source of foreign income and also millions of the population relying on coffee production for their livelihood [8].

Coffee plays an economic, social, cultural and spiritual value and has lion share in the study area. Which means coffee history and activities of all peoples in the study area have been two sides of the same coin. As many studies show that coffee consumption prevent several chronic diseases. The long term coffee consumption is associated with significant dose-dependent reductions in the risk of developing type 2 diabetes [9]. Coffee

intake also reduces the risk of liver damage in people at high risk for liver disease including hepatic injury, cirrhosis, and hepatocellular carcinoma [10]. Still this is applied in the study area particularly. This means coffee is believed to be medicine for different diseases among Kaficho people of the study area. They use coffee to treat different diseases. For example, to treat diarrhea, headache and dries wound. To nurse back to health diarrhea, coffee powder is assorted with honey and given to the patient. To treat headache, they make organic coffee and drink it over and over again. To dry wound like modern tetracycline, Kaficho people grind roasted coffee and put it on the wounded area and truly they use it still now. Not only human beings, but also the oxen among Kaficho people look to have coffee with something to eat and got motivated to plow and otherwise they feel wear out and will bring to a standstill.

Culturally the roasted coffee is presented to the owner of a house to smell it. So that, he may face good luck. When coffee boiled and ready for drink, the traditional ceremony is the head of the family pray and the first poured cup of coffee discharged on the ground for guardian spirit in Kafigna "*Showee Qoolloo*". This is assumed to create peace with "*God of the earth*" which is known as "*Coroo*". Coffee is used also for the sake of ceremony and builds important social harmony. It is the culture of Kaffa people to invite a guest, even to a meal by saying "*Please drink a cup of coffee*". Almost all inhabitants of the site have made it a tradition as not to leave their home without drinking coffee from morning up to evening to have good day. Not doing so in morning is believed to bring bad luck throughout a day. Though, the production and productivity of coffee has been challenged by various factors. One of this is coffee leaf miner pest. This pest influences the above social, cultural, economic and traditional importance of coffee seriously. Insect pests cause up to 20% of crop loss and reduce coffee value by 30 to 40% [11]. This great influence of the pest has not been addressed well except sporadic reports by different authors specifically in the study area. The in-situ conservation of wild coffee offers in interesting approach in biodiversity conservation including both flora and fauna [12]. However, still the prominence of insect pest has not been measured, described and no more information exists in such historically rich and origin land of coffee.

Hence the current study initiated to obtain baseline information about occurrence and incidence of coffee leaf miner pest to contribute significantly to the overall conservation of coffee in the particular area of this study.

MATERIALS AND METHODS

Description of the study area

Location of the study area: The study was conducted at South Nations Nationalities and Peoples Region of Ethiopia, Kaffa Zone, particularly Chena Woreda. The Woreda was chosen because of its high coffee producing potential in Kaffa Zone [13]. Chena is one of the ten Woreda's and one administrative town found in Kaffa Zone. The name Chena comes from one of the provinces in the former Kingdom of Kaffa, whose administrative center had been at Wacha. Part of the Kaffa Zone, Chena is bordered on the south by the Bench Maji Zone, on the west by Bita, on the north by Gewata, on the northeast by Gimbo and on the east by Decha. Towns in Chena include Shisho-inde. This Woreda is found in the Southwestern part of Ethiopia which is 78km, 541km and 815km far from Bonga, Addis Ababa and Hawassa, respectively.

Besides, other study area the selected study areas such as Dahera, Gawtata and Kulish Kebele's are found 18km, 26km and 7kms away from Wacha town, respectively and the Woreda lies between 07^0 09'01"N latitude and $035^0$48'51"E Longitude [14].

Most of the command area at present is covered with coffee plants and it is the base for their economy, and has cultural and social issue for the growers of this area. The geographical location of the study area is depicted below Figure 1.

Relief and drainage

According to the Woreda Agricultural and Rural Development office, the physical features of Woreda have valleys, gorges, plains, plateaus etc. The altitude of the Woreda ranges between 1050m and 2320m above the sea level. The highest elevation (2320m) above the sea level is found at Kulish; whereas the lowest elevation (1050m) above the sea level is found at Shingira (Gawtata). Chena Woreda has sorts of rivers like Kenech, Meni, Beko and Bella are some of the representatives.

Climate and agro-ecology

Based on Chena Woreda Agricultural and Rural Development Office, 2017 report the altitude of study area ranges from 1050-2320 meter above sea level. It has three Agro-climatic conditions where 7 Kebele's found in Dega, 35 Kebele's found in Dega and 2 Kebele's are found in Kolla agro-ecosystem of the Woreda.

In the Woreda the rain fall occurs for Eight months (March to October), followed by dry season as documented in Shisho-inde meteorological station. Furthermore, the rainfall pattern in the area is the bi-modal type, i.e., March through October (long rain season) and November through January (short rain season).The area receives rainfall almost all the year round. As documented at Shishinda meteorological station, the study areas very near to the station have annual rainfall of 1037 mm [14].

The mean monthly temperature ranges between 18^0c to 29^0C and annual average temperature of the area ranges from 15°C to 25°C.

Demography

Chena Woreda Agricultural and Rural Development Office 2019 report depict that the Woreda has a total population of 197391 of whom 100670 (51%) were Women and 96721 (49%) Men and 7.34% of its population are urban dwellers. The majority of the inhabitants were Protestants, with 43.62% of the population, 40.84% practiced Ethiopian Orthodox Christianity, 7.95% practiced traditional beliefs, 3.9% were Muslim and 3.09% embraced Catholicism. The four largest ethnic groups reported in this Woreda were the Kafecho (75.76%), Bench (16.19%), Oromo (3.5%), Amhara (2.73%) and all other ethnic groups made up 1.82% of the population. Kafigna was spoken as a first language by 75.43% of the inhabitants, 18.36% spoke Bench, 3.6% spoke Amharic, 3.09% spoke Oromiffa and the remaining 5.6% spoke all other primary languages reported.

Socio Economic Profile of the study area

The total area of the Woreda is 90,192 hectare from which 80% is Woinadega, 15% is Dega and 5% is Kola agro-ecology [14]. The main socio-economy of the people is mostly agriculture, products of natural forest, rearing of animals etc. The major crops grown in the area are maize, Teff, wheat, enset, beans,

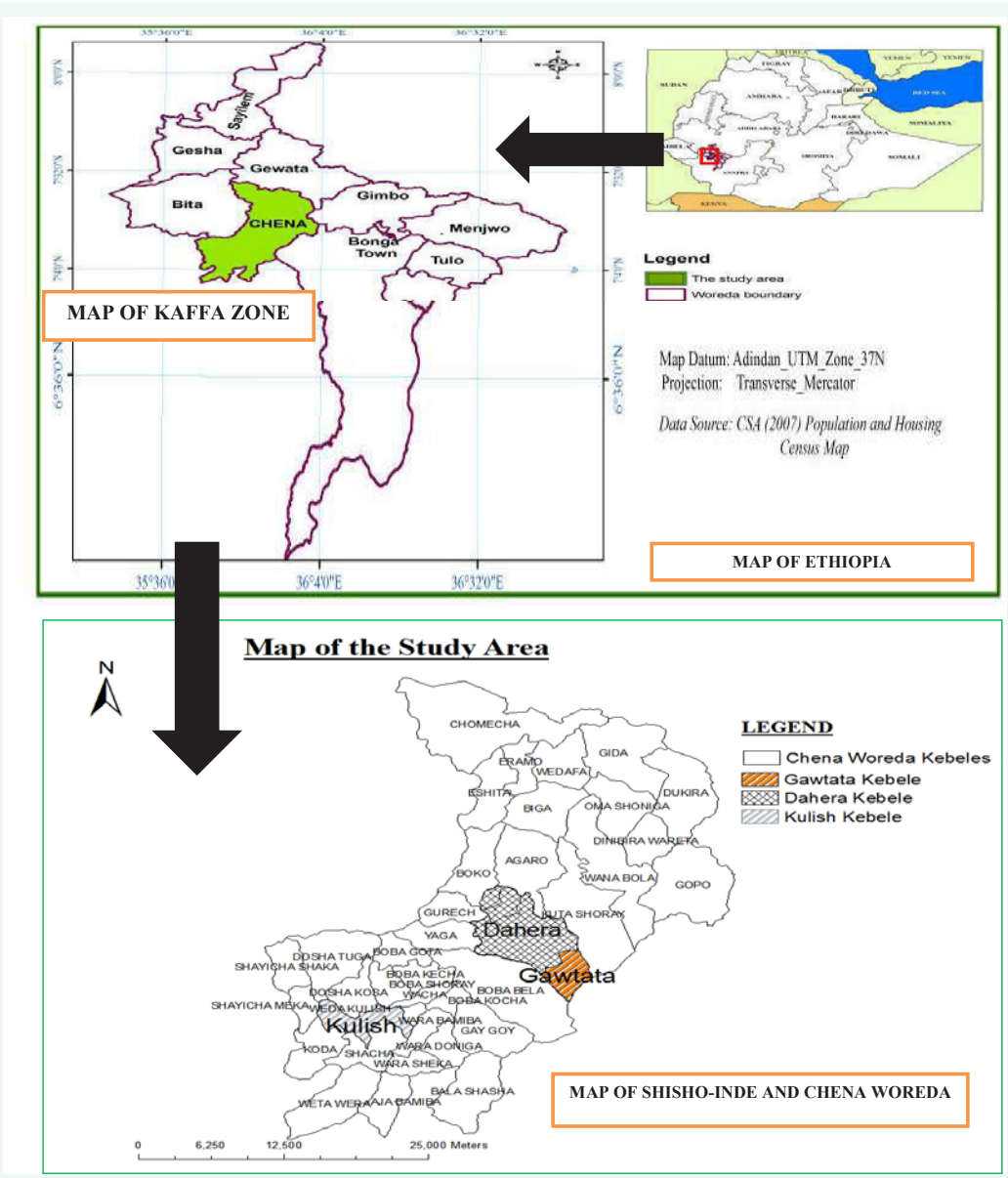

Figure 1 Map of the study area (Source: GIS, 2019).

peas, barley, sorghum and coffee. Including cash crops like coffee spices and chat are also produced in large scale. In addition, fruits and vegetables like banana, papaya, sugarcane, cabbage, potatoes, etc. are among some of the income generating products for the people. The percentage of income that generated from crop production is 25%, crop production and rearing of animals is 60%, trade is 2%, crop production and trade is 9% and others is 4%. The livestock population of Chena Woreda is, cattle-197756, sheep- 119649, goats-71570, donkeys-759, horses-14798, mules-5436 and chickens-256271 [14].

METHODS

Data Source

Both primary and secondary source of data were used for this study to have original and ground information. The primary data gathered through house hold survey questionnaires, focus group discussion (FGD), interview and direct observation techniques. Secondary data sources include different literature, published researches, map sources, books, journals, document analysis and internet.

Study design and sampling technique

Based on their coffee production potential, three different agro-ecological Kebele's were purposely selected for this study using nested design. These were Kulish, Dahera and Gawtata (Dega, Woinadega and Kola) respectively. These Kebele were selected purposely and the respondents were made by using simple random sampling method.

As a result, 126 sample respondents were taken for the questionnaires, i.e. 44 respondents from Kulish, 51 respondents from Dahera and 31 respondents were taken from Gawtata Kebele. The numbers of selected respondents from each

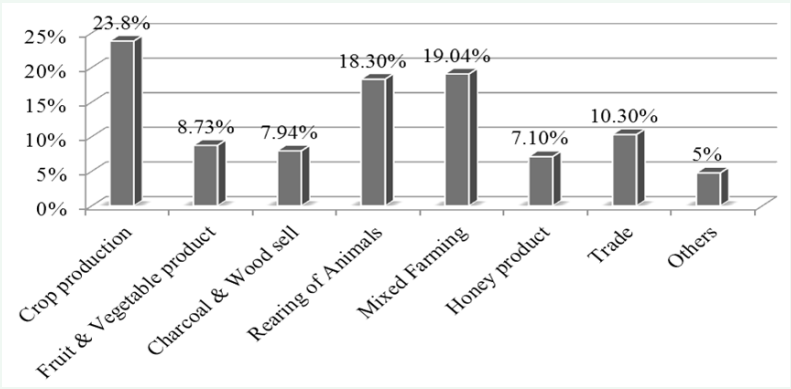

Figure 2 Basic income sources of the respondents (Source: Own survey, 2019).

Figure 3 The comparative severity of pest per leaf on each agro-ecology (Own photo capture, 2020). A/ Indicates the pest severity on coffee leaf in Dega agro-ecology, B/ Indicates the pest severity on coffee leaf in Woinadega agro ecology and C/ Indicates the pest severity on the coffee leaf in Kola agro-ecology.

Table 1: Eight years average climate data.

	Monthly Period											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Mean rain fall	13.98	60.11	91.61	118.88	100.63	127.2	162.34	170.76	98.76	81.53	38.38	20.31
Mean max. Temp.	28.28	29.08	28.72	27.73	26.98	26.54	25.26	25.43	26.48	27.2	28.17	28.29
Mean min. Temp.	10.16	10.86	11.99	11.78	12.13	11.63	11.66	11.89	12.05	11.3	10.49	9.75
Mean Temp.	19.2	20	20.4	19.8	19.6	19.1	18.5	18.7	19.3	19.3	19.3	19

(Source: CHEWARDO, 2019)

Table 2: Socio economic impact of the pest.

Items (Variables)	**Kulish**		**Dahera**		**Gawtata**	
	Frequency	**Percent**	**Frequency**	**Percent**	**Frequency**	**Percent**
Quality loss	9	20.5	12	23.5	9	29.0
Yield loss	13	29.5	13	25.5	8	25.8
Death of coffee	7	15.9	11	21.6	4	12.9
Leaf wilt	8	18.2	7	13.7	5	16.1
Others	7	15.9	8	15.7	5	16.1
Total(N)	44	100.0	51	100.0	31	100.0
Mean	2.80		2.73		2.65	
Std. Deviation	1.391		1.387		1.473	

(Source: Own survey, 2019)

Kebele were varied because of variation of the total number of population in each Kebele. Focus group discussion is another qualitative method of data collection instrument which involves 4 model farmers from each Kebele's.

Additionally, for interview 9 respondents were purposely selected from the Woreda agricultural office experts. In the study site, 138 respondents involved from three Kebele's and 9 respondents from office of Agriculture. Total respondents who involved in this study were 147. Thus, the sample size were determined depending on Cochran's formula as depicted below

The sample sizes of the households were determined based on the formula below. The formula helped to determine the required sample size.

This simplified formula assumes a 95% confidence level and the maximum variance (p = 0.5). The formula is:

$$no = \frac{Z^2 * (P)(q)}{d^2} \rightarrow n_1 = \frac{no}{(1 + no / N)}$$

where; no= the desired sample size Cochran's (1977) when population greater than 10000

n1 = finite population correction factors (Cochran's formula, 1977) less than10000

N = the total number of population

Z = standard normal deviation (1.96 for 95% confidence level)

P = 0.1 (proportion of population to be included in sample i.e. 10%)

q = is 1-P i.e. (0.9) (P=0.1)

d = is degree of accuracy desired (0.05)

Questionnaires

The questionnaire organized in logical order of checklist. It generates qualitative and quantitative data concerning the agro-ecology of pest, socio-economic impact of pest and management system. These includes total of 126 individuals.

Key informant interview

Key informant interview Interviewees was conducted with Woreda agricultural office experts because of their professional back ground in order to strengthen the information collected using questionnaire and to have a detailed in sight about agro-ecological distribution and socio-economic impact of this miner.

Focus group discussion

This is aimed to complement the sample respondents' survey and helps to acquire important and detailed information, which might be ambiguous or vague to collect by the household survey concerning to agro-ecological distribution and socio-economic impact of coffee leaf miner in the study areas of the selected Kebele's.

Direct observation

Direct survey was another method used to collect primary data and carry out through systematic observation.

Survey procedures

Survey was employed to assess pest population and the damage they inflict following similar procedure by [15].

The pest damage status was considered as follows:

1. Normal if pest population is zero to one per coffee leaf per tree
2. Low if the pest population is two to five coffee leaf per tree
3. Moderate if the pest population is six to ten coffee leaf per tree
4. High or severe if pest population is above ten coffee leaves per tree and the severity rate of damage determined because of the amount or part of leaf infected.

DATA COLLECTION TOOLS

Preliminary survey was conducted before performing the study, which was used to grasp or overview the general outlook on physical future or topography, temperature, rainfall, weather condition, accessibility, flora or vegetation type, fauna or animal types, birds and other related life's, economic activities, anthropology or social organization, clan and speculation of the study area size. So, the chosen Kebele and document analysis were taken to get some guide line and for problem identification about the title and objective. After site observation and problem identification, the questionnaires were prepared and distributed for the respondents.

Then focus group discussion and interview held with respondents about coffee leaf pest to have additional information. Physical features like altitude and location of sample collected by using GPS instrument from Agricultural Growth Program (AGP). Photographs were taken to show pest severity and distribution during data collection.

DATA ANALYSIS

Data collected from questionnaires were analyzed by using Microsoft excel version 20 or spread sheet program and SPSS version 20 software and the results of analysis were presented using descriptive statistic such as percentage, frequency distribution and in table form. Data that obtained from focus group discussion and interviews has been managed by connecting the evidences observed in narration form comparatively. The close ended questions from questionnaire were discussed using tabulation of variables with fraction values. Open ended question from interview and discussion were grouped into different categories and summarized based on similarity.

RESULT AND DISCUSSIONS

Pilot Study: On the basis of the evolved framework, an instrument with 27 statement questions representing the three factors was developed for analysis. Likert Scale was used to measure the responses of potential occurrences of the pest.

The reason for this analysis was to establish the need for the support systems required by the stakeholders. The questionnaire was subjected to external validation by experts. The pilot studies

with 45 potential coffee growers as respondents were carried out.

Cronbach's alpha results showed 0.93 percent reliability. Through Confirmatory factor analysis, all items of the questionnaire were validated. The result is analyzed as the following ways and steps:

According to the respondents, presences of coffee miner pest were major challenge to coffee production and productivities and it reduces coffee yield. Based on the response revealed from questionnaires, moderate numbers of coffee leaf miner pest were distributed relatively in Dega, while coffee leaf miner pest distribution were more sever in Woinadega and merely pest infected leaf or normal looking leaf found in Kolla agro-ecology. Additionally, the FGD, interviewees, Key informants and field observation also pointed the pest infected leaf high in Woinadega, moderate in Dega and low in Kolla agro ecosystem respectively. This means on the right way with respondents of questionnaires responses. Conversely, pest population per leaf/per tree was more in Woinadega, moderate in Dega and normal looking around Kolla. This is because of the suitable humidity and hot temperature in Woinadega agro ecosystem.

Socio-economy of most residents' depends on the crop production and importantly used crop products as for their day today income. Which means 30 respondents (23.8%) from three Kebele's responds major income sources were crop production and the highest ratio were covered with coffee production. The socio-economy of the sample respondents shows significant difference between different agro-ecosystem. Coffee has social, cultural, spiritual, historical and traditional values. Coffee and all activities of the societies have been two sides of a coin relationship. As depicted figure below.

According to the interviewees, FGD, document analysis and direct observation, the main socio-economy of the respondent depend on coffee production. Means cash crop and cereal crops basically on coffee production.

Coffee leaf miner had adverse effect on coffee production such as yield loss, quality loss, coffee death and coffee wilt. Accordingly, the percentage of respondents on each effect of leaf miner were, 12(23.5%) quality loss, 13(25.5%) yield los, 11(21.6%) coffee death, 7(13.7%) leaf wilt and 8(15.7%). Sample respondents from Dahera responds as high amount yield loss occurs. Which are 13(25.5%).Consequently, 9(20.5%) quality loss, 13(29.5%) yield los, 7(15.9%) coffee death, 8(18.2%) leaf wilt and 7(15.9%). Others from Kulish reveals as highly yield loss occurs which is 13(29.5%).Eventually, 9(29.0%) quality loss,8(25.8%) yield los,4 (12.9%) coffee death, 5 (16.1%) leaf wilt and 5 (16.1%) others in Gawtata. Therefore; the highest percentage in Gawtata is quality loss which is 9 (29.0%).

As a result, statistically there is significant difference of socio-economic impact resulted among three agro-ecology sites at 0.001 with confidence value of 0.05. In addition to those respondents of questionnaires; the researcher considers the point which rose from the FGD and interviewees and refers the documents from the Woreda agricultural office. So, as information gathered from all sides of respondents, the main socio economic impact of pest were frequent reductions of coffee bean or coffee yield loss. As a result, coffee leaf miner pest is one of the main challenges of coffee production for coffee growers. This directly or indirectly affects the income sources, reduces social harmony, and minimizes cultural view and economic value of the growers.

As the finding of current study indicates that, the views of respondents with respect to the pest distribution across altitudes and socio-economic impact that were to some extent concurrent among farmers, experts and field observations.

Because of different factors, the range of coffee pest occurrence was varied in different ago-ecology. Based on the responses taken from respondents of questionnaires, FGD and interviewees of the office experts and from observation, the occurrence of pest were more recorded during dry season than in rainy season in the study area. Some authors suggested that rain was the main source of coffee leaf miner adult and larval mortality in tropical areas, particularly during the rainy season [16]. This result was in line with the finding of [17], in which under wet conditions, plants had very low infestation levels of pest because of water entering the mine and drowning the larvae.

Similarly, the higher occurrences of coffee leaf miner were observed at mid altitudes and lower incidence was occurred at low altitudes. In fact, the pest infestation was reported to be an issue of farmers of mid altitudes than high and low altitudes. The present study showed that coffee leaf miner was present throughout the year in coffee farms at low and high elevations; its occurrence was variable among months and differed between elevations.

This result was in accordance with finding of [18] in that the proportion of mined leaves was significantly greater in the low/mid versus high elevation farm.

This might probably be because of suitable warm and humid tropical climatic condition of the Woinadega (Dahera) which enable the pest to proliferate rapidly or it might be due to predation.

High pest population were found in the simple-shade coffee forest than in complex-shade and abandoned coffee forest. This is in line with the findings of [19] who investigated the role of shaded and un-shaded coffee agro-forests on population dynamics of coffee leaf miners in Mexico and contrary with [20] finding in which the infestation grade was found to be higher in plantations under a high level of shade.

Various studies suggested that weather variables, particularly temperature and rainfall, were the primary factors determining abundance and distribution of coffee leaf miner and its natural enemies.

According to recent study, coffee leaf miner occurrences on leaves of different ages within coffee plants were assessed. But, the pest has been very common and recorded on older leaves or mature coffee plant leaves than remaining ages of coffee. This is in accordance with the findings of [21] in that; older leaves were more susceptible to coffee leaf miners damage than younger leaves.

According to over 25% of population of Ethiopia is dependent on coffee for their livelihoods. Biotic as well as a biotic factors in relation with the pest reduce coffee production in the study area as well. This directly or in directly influence the socio-economy of the society in that their economic, social, cultural, medicinal,

psychological and traditional value and their coffee have been linking as two sides of one coin.

This study confirms that the crop losses due to pests were the major threat to incomes of rural families and to food security worldwide [22]. The coffee insect pests, especially the coffee leaf miner (Leucoptera coffeella) affect coffee production [23-24]. The pest causes the green famine for the study area.

CONCLUSION

From the current study the following conclusion had made;

According to the current study, the pest severity was varied from place to place. The proportion of mined leaves was higher during the dry season than the rainy season, and also at mid than low/high elevation. That means the severity of pest population is varied and relatively high in Woinadega than Dega and Kolla agro-ecologies. Not only this, but also the pest incidence was high in mature or old coffee leaves than others.

For all location along the altitudinal gradient of study areas, pests were ranked as the major constraint for coffee production, followed by diseases, low soil fertility, lack of extension services, and changes in weather patterns. For the low altitude, poor flowering and old coffee trees were also mentioned to be the cause of low yields.

The pattern of coffee leaf miner is one of an important pest that reduces coffee utilization and reduces the cultural, social, traditional, medicinal, economic and psychological values of coffee. The results of this study provided valuable information in order to improve the knowledge of the spatial distribution of the coffee leaf miner in the coffee fields.

Generally, Understanding the impacts of weather variables and agro-ecology up on pest population dynamics is important for managing pests.

RECOMMENDATIONS

Coffee growers, users, governments, stake holders and any concerned bodies should understand the suitable niche and consequences of coffee leaf miner and to be proactive. From the present study the following points can be forwarded and recommended:

- Enhancing production and productivity of coffee through improving the traditional management system.
- Introducing improved and pest resistant coffee plant.
- Using integrated pest management system.
- Emphasis should be given to careful training program for the community focusing on the practical aspects of coffee management system.
- The stakeholders should work hand in hand with the growers to increase awareness of the local people about the pest management.
- Regular pruning and avoiding un-necessary or broad leafed shade plant is highly recommended.
- Community based conservation system (co-management) should be an integral component for the conservation of our coffee from pest.
- The government and stake holders should apply and aware about the use of biological way management practices for the coffee growers.

Further research should be conducted to understand and overcome the problems of pest.

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Appendices

Pest incidence in the coffee garden

According to direct observation during field survey five sample coffee trees were taken from each Kebele's randomly in order to check up pest occurrence.

DEGA

Tree: 1 = 12 leaf per tree pest incidences

Tree: 2 = 8 leaf per tree pest incidences

Tree: 3 = 6 leaf per tree pest incidences → **Average pest occurrence appear**

Tree: 4 = 8 leaf per tree pest incidences

Tree: 5 = 10 leaf per tree pest incidences

WOINADEGA

Tree: 1 = 44 leaf per tree pest incidences

Tree: 2 = 28 leaf per tree pest incidences

Tree: 3 = 32 leaf per tree pest incidences → **High pest occurrence appear**

Tree: 4 = 21 leaf per tree pest incidences

Tree: 5 = 50 leaf per tree pest incidences

KOLLA

Tree: 1 = 2 leaf per tree pest incidences

Tree: 2 = 0 leaf per tree pest incidences

Tree: 3 = 0 leaf per tree pest incidences → **Very low pest occurrence appear**

Tree: 4 = 1 leaf per tree pest incidences

Tree: 5 = 1 leaf per tree pest incidences

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