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STUDIES ON THE DIVERSITY OF INSECT PESTS IN WILD AND CULTIVATED COFFEE PLANTATIONS IN AND AROUND JIMMA, SOUTHWEST ETHIOPIA

BY
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List of Abbreviations

ANOVA	Analysis of Variance
BLM	Blotch Leaf Miner
CBB	Coffee Berry Borer
CBD	Coffee Berry Disease
CGA	Coffee Growing Association
CLS	Coffee Leaf Skeletonizer
EARO	Ethiopian Agricultural Association
EMSA	Ethiopia Metrology Service Agency
FAO	Food and Agricultural Organization
GDP	Growth Development Production
HSD	Honest significant Difference
IAR	Institute of Agricultural Research
IPM	Integrated Pest Management
KCB	Kenya Coffee Board
MCTD	Ministry of Coffee and Tea development
SLM	Serpentine Leaf Miner

Abstract

Insects are highly diversified in any ecosystem in which coffee plant can exist, but not well recorded under different coffee production systems in different seasons and different coffee tree shade status in Jimma southwest of Ethiopia where Coffeae arabica L. originated. Thus, this research was initiated, to study the coffee insects pest population incidence and occurrence in different seasons and shade status. Based on the shade status, the study area of cultivated and wild coffee were divided into three sites and from each site fifteen coffee plants were systematically selected for coffee plant leaf and berry insect damage analysis. Accordingly, fifteen insect families categorized under five orders were recorded and identified. Significant variations in level of coffee leaf insect pests incidence with in and between wild and cultivated were observed. The mean incidence recorded between and within wild coffee population were 24.92, 19.80 and 17.21 for wet, transition and dry seasons respectively. Within cultivated coffee, the mean incidence recorded was 31.2, 31.9 and 17.62 for wet transition and dry seasons, respectively. Frequently occurring insect pests of coffee leaves were blotch leaf miner, serpentine leaf miner and coffee leaf skeletonizer. Their leaf damage proportion on wild coffee was 53, 23 and 24% for leaf skeletonizer, serpentine leaf miner and blotch leaf miner, while in cultivated all are in equal proportion. The mean incidence of cultivated fallen berry ranged from 2-3%, while the left over ranged 12-20%. Similarly in wild fallen berry infestation by coffee berry borer ranged from 1-2% while,7-13% infestation was recorded on left over coffee. In general, there were differences in insect pests population incidence in wild coffee that might be due to the fact that the pests are shade loving. Difference between plantation and wild coffee is due to high human intervention in cultivated coffee which created unstable ecosystem that favor pest population to resurge and at the same time the activity might have affected the activity of the natural enemies.

1. Introduction

Coffee (*Coffeae arabica* L.), which is originated in Ethiopia, is the backbone of the country's economy. It accounts for 70% of the foreign exchange earning, 10% of the government revenue and employs 25% of the domestic labor force (Tsegaye *et al.,* 2000). About fourth of the Ethiopian population is directly involved in the production, processing and transport of coffee, being a private crop, is always available to feed on (Million and Bayisa, 1986).

Arabica coffee (*C. arabica*) of the Rubiaceae family has its center of origin in the highlands of southwest and southeast Ethiopia were wild coffee populations naturally occur in the undergrowth of the aforaminate rainforests at altitudes between 1,000 and 2,000m (Crowe, 2004). Seventy percent of the coffee is produced as garden coffee by small farmers, 25% is collected in forest and semi-forest coffee systems, and merely 5% is plantation coffee (Tadesse *et al.,* 2008).

There are different coffee production systems in Ethiopia mainly due to varying level of plants associated with coffee, nature of coffee tree regeneration and human intervention in coffee production system. However, it is generally agreed that there are four coffee production systems in Ethiopia. These are modern plantation, gardens, semi-forest and forest coffee (MCTD, 1999; Workafes and Kassu, 2000; Taye and Tesfaye, 2001).

Ethiopia exhibits eighteen major agro-ecological zones and seven of them are said to be suitable for Coffee production. These zones have Coffee of their own type interms of quality and marked origin. The sub humid zones lying between 1500 and 2000 m.a.s.l. are highly suitable for Coffee production in Ethiopia and the bulk of Ethiopian Coffee comes from these areas (EARO, 1999).

Arabica Coffee, which is originated in Ethiopia, is one of the most valuable crops for the country. Insect pests are among the number of factors considered to limit coffee production both in quality and in quantity (Million and Bayissa, 1986; Million, 1987, 2000 cited in Esayas *et al.,* 2008). It is also cultivated under a variety of shade trees. In these production systems, the productivity of the crop is very low ranging from +- 450- 472kg/ha cleans Coffee (Workafes and Kassu, 2000).

There is evidence which suggest that different pattern of seasonal changes in species diversity in the tropics is determined by the tendency of tropical species to breed through out the year. Whereas each temperate species tend to have a well defined restricted and predictable breeding season (Owne, 1969). Restricted periods of abundance may be dictated by periodic food supply as well as advantages in predators' avoidance and enhancement of mating (Denlinger, 1980). Le pelley (1968) described that microclimate of coffee plantation show that actual conditions of the habitat.

The major pests of coffee include boring beetles, scale insects, mealy bugs, other Hemiptera including antestia, Lepidopterous miners and defoliators. Every part of the coffee tree-roots, stems, leaves, flowers, berries and the seed in storage may all be attacked by insects in some coffee growing area (Wrigley, 1988). Pests of coffee include insects, mites, nematodes, mollusks, birds and mammals. Insect pests are the most serious and the most numerous, with over 900 species having been recorded (Mitchell, 1985).

Among the major factors limiting increased Coffee production worldwide are losses due to pests (insects disease, nematodes and weeds), both indigenous and exotic. Losses due to Coffee pests are estimated to be 13% worldwide (Nyambo and Masaba, 1997). Arabica coffee is preferred over all other species because of its superior quality and it would certainly have continued to be the exclusive producer of all coffee in the world (Herbert, 1985).

It is important to study the status of insect pests in relation to coffee plant part damage and analyze the effect of insect pests with respect to wild and cultivated coffee plantation so as to determine in which Coffee production system the pest population more pronounced with respect to different season and coffee tree shade status. This helps one to manage coffee ecosystem in a more safe way and able take measure when necessary with appropriate control method with minimum cost of time, money, labor, and ecology. Hence, the current study was initiated to obtain base line information on the status of wild and plantation Coffee pests and their natural enemies.

Ethiopians have various special cultural ceremonies related to coffee. These cultures represent a strong heritage for the country's sustainable coffee production, currently consumed in a variety of ways. Bunakela, which is coffee accompanied with roasted barley, wheat and chick-peas is still popular in most coffee growing areas of the country. Long distance travelers or hunters in Gedio and Borena still use it, while in Wollega bunakela is prepared on special cultural and family occasions. Bunakela is socially highly valuable and is a respected (holy) food to be served as the first dish to celebrate the birth of a new child, as well as an expression of success in arranging marriage or fortune telling events (Crown Coffee, 2002).

2. Literature review

2.1 Global Coffee production

The main botanical origins of coffee are two different species: *C. arabica* and *C. canephora* the former is almost exclusively cultivated in the Americas and the latter is widely grown in Africa and Madagascar. Production of both species is now expended in Asia, particularly India and Indonesia. However, small tonnages of coffee from less common species which are cultivated particularly in Africa appear sporadically in European markets. These are mainly *C. excelsa* and *C. liberica* (Coste, 1992).

The coffee plant takes approximately 3 years to develop from seed germination to first flowering and fruit production. The fruit of the coffee tree is known as a cherry, and the beans which develop inside the cherry are used as the basic element for producing roast and ground coffee, soluble coffee powders, and coffee liquor. A well managed coffee tree can be productive for up to 80 years or more, but the economic life span of a coffee plantation is rarely more than 30 years (Wrigley, 1988).

From a commercial point of view only *C. arabica* L. and *C. canephora* Pierre (Robusta coffee) are the important representatives from about 100 known species. Arabica coffee grown at medium and high altitudes accounts for roughly 70% of commercial world coffee, and for practically all of that produced in Latin America. This species is also produced in some African countries such as Ethiopia and Kenya. Robusta coffee is mainly growing in other African coffee-growing countries at low altitudes. Some other species, such as *C. liberica*, *C. dewevei* and *C. racemosa* are only produced for local consumption (Bettencourt and podrigues, 1985).

C. arabica is thought to have originated from Ethiopia vast areas of forest contain major natural and semi-spontaneous stands of this species on the high plateau of

Keffa (Jimma) and the region of Lake Tana. These are still being exploited to certain extent (Coste, 1992).

C. arabica is the only tetraploid and self pollinated species in the genus *Coffea*. All other species of Coffee are diploid and out crossed (Carvalho, 1969). The center of origin of *C. arabica* is in Ethiopia in high plateau areas at altitudes between 1300 and 2000 m. On the other hand, the origins of *C. canephora* are more widely dispersed in tropical Africa at altitudes below 1000 m. The species *C. liberica* originates from low land habitats in West Africa, often coastal. A further species, *C. excelsa*, closely related to *C. liberica*, is also a native of lowland forest habitats in west and central Africa (Wintgens, 2004).

Coffee plays vital roles in the economic development of the producing countries, being one of the main foreign exchange agricultural commodity earners. Countries like Uganda, Rwanda and Burundi derive more than 80% of their total export earnings from Coffee. There fore, Coffee is an extremely important generator of employment and of an overriding importance to the social structure and development of the Coffee growing countries (Njoroge, 1997).

Coffee is one of the most valuable export crops of the third world countries. South and Central America countries produced 60% of total exported Coffee, Africa 30%, while Asia and Oceania contributes 10% (Nyambo and Masaba, 1997).

2.2 Coffee Production Systems in Ethiopia

Ethiopia is the primary center of origin and genetic diversity of Coffee (*C. arabica* L.) (Syvain, 1958; FAO, 1968 cited in Tadesse *et al.,* 2008). Arabica Coffee grows under very diverse environments including altitude (550-2600m), annual rainfall (1000-2000mm) (Mesfin and Bayetta, 1987 cited in Tadesse *et al.,* 2008)

C. arabica is the only self-compatible species of the genus. The diploid species are all sell self-incompatible of the gametophytic type. *C. arabica* L., economically the

most important species of the genus, above some remarkable features which distinguish it from the other species of the genus. Firstly, it represents the only polyploidy species so far identified. Finally, the geographic distribution of *C. arabica* is restricted to the plateau of southwestern Ethiopia (FAO, 1968).

Ethiopia is the second largest Coffee producer in Africa (Solomon *et al.,* 2008). Whereas, as in Tsegaye *et al.,* (2000) cited in Esayas *et al.,* (2008). There are four types of coffee production systems in Ethiopia: forest coffee, semi- forest coffee, garden coffee and plantation coffee. About 95% of the coffee production from these systems can be considered as organic, although not yet officially certified (Crown Coffee, 2002). These four production system mainly due to varying level of plants associated with coffee, nature of coffee tree regeneration and human intervention in coffee production system. Accounting for 10, 35, 50, and 5% of the total production, respectively (MCTD, 1999; Workafes and Kassu, 2000; Taye and Tesfaye, 2001). Coffee grows at various altitudes ranging from 550- 2750m.a.s.l. (Workafes, 1999 cited in Tadesse *et al.,* 2008).

Forest with wild Arabica Coffee populations occur in the southeastern and southwestern highlands of Ethiopia mainly at altitudes between 1000 and 2000 m.a.s.l. (Feyera, 2008). By far the greatest amount of coffee in Ethiopia is derived from spontaneous forest coffee (FAO, 1968). Forest coffee accounts for about 10% of the total coffee production in Ethiopia (Crown Coffee, 2002). In general, Wild coffee is defined as coffee that grows and regenerates spontaneously in its natural habitat and is genetically different from known cultivars and landraces. The gene pool of these wild coffee populations is of national and international importance, because it has high potential for the breeding of new coffee varieties (Kassahun, 2006).

Semi-Forest Coffee production system is also found in the Southern and South-Western parts of the Country. Farmers thin and select forest trees so as to let in adequate sunlight to the coffee trees and still provide adequate shade. Farmers slash

the weeds once a year to facilitate harvesting of the coffee beans. This system accounts for about 35% of the coffee production (Crown Coffee, 2002). Coffee trees under this category are managed with little cultural practices, such as weeding and shade regulation. This are found in Illubabor, Jimma, Kefa, Bench-maji and west Welega zones (Demil, 1999; Paulos and Demil, 2000). It is estimated that semi-forest coffee occupies nearly 136,000 ha accounting for 34% of the total production of coffee land in the country (MCTD, 1999). However, Demil (1999) reported that currently semi-forest coffee production systems represents 24% of the total land covered by coffee and 20% of coffee production in Ethiopia.

Garden coffee is found in the vicinity of farmers' residences. It is found mainly in the Southern and Eastern part of the country (Sidamo, Gedeo, South and North Omo, Hararghe, Wolega and Gurage Zones, East and West). It accounts for about 50% of the total production. This production system is on the increase as it is currently being introduced in South West Ethiopia (Kaficho,Shekicho and Bench-Maji) (Crown Coffee,2002; Workafes and Kassu, 2000).

Plantation coffee is grown on plantations owned by the state (currently put up for sale/privatization) and on some well managed smallholders coffee farms. In this production system, recommended agronomic practices like improved seedlings, spacing, proper mulching, manuring, weeding, shade regulation and pruning are practiced. It accounts for about 5% of the total production (Crown Coffee, 2002). These large scale plantation (state coffee farms) of about 21,000 hectares are distributed into seven different farms in Limu, Tepi and Bebeka areas (Workafes and Kassu, 2000).

2.3 Insect pests associated to world Coffee

Coffee is an ever green perennial crop grown in climates without sever extremes; consequently pests can survive from year to year, but fortunately the same applies to the parasitoids and predators of these pests (Wrigley, 1988). Insect pests are the most

serious and the most numerous, with over 900 species having been recorded (Mitchell, 1985).

According to Wellman (1961) recommendation that general data on losses of coffee from insects are almost impossible to give with any degree of accuracy because of the nature of the crop, the difficulty of estimating losses, and the way the planter prefers to forget his losses or guards some of his unhappy secrets. One of the most spectacular of the insects, in the losses it causes, is the berry borer, *Stphanorders coffeae* Haged. (*S. hampei)*. This was originally an African insect, and has caused untold damage to the maturing crop in that continent.

About 50 species of scales are known to infest the various parts of the Coffee tree. The most important are: *Coccus viridis* Green, or green scale which is yellowish-green, and is found in all the tropical regions of the globe. The damage it causes is mainly due to the presence of a toxin in its saliva (Coste, 1992). General feeders such as Lepidoptera larvae eat the buds, scale insects and aphids by sucking the plant tissue and affect their development (Le Pelley, 1968; Million 1987).

Several species of cricket including mole crickets (Orthoptera) and Termite population (Isoptera) first attack the bark, then the wood of the Coffee trees, entering through earthy tunnels which they excavate along the trunk and branches (Coste, 1992).

Wood-boring Beetles: Generally speaking the species of coleopteran that bore into coffee trees prefer weak ones. Good standards of cultivation, the use of mulches, planting of multiple stem coffee trees with hard wood and irrigation will do much to reduce the potential for damage (Wrigley, 1988).

The caterpillars of several Lepidoptera attack the leave of the Coffee tree. The most harmful seem to be the *Epicampoptera spp* or rat tail caterpillars and leaf miners such as *Leucoptera coffeina* W. Several species of caterpillar of the genus

Epicampotera are found on Coffee trees in tropical Africa: *E. strandi* Bryk inwest and central Africa; *E. amrantica* Tams. In East Africa and Congo; *E. andersoni* Tams in central and east Africa; *E. vulvornata* Heing in the Congo (Coste, 1992).

Leaf miners (*Leucoptera coma* Ghesq; *L. coffeina* Wish; *L. meyrrieki* Ghesq) (Lepidoptera: Lyonetiidae) infested plants have brown irregular blotches on the upper surface of leaves; the blotch mine is inhibited by a number of small white caterpillars. Mined leaves are usually shed prematurely (Hill, 1975. Their mining, which reduces the photosynthetic area of the leaf, causes same damage but the main losses of the production seem to be due to premature shedding of leaves (Singh, 1983).

Coffee leaf skeletonizer *Leucoplema dohertyi* Warren (Lepidoptera: Epiplemidae). These pests are recorded as minor pests of Arabica and Robusta coffee in Kenya, Uganda and Democratic Republic of Congo. Eggs are laid on the under side of leaves, often on patches of old skeletonizer damage (Hill, 1975). Where as, the eggs of *L. coffeina* and *L. meyricki* are laid at random, separately in small groups of two to six, on the upper surface of the leaves. The larva bores through the base of the egg straight into the leaf where it mines into the palisade tissue under the upper epidermis. They are very sensitive to light and fly only in shaded areas or when the sun is clouded over. (Wrigley, 1988).

Gaint looper (Lepidoptera: Geometridae) young caterpillar chew pits in the upper leaf surface; older caterpillars chew circular holes right through the leaf. The older caterpillars eat at the margin of the leaf leaving a jagged edge. They also feed on buds, young berries, terminal shoots and the bark of sucker stems. It has become a major pest of Arabica coffee in Kenya recently after very frequently uses of parathion in coffee plantations. The caterpillar moves in the typical looping motion. The color varies from pale grey to dark brown (Hill, 1975).

Coffee thrips *Diarthrothrips coffeae* Wiltams (Thysanoptera: Thripidae) the adults and nymphs feed on the underside of the leaves and cause silvering (Singh, 1983). In Kenya out breaks about every four year in the hot weather of February and March (Hill, 1975). There fore, if the population exceeds two per leaf (adults plus nymphs), then spraying may necessary (Wrigley, 1988).

Antestia bug *Antestiopsis spp*. (Hetroptera: Pentatomidae) is a major pest of Arabica coffee in the wetter regions of east Africa (Singh, 1983). Both nymphs and adults feed on the berries causing the young berries to drop and the production of soft or rotten beans by the bigger berries. When the Antestia infestations are high the growing points are also damaged, resulting into dense matted growth, such coffee trees results low yields of poor quality beans. They are sucking insects and by their habit of feeding transmit fungus. Infested berries develop dark brown patches. The bug also feeds on the follower buds. They also some times attack foliage (Singh, 1983). Wellman (1961) also suggests that the bugs pierce the fruits, entering with their beaks into the endosperms of the seeds, and inject spore material into the coffee beans. The result of this feeding are the following types of damage: (1) blackening of flower buds; (2) fall of immature berries; (3) rotting of the beans with in the berry or conversion of the substance of the bean into a soft paste; on the drying tables the parchment shows longitudinal brown streaks ("Zebra beans"); (4) multiple branching and shortening of internodes.

Coffee Berry borer (Hypothenemus hampei) (Coleoptera: Scotylidea) Cofee berry borer (CBB) is a sever pest of Coffea species, of which *C. canephora* is the most preferred. Damage is caused by the females feeding on young berries, resulting in significant losses through premature falling. The bulk of the damage is on the endosperm of the mature bean, extensively damage or completely destroyed by the adult or larvae feeding and tunneling in it (Lan and Wintgens, 2004). As, Singh (1983) reported that this pest is the most serious pest of robusta of coffee and also damage Arabica plantation of lower altitudes but is uncommon above 1,500m.

Coffee berry moth (Lepidoptera: Pyralidae) typical symptoms of attack are berry clusters in which the berries are webbed together and one or more is brown, dry and hollow (in the absence of berries the cater pillars may be found boring in the tips of green branches). If the caterpillar hatches out in the vicinity of every young berries it will graze them off but is too large to bore inside them. It is a minor pest of coffee, especially when it is grown without shade (Hill, 1975).

Coffee berry butterfly (Lepidoptera: Lycaenidae) single holes are bored into the sides or ends of large green berries turn brown and the edges of the holes bend up to form a distinct rim. Many affected berries are shed. The damaged berry is hollowed out and is clean inside, since the caterpillar pushes its excreta out through the entrance hole. Both beans are usually eaten. It is occasional sever outbreaks have occurred especially at higher altitudes (Hill, 1975).

According to Wrigley (1988) Fruit flies (Diptera: Tephritidae) pests have no direct damage to the coffee cherry, but the fly has been suspected of introducing organisms into the pulp that cause an undesirable flavor when the coffee is brewed. After much investigation this is now considered highly unlikely. Very occasionally the female flies lay their eggs in young green berries.

More than 10 mealy bugs and about 25 scale insects have been recorded from the aerial parts of coffee trees in east Africa, but only a few of them are considered economically important. Sooty molds are found associated with infestations by mealy bugs or soft scale insects. Kenya mealy bug [*Planococcus kenyae* (Lep.)] is common species occurring on both Arabica and robusta coffee. It attacks tender shoots, leaves and young berries (Singh, 1983).

2.4 Ethiopian Coffee insect pests

Although Ethiopia is the homeland for Arabica Coffee and the environmental conditions are suitable for Coffee production, the average national yield is very low. Insect pests are among the factors considered to limit Coffee production in both

quality and quantity (Million and Bayissa, 1986; Million, 1987; 2000). Over 47 species of insect pests are recorded on Coffee (Million and Bayissa, 1986, 1987; Crowe and Tadesse, 1984 cited in Esayas *et al*., 2008). Among which Antestia bug, *Antestiopsis intricate*, *A. facetoids* and Coffee blotch miner, *Leucoptera caffeinia* are the major ones inflicting considerable damage. On the other hand, insect pests such as Coffee berry borer, *Hypothenemus hampei*, Coffee thrips, *Diarthrothrips coffeae*, green scale, *Coccus alpinus* and Coffee cushion scale, *Stictococcus formicarius*, are potentially important pests (Million, 1987 cited in Esayas *et al*., 2008).

Insect pest problems are more pronounced in intensive coffee production system (plantation) compared to garden and semi forest coffee production systems mainly due to changes in cultural practices associated with the newly planted cultivars (Million, 1987).

In Ethiopia, most of the insect pests of Coffee have remained less important as opposed to many Coffee producing countries. One of the possible reasons is the existence of diverse natural enemies, which the population at low level mainly in the relatively undisturbed Coffee ecosystems, in which pest, and natural enemy balance is maintained (Crowe and Tadesse, 1984; Million and Bayissa, 1986; Million, 2000). In addition, the genetic diversity of Arabica Coffee coupled with cultural practices with minimum or no input used by subsistence farmers could have contributed to the suppression of insect pests of Coffee (Tsegaye *et al.,* 2000). Nevertheless, if there are any adverse agronomic/farm practices that affect the natural biological balance between pest and their natural enemies, these minor pests can pose a serious problem to coffee industry (Esayas *et al.,* 2008)

2.4.1 Key coffee insect pests

Even these key pests are not always present at level capable of causing significant damage, but by virtue of their feeding habits and their ability to multiply, they are potentially damaging (CGA, 1987). Among totally forty-seven insect pests of coffee

were reported only two insect pests Antestia bugs and Coffee leaf minor are the major insect pests (Esayas *et al.,* 2008).

Antestia bug, *Antestiopsis spp.* There are 3 species of Antestiopsis in Ethiopia, namely *A. intricate* (Ghesquiere and Carayon), *A. facetoides* (Greated) and *A. orbitalis* Carayon. *A. intricate* is the most common bug found in all coffee growing areas except Hararghe, where only *A. facetoides* is found (Greated, 1966, Crowe and Tadesse, 1984 and Million, 1987 cited from Esayas *et al.,* 2008). Weather factors, host plant, and natural enemies may be attributed for distribution and seasonal changes in population of the insect (Esayas *et al.,* 2008).
In Ethiopia, Antestia bugs can cause about 9% berry fall (Mekuria *et al.,* 1993), and up to 48% berry darkening (Million, 1987; IAR, 1996a; 1996b). Mekasha (1993) reported that branches of coffee trees infested with four pairs of the bug caused the highest number of damaged Coffee flower bad (1.2), 54.1% of berry fall, 90.2% of bean damage, and the lowest yield (0.41kg/tree) of red cherry (Esayas *et al.,* 2008).

Coffee blotch leaf minor, *Leucoptera spp*. There are two species of Coffee blotch miner attacking Coffee leaves, namely, *L. meyricki* (Ghesquier) and *L. caffeina* Washbourn. The latter is the most important, commonly occurring in shaded Coffee. The former species is of minor importance in Ethiopia probably due to the fact that Coffee is grown under shade which is not conducive to the normal development of this species (Million, 1987), but it is the most damaging species in other Coffee growing countries such as Kenya, Tanzania and Uganda (Nyambo *et al.,* 1998 cited in Esayas *et al.,* 2008).

When the larvae hatches it feed inside a leaf just below the upper epidermis resulting in leaf damage (Crowe and Tadesse, 1984). Brownish blotch, covering on area ranging from a small spot up to three quarter of a leaf, is created depending up on the number of larva and size of leaf attacked (Million, 2000).

2.4.2 Potentially important insect pests

Coffee berry borer, *Hypothenemus hampei* (Ferrori) population had a marked seasonal variation both on dry left over and fallen berries. More over, weather factor showed a marked influence on its population dynamics (Esayas *et al.,* 2004). In Ethiopia it attacks only dry left over and fallen berries. Damage on green berries was almost negligible (< 1%) (Million, 2000; Esayas *et al.,* 2003).

Coffee scale insects, out of the seven species of scale insects recorded on Coffee in Ethiopia, Coffee cushion scale, *Stictococus formicarias* Newstead and green scale, *Coccus alpinus* De Lotto are potentially important pests (Million, 2000). Both species are also present in Jimma but at a low level of infestation (Million, 2000).

The yellow nymphs feed on the leaves and green berries. When fully grown, the nymph drops to the ground and update in the soil. When the brown adult thrips emerges, it flies back to the tree and continues to feed (Crowe and Tadesse, 1984).
Coffee thrips *Diarthrothrips coffeae* Williams is one of the potentially important insect pests of Coffee. Thrips defoliated a large number of Coffee trees at both the Jimma and Tepi areas (IAR, 1972; 1997a).

2.4.3 Minor insect pests of Coffee

Serpentine leaf minor, *Cryphiomystis aletreuta* (Meyrick) appears every year after the onset of the short rains affecting young leaves (Million, 2000). Serpentine leaf miner is a very common pest found in most Coffee growing areas. This insect is well suppressed by its natural enemies; however, it can easily build up to a damaging level in the absence of its natural enemies (Million, 1987).

Coffee leaf skeletenizer, *Leucoplema dehertyi* (Warren) larvae feed on the underside of leaves, usually near the midrib eating every thing except the veins and the upper epidermis, leaving irregular lace-like patches in the leaf (Crowe and Tadesse, 1984).
Cocoa stem borer is becoming an important pest occurring in many Coffee growing regions of the country (IAR, 1996c).

As,Million (1987) concluded among more than three species of fruit flies were available infesting Arabica Coffee in Ethiopia. *Ceratitis rosa* Karsch, *C. capitata* (Wiedemann) and *Trirhithram cafeae* Bezzi were the most frequently found and relatively abundant species.

2.5 The role of tree shade to coffee

Around the world, coffee fields produce more than just coffee: they also produce food and medicinal plants, fire wood and timber, they provide habitat for fauna and flora, and they supply essential ecological services such as biological nitrogen fixation and soil and water protection. Their positive effects on microclimate and soil fertility are increasingly recognized as key to the long-term ecological sustainability of coffee systems. Depending on the pruning intensity, the shade pattern can vary widely from light and dispersed shade of less than 30% shade intensity to heavy and homogeneous shade exceeding 70% intensity (Bee *et al.,* 1998 cited in Muschler, 2004). Arabica Coffee has been found growing naturally under the canopy strata of various shade tree species and, thus, it flourishes best when grown under shade compared to open sun condition (Yacop *et al.,* 1996 cited in Endale *et al.,* 2008).

Shade trees may be provided in Coffee plantations to moderate light intensity and day time temperature, reduce weed growth as well as influence the physical and chemical properties of soils through their litter and root activities (Webster and Wilson, 1969). But, according to Amoah *et al.* (1997) over a period of five cropping seasons, un-shaded Coffee yielded about 37% more than shaded Coffee.

The use of shade has a direct relation ship with the behavior of beetles. The adults are very active during bright, worm and sunny days for flying, mating and eggs lying. If sufficient shade is maintained, egg lying will be affected (Lan and Wintgens, 2004).

Percentage light regimes recommended for coffee production is about 50% (IAR, 1996a). Excessive or inadequate shading by over head shade trees, which is

responsible for such unregulated shade/light levels, and sub-optional or high population density of coffee trees are the major constraints which accounts for low production and productivity of coffee in the country (Yacob *et al.,* 1996).

High humidity (above 50% at 1400hr), which is an advantage, may be enhanced by providing shade and wind breaks. However, at higher altitudes excessive shading increases the level of Botrytis. Low humidity (below 40% at 1400hr) may have an adverse effect on coffee quality. This may be partially offset by the use of shade. Shade provides some protection against damage (Yacob *et al.,* 1996 cited in Anteneh, *et al.,* 2008).

2.6 Coffee insect Pest management

It is important to any pest management system to monitor the population fluctuations and to allow any form of control to exert itself on the population. A monitoring system allows management decisions to be made in time to allow the most effective and efficient use of chemical pesticides. It follows that this allows the least possible use to be made of these chemicals, thereby reducing the effect of them on beneficial organisms (CGA, 1987). Thus, the most important objective of future research should be a reduction in the use of pesticides. These can cause problems of residues in the crop off flavors in the brewed coffee, pollution of the environment and toxic hazards to spray operators. Biological and cultural control measures avoid these problems and are cheaper in the long run than pesticide application (Crowe, 2004).

The integrated pest management (IPM) approach is necessary for sustained control of pests in perennial crops under tropical environments. It attempts to bring the pest population to an acceptable level by combining all possible control measures (mechanical, physical, cultural, chemical and biological) in a complementary and comprehensive manner (Lan and Wintgens, 2004).

The best policy for controlling insect is to encourage the parasitoids and predators, and apply insecticides only when necessary and as a supplement to the natural

enemies of the pest. Spraying should be a last resort as it may create an upsurge of a minor pest due to the destruction of its predators (Wrigley, 1988).

2.6.1 Cultural control

These are regular farm operations designed to destroy pests or prevent them causing damage of economic proportions and often are by far the best methods of control since thy can combine effectiveness with minimal extra labor and cost (Hill, 1975). For example, the best method of control coffee berry borer is crop hygiene, both in the field and in the stores. The crop should be picked regularly, every fortnight in the heavy fruiting season and monthly at other times. No ripe or dried berries should be left on the ground or on trees and all infested berries should be burnt (Lan and Wintgens, 2004). Coffee berries should be collected as soon as they ripen. All over-ripen or dry leftover and fallen berries should be collected often harvest and destroyed if attacked in order to deprive the borer the opportunity for breeding and leave little host for immigrating borer (Million, 1987; Esayas *et al.,* 2003, 2004 cited in Esayas *et al.,* 2008). In general shade tree regulation and pruning can reduce the populations of the borer and causes conditions, which are suitable for the natural enemies of the borer (Crowe and Tadesse, 1984 cited in Esayas *et al.,* 2008). Pruning of coffee trees and shed tree regulation can also reduce antestia populations by providing unfavorable temperature and humidity conditions to antestia bugs, which prefer dense foliage (Crowe and Tadesse, 1984; IAR, 1996c cited in Esayas *et al.,* 2008). However, it did not influence damage on flower bud, coffee bean development and yield (Mekasha, 1993).

2.6.2 Biological control

Antestia eggs, about 45-50% are attacked by three species of parasitoids, predominantly by *Asolcus suranus* Nixon followed by *Hodronotus antestiae* Dodd (Hymenoptera: Eupelmidae), which account for 33%, and 7% of egg parasitization, respectively (IAR, 1985; 1986; 1987; Million, 1987 cited in Esayas *et al.,* 2008). Crowe and Tadesse, 1984 cited from Esayas *et al.,* (2008) recommended that, egg masses of the insect can be collected by hand and hang in a basket away from the

coffee plants. Parasitoids coming out of the eggs can fly, in to the coffee, while the antestia nymphs remain behind to die. Mantids were an important predator of nymph and adult stage, which was observed in most coffee growing areas (IAR, 1984 cited in Esayas, *et al.,* 2008).

Blotch leaf miner was attacked by eight species of parasitoids (Million and Bayissa, 1986; IAR, 1987), of which *Aphidencyrtus aphidivorus* and *Pediobias caffeicola* Ferr. Were the most abundant species (IAR, 1982, 1983, 1987 cited in Esayas *et al.,* 2008).

2.6.3 Host plant resistance

Antestia bug feed on different Coffee Berry Disease resistant genotypes showed no significant differences in the nymphal period; however, significant differences were observed in the duration of adult stages (IAR, 1996a cited in Esayas *et al.,* 2008). This is also to blotch leaf miner has been demonstrated by the lower mean number of eggs laid, frequency of oviposition and percentage leaf damage, which may be an indication of the existence of antixenosis type of resistance in *C. arabica* cultivars (Esayas and Chemeda, 2007a cited in Esayas *et al.,* 2008).

2.6.4 Chemical control

Chemical control is recommended only when the pests are out of control and cultural practices have failed. For such reason to control attendant ants of Mealy bug spraying soil around the base of coffee trees or shade trees with insecticides such as quinalphas 1.5% or methyl parathion 2% or malathion 5% (Lan and Wintgens, 2004). According to Crowe and Tadesse (1984) cited in Esayas *et al.,* (2008) recommended spraying should be done when the average population of antestia (adult plus nymph) reaches more than 5 per coffee tree. However, in order to conserve natural enemies, the use of chemical insecticide, as much as possible, should be avoided and priority should be given to other alternative control methods. It is also recommended that if more than 30 blotch leaf miner moths flutter out from

a single tree then the trees should be sprayed one week later with fenitrothion at the rate of 2ml of 50% EC in 1 liter of water (Crowe and Tadesse, 1984 cited in Esayas *et al.,* 2008).

Only a few insecticides were tested against coffee pests. Malathion at the rate of 0.25% a.i. was once recommended for the control of antestia bug and was later replaced by fenitrothion on some other coffee pests such as serpentine leafminer, coffee aphid and leaf skeletonizer. DDT smoke method was developed which is cheaper and safer than the methods mentioned above. It was successfully tried in the Ghimbi and Mugi areas (IAR, 1970; 1971; cited in Esayas *et al.,* 2008).

3. Objectives of the study

3.1. General objective

To study the status of major coffee insect pests under wild and cultivated coffee plantation

3.2. Specific objective

- To investigate shade factors to same common coffee insect pests
- To compare the abundance of common coffee insect pests of wild and cultivated coffee plantation in association to wet, transition and dry seasons
- To investigate coffee berry infestation interms of dried left over and fallen berries

4. Materials and Methods

4.1 Description of the study area

The study sites for the investigation of insect pests of cultivated coffee were selected near Jimma Agricultural Research Center where the laboratory studies done. The study site for wild coffee is 22 km away from Jimma town to the North. Canopy coverage determination and general inventories were done at each site. Thirty by thirty meter plot size was used to describe the shade status for each site. Each population of coffee plant site classified into low, medium and dense shade tree coverage interms of shade tree coverage as less than 40%, 40%-70%, and more than 70%, respectively. Jimma which is 352km far away from Addis to southwest of Ethiopia found at altituds ranging between 1500 and 2500m with an average annual temperatures of 18-20^{0}c and annual rainfall ranging between 1500mm and 2500mm (Friis, 1992 cited in Tadesse, 2003).

Manna is one of the districts in the Oromia regional state in Jimma zone which is found to south west of Ethiopia 22Km away from Jimma town to the North and 374Km away from Addis Ababa was selected for wild Coffee insect pest analysis as FAO (1968) reported that in Manna district coffee was planted under forest condition, and there was an attempt to establish a new plantation in poor soil conditions in a dry and exposed situation. Some tall weeds had been left between the rows as shelter, but these were depriving the soil further of its moisture without affording adequate protection. The topography of this district shows that 2.9% high land; 94.1% medium and 2.59% of its land is low land. Out of 21, 369.94 ha of coffee plantation only about 50 ha is cultivated coffee. The rest are naturalized which we call it wild coffee. The mean of ten years metrological data obtained from the Ethiopian Metrological Service Agency (EMSA, 2010) of Jimma branch from Yebu town of Manna district near by wild coffee population indicate that the average annual rainfall is 167.85mm and the mean annual minimum temperature is 12.80^{0}C and the mean maximum tempreture is 27.9 ^{0}C, (Appendix 8) Manna is located at an altitude of 1982 m a.s.l. with coordinates of 7^0 41'N and 36^0. 49E.

Melko is found 8km to the west of Jimma town where Jimma Agricultural Research Center (JARC) and cultivated coffee is located. The area is found under Jimma zone of Oromia region to the southwest of Ethiopia having coordinates of 7^0 46'N and 36^0 00E and an altitude of 1753 m a.s.l. Its 40 years mean annual rainfall is 134.36mm, minimum temperature is 12.77 ^{0}C and maximum temperature is 26.14 ^{0}C according to JARC metrological division (Appendix 8).

4.2 Experimental tree selection and damage assessment

A reconnaissance survey was carried out in August 2009 to get general information about wild and plantation coffee populations and to select, and tag experimental trees. Based on general uniformity of coffee trees and shade status of wild and cultivated coffee population, each population had been classified into three wild and three cultivated coffee sites. Then from each site fifteen trees have been systematically selected by employing zigzag sampling method, using nested design as mixed model and tagged for leaf and berry damage assessment. Further more, each tree was stratified into three canopy layer and a pair of branch from each layer had been selected for the assessment of both leaf and berry damaging insects.

Damage assessment has been made by counting total and damaged leaves from lower, middle and upper canopy branch leaves once monthly at the beginning of the first five days starting from August 2009 to April 2010 that cover all wet, transition and dry seasons of the year. The percentages of damaged leaves were computed from the cumulative number of damaged leaves over the total number of leaves for each canopy branches multiplied by hundred.

To study the level of damage caused by coffee berry borer, one hundred left over dried coffee berries have been collected from randomly selected 20 coffee trees for each selected site following Remond and Cilas (1997) and Baker (2000) methods. Similarly, fallen berries have been collected from ground around each sample trees from each selected site of cultivated and wild coffee of Melko and Manna study areas, and put in

labeled paper bag, then brought to Entomology laboratory at Jimma University of Agricultural College. Finally, all the berries collected will be examined for the presence or absence of entrance hole. Damaged berries with entrance hole(s) were separately dissected with surgical blade to confirm borer damage.

4.3 Survey, collection and identification

Surveys on insect pests of coffee and their natural enemies were conducted in Melko where cultivated coffee was found and Manna where wild coffee was found. To obtain a representative insect samples during different coffee fruit development phenology and seasons, surveys were made nine times in all selected wild and plantation coffee. Based on general uniformity of coffee trees and shade status each of the two coffee plant type were classified into three forests. From each site, 15 trees were selected following systematic sampling techniques and every encountered insect feeding on the coffee plant were collected using hand collection and Aspirators. Plant parts damaged by the insect pests (leaves, stems, branches, flowers and fruits) have been recorded. All collected insects were labeled by host plant, co-ordinates of the area, date of collection and developmental stage of the pests. Immature stage of the insects that were collected was reared in the laboratory using host plant part as food source in cages to determine their identity on the basis of adult characteristics. The natural enemies that were encountered while collecting immature stages of common insect pests were allowed to emerge in rearing cages and then coded and preserved separately for identification. Insects, which were frequently recorded and common, were identified in the field using hand lens and color copy of the insect field book (Kenya coffee atlas, 2003). In general all specimens were identified to the family level.

4.4 Data processing and analysis

For statistical analysis percentage leaf and fruit damage incidence were considered of damaged leaves and fruits were tested for normality using SAS software proc univariate. Data violet the assumption of ANOVA was transformed before running the analysis of variance (ANOVA). Transformed percentage damaged leaf and fruit data were analyzed using the SAS package for windows-v 9.2 (SAS institute Inc. cary NC, USA). To analyze coffee plant-insect association one-way ANOVA with nested design was used. In order to analyze variation in infestation across sites of wild and cultivated coffee and (seasons); nested design of SAS proc mixed was used. Means for significant ANOVAs (F-ratios) were separated using Tukey's Honestly Significant Difference (HSD) test at 5% level.

Insect damage on dried left over coffee and fallen coffee berries were computed using Excel by dividing damaged berry to the total sample collected.

5. Result

5.1 Abundance of insect pests in cultivated and wild coffee plantation

Insect abundance among which was recorded in both wild and cultivated Jimma coffee southwest of Ethiopia recorded 15 insect families from 5 insect orders (Table 1). Among the recorded coffee insect pest family, 5 of them from only wild and no family exclusively found only in cultivated coffee plantation. The rest 10 families were collected from both wild and cultivated coffee plantations (Table 1)

5.2 Damage intensity of coffee leaf insect pests

According to the data compieled from cultivated coffee of Jimma percent of incidence of coffee leaf damaged by coffee leaf insect pest categorized into three ranges these are 1st those showed less than 15% leaf infestation; 2nd those showed 15% to 30% and 3rd those showed above 30% leaf infestation range with respect to coffee population type. To put the coffee population in one of the three category of the above range each sampled tree percent leaf damaged was counted and labeled accordingly. Thus in cultivation coffee type population only 8% of coffee leaf damage showed less than 15% , 48% of coffee leaf damage incidence showed between 15 and 30%, and 44% of damaged coffee leaf showed more than 30% at Melko. The result of analysis of variance among cultivated coffee population showed a significant difference ($P \leq 0.05$). The same was also true for wild coffee population. At cultivated coffee of Melko, the highest coffee leaf damage of 39% was at site T23, the least coffee leaf damage of 28% was observed at site T21 on the least coffee shade status. Similarly leaf damged category in percent at wild coffee showed that 13% of them damaged below 15%, 86% of them showed between 15 and 30% coffee leaf damage and only 1% of them showed above 30%. At wild coffee of Manna the highest coffee leaf damage of 36% was recorded at site T3 which is the highest shade status followed by medium shade status of site T2 with 33% leaf damage. The least, 31%, coffee leaf damage was observed at site T1 which has the lowest shade status.

Table 1: Total insect pest of coffee collected and identified to family level

Common name	Order	Family	Abundance	Plant part attacked mostly	Collected site
Antestia bug	Hemiptera	Pentatomidea	*	Cherry	Manna
Blotch leaf minor	Lepidoptera	Lyonetiidae	**	Leaf	Melko, Manna
Brown tortrix	Lepidoptera	Tortricidae	*	Leaf	Melko, Manna
Berry butter fly	Lepidoptera	Lycaenidae	*	Berry	Melko, Manna
Coffee leaf minor	Lepidoptera	Lyonetiidae	**	Leaf	Melko, Manna
Coffee leaf skeletonizer	Lepidoptera	Epilemidae	**	Leaf	Melko, Manna
Coffee aphid	Homoptera	Aphididae	*	Leaf and Berry	Melko, Manna
Coffee cushion scale	Homoptera	Stictococcidae	*	Leraf and Berry	Melko, Manna
Coffee fruit fly	Diptera	Tephritidae	**	Berry	Melko, Manna
Coffee hawk moth	Lepidoptera	Sphingidae	*	Leaf	Manna
Coffee thrips	Thysenoptera	Thripidae	*	Leaf	Melko, Manna
Green scale	Hmoptera	Coccidae	*	Berry and Twing	Melko, Manna
Gain looper	Lepidoptera	Geometridae	*	Leaf	Melko, Manna
Helmet scale	Homoptera	Coccidae	*	Leaf, Berry	Manna
Mussel scale	Homoptera	Diaspididae	*	Leaf,twing and berry	Manna
Serpentine leaf minor	Lepidoptera	Gracillaridae	**	Leaf	Melko, Manna
Stinging caterpillar	Lepidoptera	Limacocidae	*	Leaf	Manna

Note: * represents rare insect pests those recorded only two or less than two times.

** represents those recorded more than two times during survey times.

The analysis of coffee leaf damage in the three seasons showed highly significant difference ($P \leq 0.0001$) in both cultivated and wild coffee (Tables 3 and 2, respectively). The highest leaf damage of 39% was recorded in transition and the lowest coffee leaf damage of cultivated coffee of 33% was recorded in dry season. Similarly, in wild coffee of Manna the highest coffee leaf damage of 40% was observed in wet season, and the least coffee leaf damage of 28% was recorded in dry season (Appendix-1).

It has been observed that except during dry season in which there was significant different ($P \leq 0.05$), there has not been significant difference observed between different wild coffee populations during wet and transition seasons. There is also significant difference within each site across different seasons of the year, except at site T3 where no significant difference was observed between transition and dry seasons. At cultivated coffee there has been observed significantly varied among different coffee population site (Table 2) and also showed significantly different with in three different seasons of the year.

Table 2: Leaf damage of wild coffee in different data collection seasons within and among three wild coffee populations in Jimma (Mean ±SE).

season	*T1*	*T2*	*T3*	*P-value*
Wet	24.25±0.7097Aa	24.81±1.023Ad	25.69±0.6404Af	0.4575
Tran.	18.68± 0.9874Bb	19.51±0.8743Be	21.20±0.8862Bg	0.1537
Dry	15.08±0.5258Cc	16.87±0.7183De	19.68±0.6572Dg	0.001
P-value	< 0.001	< 0.001	< 0.001	

Means followed by the same letter(s) within a row (upper case) and among column (lower case) are not statistically significant at (Tukey's standardized range test at α = 0.05).

Note: T1, T2 and T3 represent the study area of wild coffee with low, medium and high shade status, respectively.

Table3: Leaf damage of cultivated coffee in different data collection seasons within and among three cultivated coffee populations in Jimma (Mean ± SE)

season	*T21*	*T22*	*T23*	*P-value*
Wet	26.98±0.7492Aa	31.27±0.5432Bc	35.34±0.7029Ca	<0.0001
Tran.	27.87±1.77Da	33.25±0.8822Ed	34.59±1.0819Ea	<0.0017
Dry	15.38±0.636Fb	16.96±0.4635Fe	20.53±0.7702Gg	<0.0001
P-value	< 0.001	< 0.001	< 0.001	

Means followed by the same letter(s) within a row (upper case) and among column (lower case) are not statistically significant at (Tukey's standardized range test at α = 0.05).

Note: T21, T22 and T23 represent the study area of wild coffee with low, medium and high shade status, respectively.

5.3 Percent proportion of cultivated damaged coffee leaf by insect pests

5.3.1 Leaf damage by skeletonizer insect pest

Skeletonizer coffee leaf insect pests as showed in (fig1) of wild coffee leaf damage by mean percent proportion skeletonizer ranked first with 75% and 75% at wild and cultivated coffee respectively. Proportion of leaf incidence with respect to seasons by this insect showed 86%, 70% and 67% during dry, wet and transition seasons respectively at wild coffee. Similarly in Cultivated coffee ranked first in proportion among coffee leaf damage insect pests with 89%, 64% and 80% during dry, wet and transition seasons respectively (fig2). The incidence proportion of this insect with respect to shade status showed the highest at high shade status T3 and T23 in both wild and cultivated coffee with incidence 77% and 92% respectively while the lowest proportion of this insect appeared at the lowest coffee shade status T1 and T21 in both wild and cultivated with incidence 72% and 66%, respectively.

5.3.2 Serpentine leaf miner

Serpentine leaf miner which is the 2nd rank with 18% and 22% coffee leaf incidence proportion at cultivated and wild coffee population respectively showed. Interms of seasons with the least 14% and 10% leaf damage incidence proportion during dry season at both cultivated and wild coffee respectively while the highest of its proportion with 25% at cultivated and 32% at wild during wet and transition seasons respectively. With respect to shade status it showed the highest proportion with 26% and 24% leaf incidence at the least coffee shade status T21 and T1 respectively in both coffee plantation (fig1 and 2).

5.3.3 Blotch leaf miner

Blotch leaf minor which is the 3rd abundance among leaf insect pest with 3% and 5% leaf incidence at wild and cultivated coffee plantation respectively. The incidence of coffee leaf damage by this insect in proportion to the other leaf insect pests with respect to seasons showed the least incidence during transition season was 4% and 1%

at cultivated and wild coffee respectively. The data with respect to shade status also showed that the highest leaf incidence proportion of this insect appeared at the least shade status with 4% and 7% in wild and cultivated coffee population respectively while the least incidence proportion recorded at high shade status in both cultivated T23 and wild T3 coffee plantation with 3% coffee leaf damage (fig1 and 2).

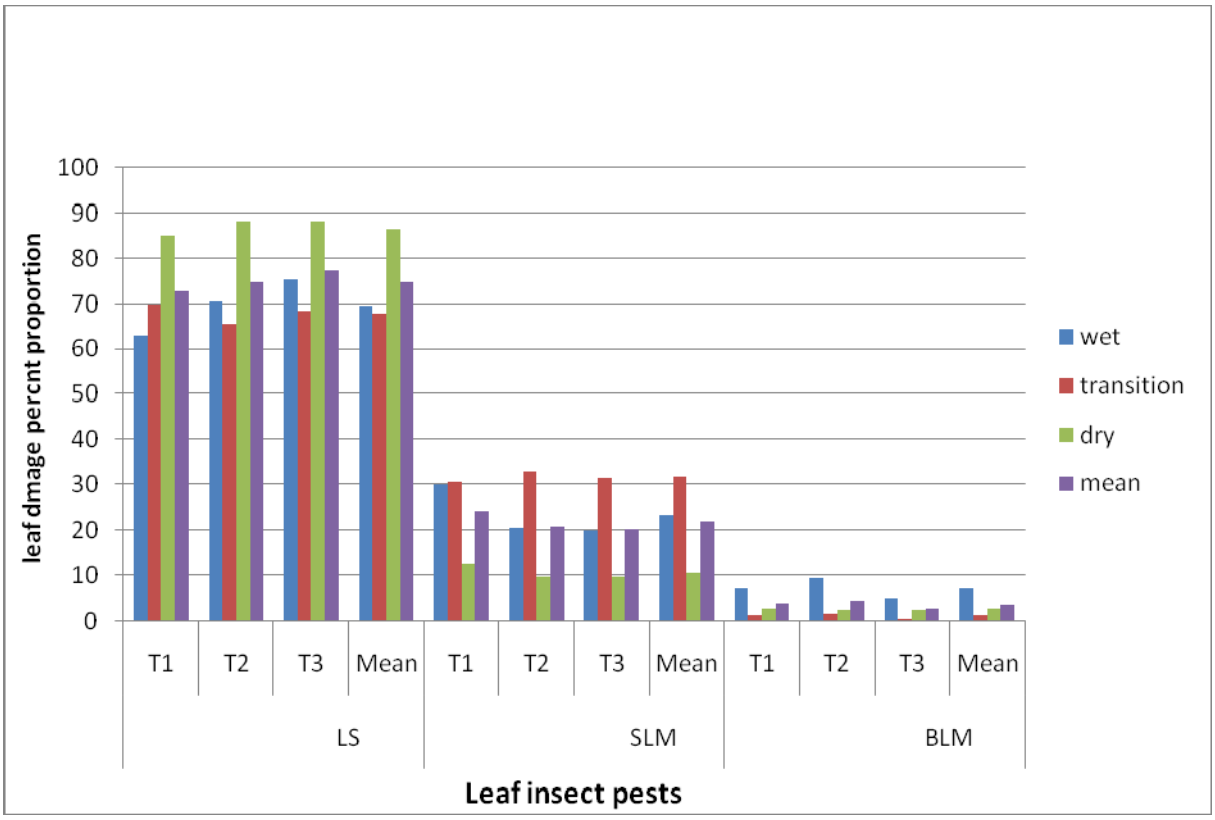

Fig-1: Wild coffee leaf damage proportion through different shade status and different seasons

Note: LS= leaf skeletonizer
SLM= Serpentine Leaf Miner
BLM= Blotch Leaf Miner
T1= Low shade status of wild coffee population
T2= Medium shade status of wild coffee population
T3= High shade status of wild coffee population

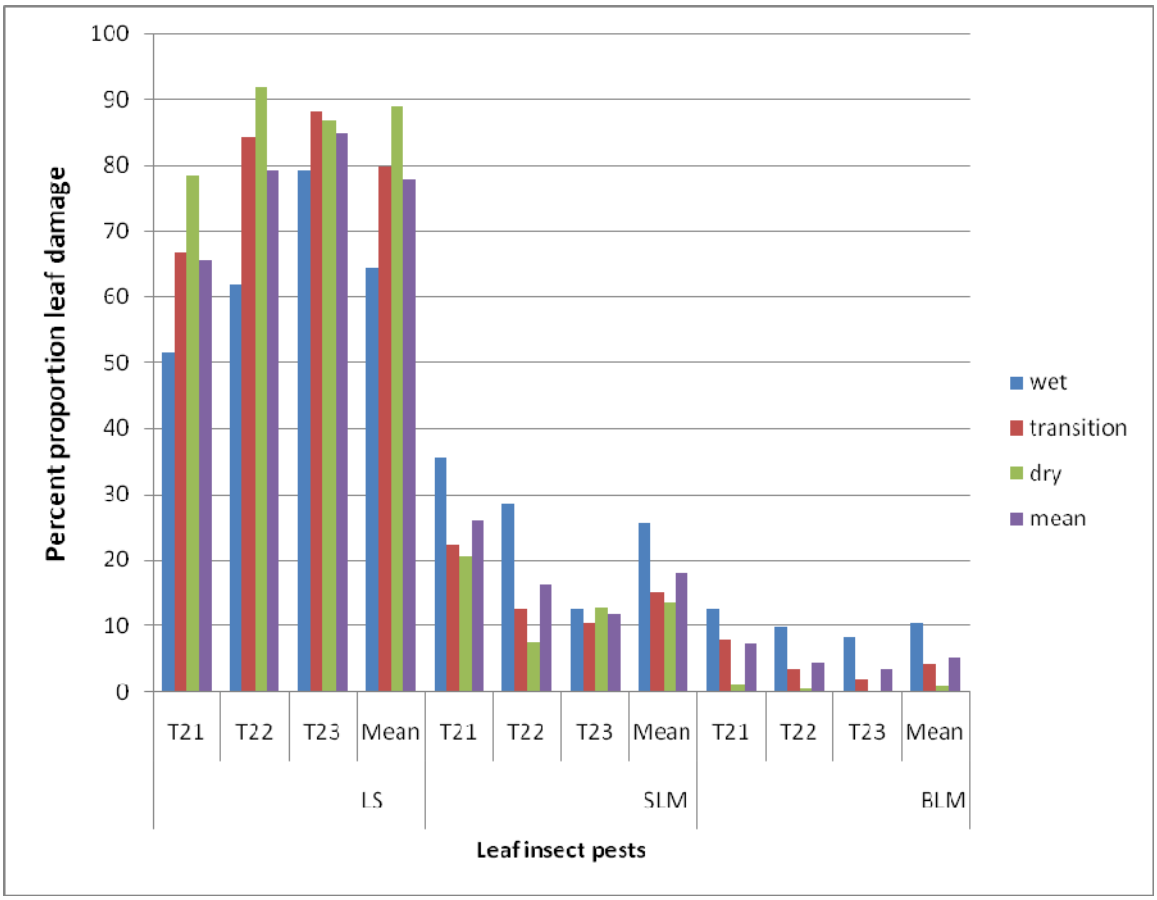

Fig-2: Cultivated coffee leaf damage proportion through different shade status and different seasons

Note: LS= leaf skeletonizer
SLM= Serpentine Leaf Miner
BLM= Blotch Leaf Miner
T21= Low shade status of cultivated coffee population
T22= Medium shade status of cultivated coffee population
T23= High shade status cultivated coffee population

In general, as figs 1 and 2 show as data across each season is represented indifferent color. Coffee leaf skeletonizer leaf damage ranked above all the leaf insects damage in proportion incidence of leaf damage, while blotch leaf coffee leaf miner leaf damage indicate the lowest in both cultivated and wild coffee population. The figure also shows us leaf skeletonizer leaf damage reach pick during dry season in both wild and cultivated

coffee plant, where as serpentine leaf miner leaf damage reach pick during transition in wild but rich pick during wet in cultivated season and finally blotch leaf miner leaf damage reach the highest position during wet season in proportion in both wild and cultivated coffee plant.

5.4 Incidence of coffee berry insect pests

The mean incidence of coffee berry borer which was observed in all coffee population of cultivated and wild coffee plant of left over and fallen coffee berries are analyzed. Hence, the data showed 13% and 20% in wild and cultivated coffee plantation respectively on left over dried coffee berry. While, on fallen dried coffee berry the highest infestation showed with 2% and 3% on wild and cultivated coffee, respectively.

Coffee berry moth mean incidence that is observed during survey on coffee berry showed at cultivated coffee that was 11% infestation. Where as, the wild coffee plantation observed with 7% berry infestation by coffee berry moth (Appendix- 7)

5.5 Natural enemies of coffee insect pests

Natural enemies that are frequently occurring parasitizing immature stages of coffee insect pests including Antestia bug, coffee leaf skeletonizer, coffee berry borer, coffee leaf miner and serpentine leaf miner have been collected and identified to the family level (Table-4). Thus at Melko of Jimma wild coffee population and wild coffee of Manna hymenoptera parasitoid from the families Braconidae, were found parasitizing coffee leaf miner and coffee leaf skeletonizer at the larval stage, Eupelmidae also found parasitizing egg of antestia bug, coffee berry borer larva was found parasitized by bethylidae at both wild and cultivated coffee plant whereas serpentine leaf miner at the larval stage was observed parasitized by eulophidae at both wild and cultivated coffee plantations.

Table-4: Natural enemies of coffee inset pests recorded in Jimma.

Host	Stage of host attacked	Natural enemies	Collected
Antestia (*Antestiopsis)*	Egg	Eupelmidae	Manna
leaf skeletonizer (*Leucoplema)*	Larval	Braconidae	Melko, Manna
Coffee berry borer (*Hypothenemus)*	Larval	Bethylidae	Melko, Manna
Blotch leaf miner *(Leucoptera)*	Larval	Braconidae	Manna
Serpentine leaf miner (*Cryphiomystis)*	Larval	Eulophidae	Melko, Manna

6. Discussion

A one year survey of wild and cultivated coffee insect pests in Jimma yielded fifteen insect families from five insect orders. The present research finding revealed that more insect diversity was found in wild coffee plantation as the insect families were found in wild coffee plantation as compared to ten insect families in cultivated coffee plantation. This observation might have revealed that more stable wild coffee that encountered little human intervention was able to posses more insect and lead to more diversity of insects. This findings is in line with that by Wrigley, (1988) who reported that in climates without severe extremes, consequently pests can survive from year to year, so does to the parasitoids and predators of these pests. Ecological theory predicts that natural ecosystems with higher species diversity are inherently more stable than those with limited number of species (Nooris *et al.,* 2003). In general stability clearly leads to diversity (Culin and Yeargan, 1983).

The coffee leaf damage incidence of each sampled tree for all surveyed seasons were categorized with high level infestation comprises 40% at cultivated while only 1% leaf damage recorded in cultivated coffee plantation. This leaf damage inflation at cultivated coffee supposed to be due to uncontrolled chemical pest side and fertilizer application and change of natural coffee genetic make up might have exposed coffee leaf to be affected by the insect pests easily. This in lined with Kenya Coffee Board (1996) report that the population of both predators and parasitoids are usually more sensitive to the careless use of insecticides than the pests themselves. Kassahun (2006) also reported that the gene pool of these wild coffee populations is of national and international importance, because it has high potential for the breeding of new coffee varieties. Allelochemicals often discourage some insects from feeding or ovipositing (Elzingas, 1997). Generally according to Singh (1983) pests intensify themselves in areas where the amounts of fertilizers, irrigation and the extent of cropping are increased. According to Haukio and Honkanen (1997), spatial variation in plant quality is recognized as fundamental feature of forest insect population

dynamics. Insect pest problems are more pronounced in intensive coffee production system (plantation) compared to garden and semi forest coffee production systems mainly due to changes in cultural practices associated with the newly planted cultivars (Million, 1987 cited in Esayas *et al.,* 2008).

The variation of insect incidence across different site of both cultivated and wild coffee that were varied according to their shade status in which more incidence of coffee leaf damage 39% and 36% at cultivated and wild coffee respectively recorded from high shade status where as lower incidence 28% and 31% leaf damage in cultivated and wild coffee respectively was observed at low shade status might have been due to the coffee leaf insect pests more attracted to shady environment and/or might have been the interruption of the activity of natural enemy by the shade canopy as it is supported by Lan and Wintgens (2004) who recommended that the use of shade has a direct relation ship with the behavior of the beetle. The adults are very active during bright, worm and sunny days, flying, mating and laying eggs. If sufficient shade is maintained, egg lying will be affected.

The collected data of coffee leaf damage during different seasons showed high variation. The highest leaf damage incidences were observed during wet season with 40% and 39% leaf damage at cultivated and wild coffee plantation respectively. Where as, the least coffee leaf damage incidence 28% and 22% recorded in wild and cultivated coffee population respectively during dry season. This might have been happened due to more conducive environment during rainy season allow the coffee leaves to recover that provided more host for pests to breed more and cause damage to coffee leaves. This assumption in lined with concentration hypothesis as (Ambrose, 2004) concluded that insect herbivores reach larger populations per plant in areas with high density of host plants than in areas where host plants are patchy or rare. Denlinger (1980) also evidenced that most important factor for insect fluctuation in wet and dry seasons is rainfall. It has also an indirect effect (Chaniotis *et al.,* 1971) and also by Thanka and Thanka, (1982) suggested that though rainfall contribute for insect abundance and fluctuations significantly, it can be responsible

for all of the observed fluctuations. Generally, Snigh (1983) recommended that rainfall, human activities, climate and food played great roles in the distribution, abundance and habitat association of insects

Coffee leaf skeletonizer was observed in all wild and cultivated coffee populations during all seasons in proportion with other coffee leaf insect pests. Thus, It was recorded the highest leaf incidence damage proportion with 85% and 68% during dry season at cultivated and wild coffee plantation. This highest proportion recorded during dry season might have been due to the capability of the insect to exist where its natural enemy perished and the rest insect pests coming down in number also supported as Million and Bayisa (1986) reported that coffee leaf skeletonizer was one of the potentially occurring insect pests of coffee.

The second important coffee leaf insect pests in Jimma after coffee leaf skeletonizer is Serpentine leaf miner in which it appeared the least proportion of leaf incidence damage with 9% and 14% at wild and cultivated coffee plantation during dry season respectively. This hiving the least coffee leaf incidence during dry season by this insect pest might have been due to less drought existence of the insect and due to its natural enemy existence during this season which in lined with Million (2000) report that Serpentine leaf minor, *Cryphiomystis aletreuta* (Meyrick) appears every year after the onset of the short rains affecting young leaves. Million and Bayisa (1986) also stated that coffee serpentine leaf miner was very common in most coffee growing areas of Ethiopia though their population was highly suppressed by the natural enemies.

The third abundant common coffee leaf insect pest of Jimma southwest of Ethiopia is blotch leaf miner that is found in the third level in proportion causing coffee leaf damage recorded 5% leaf damage incidence in wild and 2% leaf damage incidence in proportion of cultivated coffee leaf damage. The research also showed us the lowest coffee leaf incidence damage proportion 10% and 12% recorded by blotch leaf miner during transition season in both cultivated and wild coffee populations respectively.

This might have been due to more efficient season of their natural enemy during this season that checks their number to decline.

The coffee berry borer incidence on dried left over and fallen coffee in Jimma showed that the highest berry damage incidence recorded 10% and 14% at wild and cultivated left over dried berry coffee plantation respectively. While, the least record with 1% and 2% were observed on fallen dried berry. As it was recorded with respect to shade status the highest berry infestation appeared with high shade status in both cultivated and wild coffee plantation left over dried berry with 13% and 20% berry borer infestation respectively. The reason why the low infestation on fallen berry might have been due to the more exposure of berry to its pest to be attacked and the coffee plantation under high shade with high infestation might have been due to the pest were more interested to the more shady one this assumption in lined with the report of Hill (1975) that It is a minor pest of coffee, especially when it is grown without shade.

The other coffee berry insect pests which were frequently recorded insect pests at both cultivated and wild coffee plantation in Jimma was coffee berry moth with only 5% and 11% coffee berry infestation observed at wild and cultivated coffee population respectively showed that though the pest was common in this area it is as a miner pest in line with that by Crowe (2004) report that this pest was a miner pest of Arabica coffee for many years in east Africa and south Africa including Ethiopia.

The natural enemy of common insect pests of cultivated and wild coffee plantation in Jimma collected from immature stage of their host such as from larvae of coffee leaf Skeletonizer and blotch leaf miner Braconidae parasitoid merge in lined to Le pelley (1968) report that larvae and pupae of coffee leaf Skeletonizer were parasitized by a number of different parasitoids such as *Euplectrus epiplemae* (Eucophidae) in Uganda and Congo and *Apanteles epiplemicidus* (Braconidae) from Congo; *Cratichneumon spp* (Icheneumonidae) from Kenya. And also the outer reported that blotch leaf miner particularly *L. caffeine* parasitized by *Parahormius leucoptera*

(Bracoindae), *Hemiteles spp.* (Ichneumonidae), and thirteen species of Eulophidae recorded from Kenya, Tanzania, Malawi and Uganda.

From the larvae of Serpentine leaf miner that was collected from coffee plantation in Jimma showed that a number of the pests parasitized by Eulophidae supported as Million and Bayisa (1986) reported that serpentine leaf miner attacked by hymenoptera: Eulophidae species of *Sirrospilus sp.* and *Derosfenus coffeae* Ferriere.

Finally Antestia bug though rarely the pest was observed at Manna coffee plantation, it is the most economically important insect pests of coffee fruit and flower of coffee plantation was observed parasitized by Eupelmidae. This is supported by the report of Million (1987) that the egg stage of Antestia bug was parasitized by two species of *Eupelmidae, Anastatus antestiae* (Ferriere) and *pediobius sp. nr. minimus* Deluchi and two species of Scelionidae, *Asolcus suranus* (Nixon) and *Hadronotus antestiae* Dodd. Weather factors, host plant, and natural enemies may be attributed for distribution and seasonal changes in population of the insect (Esayas *et al.,* 2008).

7. Conclusion and Recommendations

7.1. Conclusion

- The study tried to see the distribution of coffee insect pests and their natural enemies at Jimma in wild and cultivated coffee under different shade status and seasons in 2009/2010.

  - From the study with respect to seasons revealed that the highest coffee leaf damage at both cultivated and wild Jimma coffee plantation rich pick with about 40% leaf damage incidence during wet season showed that the most fortunate time for insect pests to highly abundant in the area.

  - Having high coffee leaf and fruit incidence damage with respect to coffee shade status relatively in both cultivated and wild coffee plantation of Jimma showed in average with 30%, 34% and 36% leaf damage incidence at low, medium and high shade status respectively. Hence, most of coffee insect pests are shade loving insects in which they hide them selves from direct sun shine and their natural enemy. Thus the more shaded one the more likely to be infested by insect pests.

  - Coffee leaf damage incidence out of the total damaged leaves with 45% and 55% recorded at wild and cultivated coffee plantation of Jimma respectively. This showed that human intervention in cultivated coffee plantation by applying chemical pest side, fertilizer and genetic seed improvement process aggravated the proplem in making 10% higher than wild leaf infestation.
  - The insect pests of coffee berry borer more with berry infestation that ranged to 20% and 3% on left over and fallen dried berries of coffee plantation respectively. This showed that the left over which was not picked on time from coffee tree more exposed to coffee borer infestation. How ever, it was less infestation than before reported from other countries.

7.2. Recommendations

- ✓ Detailed study that show the relation of coffee insect pests to wild coffee at coffee genetic level needed and coffee plantation stage needed great investigation to know which factors more pronounced for coffee insect pest abundance.

- ✓ The research finding showed each insect coffee pests live with at least one of their own natural enemy in the same habitat. So, great study of natural enemy with respect to their microclimate and their general character is needed. So that, one can exploits them with maximum efficiency.

- ✓ Specifically how much yield and quality of coffee product loss can be appeared either directly or not by each and every individual insect pest has to be known to know to what extent do tolerance of damage is axceptable so that one can leave in harmony with insects.

- ✓ Microclimate of coffee plant is another factor of coffee insect pest distribution. Thus detailed study of this microclimate such as type of tree shade with in coffee plantation, type of weed grew, soil type and elevation of coffee plantation land contribution to natural enemy and coffee insect pests diversity has to be known. So that one can support natural enemy to be able to exist in balance with insect pests continuously.

References

Ambrose, D.P. (2004). *The insects: Structure, Function and biodiversity*. Xpress Grafics, Delhi-28, India.

Amoah, F.M., Osei-bonsu K. and Oppong F.k. (1997). The effect of shade, stem number and spacing on robusta coffee yield in Ghana. **In:** *Association scientifique international ducafe, 17th international scientific colloquium on coffee* (Amoah F.M. ed.) 528-534pp. Cocoa Research Institute, Akim-Tafo, Ghana.

Anteneh Netsere, Endale Taye, Taye Kufa and Tesfaye Shimber (2008). Research on Arabica Forest Coffee Field Management. **In:** *Coffee Diversity & Knowledge. Proceeding of National Workshop Four Decades of Coffee Research and Development in Ethiopia* 14-17August 2007.. (Girma Adunga, Bayetta Bellachew, Tesfaye Shimber, Endale Taye and Taye Kufa, eds.) 196-200pp EIAR, Addis Ababa. Ethiopia

Baker, P.S. (2000). Pest. Cabweb. Monthly feature: Coffee berry borer CBB international Wallingford, UK. htt://pest.cab.web.org/.date of assessed 1/15/2010.

Bettencourt, A.J. and Podrigues C.J. (1985). Principles and practice of coffee breeding for resistance to Rust and other diseases. **In:** *coffee agronomy vol.4* (Clarke R.J and Macrae R. eds) 43-90pp. Booker Agriculture International Limited, Thame, Oxon., UK.

Carvalho, A. (1969). Principles and practice of coffee plant breeding for productivity and quality factors: Coffee Arabica. **In:** *Coffee agronomy* (Clarke R.J and Macrae eds.) 129-165pp. vol.4 Elsevier *Appl. Sci*. London.

Chaniotis, B.N, Nealy, J.M., Correa, M.A., Tesh, R.B., and Johnson, K.M. (1971). Natural population dynamics of phlebotomine sandflies in panama. *J. Med. Entomol.* 8: 339-352.

CGA (1987). *Coffee Hand Book*. Cannon press. Harare, Zimbabwe.

Coste R. (1992). *Coffee: The plant and product*. Dover publication Inc. Hong Kong.

Crowe T.J. (2004). Coffee pests in Africa. **In:** *coffee: growing, processing, sustainable production* (Wintgens J.N. ed.) 389-418pp. WILEY-VCH verlag GmbH & Co. KGaA. Weinheim, Jermeny.

Crowe, T.J. and Tadesse Gebermedhin (1984). *Coffee pests in Ethiopia, their Biology and control*, IAR. Addis Ababa, Ethiopia.

Crown coffee (2002). Ethiopian Coffee Speciality (un published). Addis Ababa, Ethiopia.

Culin, J.D., and Yeargan.K.V (1983). A comparative study of spider communities in alfalfa and soybean ecosystems: Foliage-dwelling spiders. *Ann. Entomol. Soc. Am.* **76**:825- 831.

Demil Teketay (1999). History, Botany and Ecological requirements of coffee. *Walia*. **20:** 28-50.

Denlinger, D.h.(1980). Seasonal and annual variation of insect abundance in the Nairobi Kenya national park. *Biotropica*. **12:**100-106.

EARO (1999). Progress report for the period 1997, Addis Ababa, Ethiopia.

EMSA (2010). Ethiopian Metrological service Agency. Addis Ababa, Ethiopia.

Endale Taye, Taye kufa, Anteneh Netsere, Tesfaye Shimber, Alemseged Yilma and Tesfaye Ayano (2008). Research on Arabica Coffee Field Management. **In:** *Coffee diversity and knowledge* (Girma Adunga, Bayetta Bellachew, Tesfaye Shimber, Endale Taye and Taye Kufa, eds.) 187-200pp. EARO, Addis Ababa, Ethiopia.

Esayas Mendesil, Bekele Jembere and Emiru Seyoum (2003). Occurrence of coffee berry borer, *Hypothenemas hampei* (Ferri) (Coleoptera: Scolytidae) on *coffea Arabica* L. in Ethiopia. *J. Biol. Sci.* **2:** 61-72.

Esayas Mendesil, Bekele Jembere and Emiru Seyoum (2004). Population dynamics and distribution of coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) South western Ethiopia. SINET: *Ethiopian Journal of sciences* **27:** 127-134.

Esayas Mendesil, Million Abebe and Chemeda Abdeta (2008). Review of research on coffee, Tea and Spices insect pests in Ethiopia. **In:** *increasing crop production through improved plant protection*. Vol. II (Abraham Tadesse ed.) 117-140pp. PPSE and EIARO. Addis Ababa, Ethiopia.

Esayas Mendesil, Million Abebe, Chemeda Abdeta and Mekuria Tadesse (2008). Coffee insect pest in Ethiopia. **In :** *Coffee Diversity & Knowledge. Proceeding of National Workshop Four Decades of Coffee Research and Development in Ethiopia* 14-17August 2007. (Girma Adunga, Bayetta Bellachew, Tesfaye Shimber, Endale Taye and Taye Kufa, eds.) 279-296pp. EIARO. Addis Ababa, Ethiopia.

FAO (1968). Food and Agricultural Organization coffee mission to Ethiopia, 1964-1965. FAO. Rome, Italy.

Feyera Sanbata (2008). Biodiversity and Ecology of Afromontane rainforests with wild *Coffee arabica* L. populations in Ethiopia. Ph.D. Dissertation. Ecology and Development Series No. 38. Cuviller verlag Gottinge, Germeny. 144pp.

Haukio. J.E and Honkanen. J (1997). *Herbivore-induced responses in trees internal Vs. external explanations*. Cambridge University press. Cambridge.

Herbert, A.M. (1985). Coffee selection and breeding. **In:** *Coffee: botany, biochemistry and production of beans and beverage* (Clifford, M.N and Wilson, K.C. eds). CROOM HELM. London.

Hill, D.S. (1975). *Agricultural insect pests of the tropics and their control*. Cambridge University press. London.

IAR (1972). Jimma research station, progress report for the period April 1971 to March 1972. Addis Ababa, Ethiopia.

IAR (1996b). Jimma Agricultural Research center progress report 139pp for the period 1992-1993). IAR, Addis Ababa, Ethiopia.

IAR (1996c). Recommended production technologies for coffee and associated crops. Institute of Agricultural Research, Jimma Research Center, Jimma.

IAR (1997a). Jimma Agricultural Research center progress report for the period 1994, part I coffee, IAR,Addis Ababa, Ethiopia.

IAR(1996a). Jimma Agricultural Research Center progress report for the period 1986-1991 part 1 coffee IAR, Addis Ababa, Ethiopia.

Kassahun Tesfaye (2006). Genetic diversity of wild Coffea arabica populations in Ethiopia as acontribution to conservation and use planning. Ecology and Development Series, No.44. Cuvillier Verlag, Göttingen.

Kenya Coffee Atlas (2003). An atlas of coffee pests and diseases. Nayrobi, Kenya.

Lan, C.C. and Wintgens, N.J. (2004). Major pests of coffee in the Esia Pacific Region. **In:** *coffee: growing, processing, sustainable production* (Wintgens, J.N. ed.) 389-418pp. WILEY-VCH verlag GmbH & Co. KGaA. Weinheim, Jermeny.

Le Pelley R.H (1968). Pests of coffee. Longmans green and Co. Ltd., London.

MCTD (1999). Coffee statistics hand book. Addis Ababa, Ethiopia.

Mekasha Chichayebelu (1993). Importance and control of antestia, *Antestiopsis intricate* (Ghesquire and Carayon) on *Coffea arabica* L. at Bebeka coffee plantation development project in south west Ethiopia. MSc. Thesis, Alemaya University of Agriculture, Alemaya, Ethiopia. 62pp.

Mekuria Tadesse, Million Abebe and Teklemariam Ergie (1993). Antestia bug as possible cause of coffee berry fall at Tepi State Farm. **In:** *proceeding of crop protection society of Ethiopia*, March 5-6, 1992, Addis Ababa, Ethiopia.

Million Abebe (1987). Insect pests of coffee with special emphasis on Antestia bug, *Antestiopsis intricate*. **In:** *Ethiopia Insect scenes and Applocatopm*, **8:**977-980.

Million Abebe (2000). Significance of Arthropod pests of coffee in Ethiopia. **In:** *proceedings of workshop on the control of CBD in Ethiopia,* 66-71pp. 13-15 August 1999. IAR, Addis Ababa, Ethiopia.

Million Abebe and Bayisa Mormene (1986). A reviw of coffee pest management research in Ethiopia. **In:** *A review of crop protection research in Ethiopia*. Proceedings of the first Ethiopia crop protection svmposium. 4.8 February 1985. (Tsedeke Abate, ed.) 163-178pp. IAR, Addis Ababa, Ethiopia.

Mitchell H.W. (1985). Cultivation and harvesting of the Arabica coffee Tree. **In:** *coffee agronomy vol-4* (Clarke R.J and Macrae R. eds) 43-90pp. Booker Agriculture International Limited, Thame, Oxon., UK.

Muschler R.G. (2004). Shade management and its effect on coffee growth and quality. **In:** *coffee: growing, processing, sustainable production* (Wintgens J.N. ed.) 389-418pp. WILEY-VCH verlag GmbH & Co. KGaA. Weinheim, Jermeny.

Njoroge J.M. (1997). Environmentally friendly and sustainable coffee management. **In:** *Association scientifique international ducafe, 17thinternational scientific colloquium on coffee* (Amoah F.M. ed.) 481-494pp. Cocoa Research Institute, Akim-Tafo, Ghana.

Nooris. R.F (2003). *Concept in integrated pest management*. Prentice-Holl, inc. New Delhi.

Nyambo, T.B and Masaba, M.D (1997). Integrated pest management in coffee: Needs, limitations and opportunities . **In:** *Association Scientifique International du Café 17th international conference on coffee science in Kenya* (International Scientific Colloquium on coffee ed.). 629-638pp. Internationa Instiute of Biological Control. Nairobi, Kenya.

Owne, D.F (1969). Species diversity and seasonal abundance intropical (sphinidae: Lepdoptera) *Proc Ent Soc lond ser*. **44:**162:168.

Paulos Dubale and Demil Teketay (2000). The need for forest coffee germplasm conservation in Ethiopia and its significant in the control of coffee diseases. **In:** *proceeding of the workshop on control of Coffee Berry Disease (CBD)* in August 13-15, 1999, 125-135pp. Addis Ababa, Ethiopia.

Remond, F. and Cilas, C. (1997). Lechantillonnage des dats causer per le scolyte du trait due caf : definition de sondage le terrain. **In:** *17th international scientific colloquium on coffee* July 20-25, 1997, (Association for coffee science and information on coffee, eds.) 656-663pp. Nairobi, Kenya. Abstract.

Singh, J. P.(1983). *Crop protection in the tropics*. Vikas publishing house pvt Ltd. India.

Solomon Endris, Behailu W/Senbet, Abrar Sualeh and Nigussie Mekonen (2008). Qualitative characteristics of wet processed Arabica coffee Evaluated under different processing stages. **In:** *vol. I proceeding of the Inaugural of the first conference of Ethiopian Horticultural Science Society* Murch 23-24, 2006 (Lemma Dessalegne, Endale Gebre, Hailemichael K/Mariam, Zebene Wouldu, Terefe Belihu, Asfaw Zelleke, Lakew Belayneh eds.) 259-266pp. EHSS. Addis Ababa, Ethiopia.

Tadesse Woldemariam, Mantred Denich, Fronz Gatzweler. Girma Balcha and Denel Tekatay (2008). Insitu conservation of Genetic Resources of wild Arabica coffee in montane rain forest Ethiopia **In:** *Coffee Diverslly & Know Ledge* (Girma Adugna. Bayetta Ballachew Tesfya Shimber, Endal Taye and Taye Kufa. eds) 29-343pp, EIRO. Addis Ababa, Ethiopia.

Tadesse Woldemariam (2003). Vegetation of Yayu forest in south western Ethiopia: Impacts of human use and implication for *in-situ* conservation of wild *Coffee Arabica* L. populations Ph.D dissertation. Ecology and development series. No.10, cuviller verlag Gottinge, Germany. 162pp.

Thanka, L.K. and Thanka, S.K. (1982). Rainfall and seasonal changes in arthropod abundance on tropical oceanic island. *Biotropica.* **14:** 114-123.

Taye Kufa and Tesfaye Shimber (2001). Organic coffee production: Hopefor small-scale farmers in Ethiopia. **In:** *19th international conference on coffee science* , (Association for coffee science and information on coffee, eds). May 14- 18, 2001. Trieste, Italy.

Tsegaye Yilma, Getachew Olana and Tesfaye Zegeye (2000). Some Socio Economic issue related to fungicide use against CD in Ethiopia. **In:** *Preceding of workshop on the command (CBI) in Ethiopia* 13-14 August 1999 72.84 pp. IAR Addis Ababa, Ethiopia.

Webster C.C. and Wilson P.N. (1969). *Agriculture in the tropics*. Longman, London.

Wellman F.L (1961). *Coffee: Botany, cultivation and utilization*. Leonard Hill [Books] Ltd. London.

Wintgens J.N (2004). The coffee plant. **In:** *Coffee: Growing, processing, sustainable production* (Wintgens J.N ed). 3-56pp. WILEY_VCH verlag Gmbh and Co. kGaA, Weinheim.

Workafes Woldesadik and Kassu Kebede (2000). Coffee production system in Ethiopia Addis Ababa **In:** *proceeding of the workshop control of coffee Berry Disease* (CBD), August 13-15, 99-106, pp. IAR, Addis Ababa, Ethiopia.

Wrigley G. (1988). *Coffee: Tropical Agriculture series.* John Wiley and Sons. Inc., New York.

Yacop Edjamo, Tesfaye Shimber, Alemseged Yilma, Taye Kufa, Anteneh Netsere, Tekele Negewo, Mohammednur Abachebsa and Bekele Bogale (1996). Advance in coffee agronomy research in Ethiopia. **In:** *proceedings of Inter-Africa coffee organization* (*IACO) workshop.* 4-6 september 1995, 40-55pp. Kampala, Uganda.

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APPENDICES

Appendix1: General data of wild coffee leave damage by most common coffee insect pests per selected coffee tree at Manna

Tree NO	Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
1	32.35	33.33	30.43	33.33	33.85	33.85	13.79	12.31	13.64	09.26	09.68	12.50	08.00	13.56	15,15	14.89	15.91	17.74	19.30	22.22	24.59	25.45	22.95	21.57	21.82	20.69	21.21
2	34.43	27.14	38.67	32.14	36.06	38.03	16.00	15.52	17.39	12.50	12.24	16.40	11.54	22.73	18.33	18.37	19.84	18.52	16.33	25.86	20.00	22.03	31.11	20.34	20.69	26.79	28.07
3	39.62	33.80	32.02	40.67	38.80	43.04	18.37	19.70	21.62	08.70	09.84	11.59	16.67	20.69	20.97	16.67	16.98	20.00	15.69	23.64	23.81	10.00	25.49	22.81	13.56	29.09	21.31
4	45.07	36.25	35.71	42.86	42.03	47.30	20.00	24.24	25.71	12.07	13.64	13.43	15.69	18.00	24.61	18.75	19.67	21.31	12.73	26.78	28.12	14.28	27.12	20.97	16.67	31.58	28.57
5	30.77	37.50	30.16	30.98	34.43	37.29	13.23	13.79	14.75	11.11	13.46	15.00	13.33	15.52	19.67	18.18	16.00	20.69	17.24	21.05	23.43	20.69	23.64	18.75	221.05	27.12	18.18
6	32.95	39.19	26.67	38.89	33.33	26.76	18.18	16.42	19.12	11.47	13.33	14.75	14.75	13.79	13.79	15.69	15.55	15.52	11.11	16.58	20.00	19.64	18.88	18.03	22.41	21.57	28..03
7	25.00	28.17	37.66	22.72	26.98	32.83	12.06	11.67	09.84	06.78	07.27	08.77	07.14	13.33	15.69	12.24	16.13	12.76	15.09	13.56	21.21	15.00	10.00	21.67	18.18	15.52	20.97
8	36.62	29.85	32.39	24.59	24.59	30.88	11.11	11.29	13.33	06.12	05.55	06.90	07.69	10.00	15.09	13.46	12.96	12.00	16.98	18.33	22.73	13.63	20.69	20.33	28.33	21.31	22.22
9	39.28	35.94	28.98	32.26	35.59	36.67	11.86	14.81	17.65	07.84	09.80	10.20	11.76	14.89	13.72	14.90	16.67	16.67	13.46	13.11	22.22	16.39	12.28	20.69	14.03	16.36	27.59
10	33.87	41.67	36.84	33.90	38.46	41.72	14.00	15.15	20.31	08.33	11.86	12.07	14.00	12.96	20.75	19.67	14.61	19.61	15.79	16.67	23.08	18.37	18.64	24.56	22.64	16.95	22.95
11	32.83	29.33	35.44	30.88	30.98	35.21	13.11	12.86	13.85	09.10	09.09	12.70	18.75	12.70	21.67	20.34	17.39	24.56	16.07	17.54	21.53	17.02	18.33	16.95	18.18	21.05	16.67
12	28.12	34.25	30.98	27.87	33.82	29.69	09.26	15.94	16.13	03.92	11.47	12.28	08.16	15.00	16.36	11.11	18.42	23.53	17.86	19.64	24.24	20.00	20.97	22.95	20.34	20.69	17.74
13	28.98	31.17	34.88	32.31	37.14	32.05	14.75	16.93	17.14	07.02	06.90	09.52	14.00	17.54	20.00	25.86	22.22	21.14	10.53	12.50	12.67	12.73	11.32	23.81	16.67	12.96	19.05
14	27.42	26.09	30.88	29.85	23.88	29.51	08.47	10.53	11.67	05.77	07.84	07.27	10.42	12.24	15.69	12.24	13.95	14.58	22.81	16.36	21.57	20.75	17.65	18.03	24.49	24.56	24.14
15	30.51	28.30	40.03	34.37	29.51	38.60	12.07	14.54	14.54	07.41	10.87	10.64	12.00	13.64	19.56	13.95	17.07	17.78	27.45	15.25	23.08	29.09	16.95	23.33	32.07	22.03	28.33
Mean	33.19	32.85	33.45	34.03	33.30	35.56	13.75	15.05	16.45	08.49	10.19	11.60	12.26	15.12	18.74	16.42	16.88	18.43	19.66	18.61	21.95	18.34	19.73	20.99	20.74	21.88	23.00

Appendix 2: General data of cultivated (plantation) coffee leave damage by most common coffee insect pests per selected coffee tree at Melko

Tree NO	Aug			Sep			Oct			Nov			Dec			Jan			Feb			Mar			Apr		
	T21	T22	T23	T21	T22	T23	T21	T22	T23	T21	T22	T23	T21	T22	T23	T21	T22	T23	T21	T22	T23	T21	T22	T23	T21	T22	T23
1	35.09	52.46	55.55	51.67	42.86	45.31	23.52	34.33	34.54	13.04	18.37	22.64	19.23	18.75	23.53	15.68	15.91	14.54	23.81	18.33	19.15	14.28	24.24	21.43	18.18	21.31	27.08
2	27.91	43.86	53.06	43.75	51.78	37.50	42.86	26.78	37.21	22.50	15.91	20.00	17.39	14.00	26.41	11.90	10.71	21.43	19.64	20.83	24.53	23.33	21.67	23.63	21.31	23.44	22.95
3	50.98	51.06	68.42	50.88	50.72	50.00	36.73	20.34	38.00	18.03	14.58	16.07	24.14	17.65	25.64	13.21	10.32	23.40	21.82	23.53	24.56	22.81	19.05	18.87	19.05	20.63	25.86
4	58.93	46.15	59.42	67.69	54.10	53.97	32.72	36.54	31.58	13.46	16.36	15.38	12.24	15.09	14.89	13.64	18.03	16.67	21.74	19.57	14.00	20.00	18.03	26.31	19.30	20.00	23.64
5	47.54	48.72	54.23	35.85	67.00	44.44	23.40	24.39	41.30	06.38	10.96	14.00	06.98	06.82	13.89	15.22	11.11	18.75	24.00	20.59	23.64	22.41	22.22	28.81	20.00	17.65	25.00
6	38.64	56.72	60.65	55.32	44.93	58.73	29.27	35.48	46.67	08.89	19.64	22.05	12.24	17.65	22.72	11.67	19.35	22.64	18.03	18.18	24.56	26.41	25.86	25.45	18.75	21.74	23.64
7	42.86	45.45	60.71	60.71	44.54	50.85	25.94	32.73	30.51	17.39	15.00	22.41	19.67	20.31	14.00	16.67	20.37	20.34	16.67	17.86	22.22	20.00	19.64	27.12	18.18	22.22	24.14
8	41.93	63.08	54.93	56.10	53.33	50.72	24.24	46.30	24.59	13.79	23.53	17.54	08.16	18.75	14.75	09.09	18.75	221.43	15.52	21.15	22.64	17.24	21.82	23.33	23.33	22.00	26.31
9	35.82	48.27	61.19	33.84	47.27	57.14	31.37	42.86	30.00	12.50	17.31	19.64	11.86	18.00	20.33	18.03	17.07	25.92	14.81	18.00	25.00	16.67	18.87	22.41	22.41	24.07	25.45
10	25.40	52.73	58.93	23.73	56.60	58.00	15.55	39.53	29.79	07.50	13.51	24.07	07.14	17.82	14.63	17.24	15.22	18.00	18.87	22.03	22.00	17.86	22.41	21.82	22.41	18.18	26.78
11	37.93	48.39	30.61	49.10	51.56	30.23	25.49	32.79	21.95	10.87	14.81	18.37	12.50	14.889	10.00	15.69	15.79	17.02	21.57	17.02	20.83	23.21	20.34	25.58	22.00	23.21	24.00
12	36.73	53.03	59.37	40.38	46.15	61.40	23.25	25.00	38.46	08.12	09.43	14.89	09.76	06.12	23.81	14.28	16.67	22.03	19.15	21.74	25.92	20.75	20.83	28.57	23.64	26.41	18.75
13	39.68	45.76	63.64	32.83	52.83	56.00	19.64	29.63	35.55	06.12	12.76	21.95	06.38	14.28	18.75	08.00	16.28	18.03	20.00	18.18	29.31	21.15	25.00	21.74	18.00	20.83	19.61
14	36.55	51.56	62.71	27.87	55.07	54.54	22.64	32.61	35.29	05.55	16.33	19.61	09.09	15.55	18.37	12.19	10.26	15.87	21.28	23.73	25.42	23.73	22.81	24.59	20.83	22.00	28.30
15	16.76	43.15	65.08	46.03	42.37	65.00	36.00	21.57	38.46	11.90	11.76	18.18	05.13	09.30	24.39	06.82	14.63	21.82	14.63	20.41	23.64	20.00	20.00	24.14	22.73	20.41	30.00
Mean	40.12	50.02	57.90	45.05	50.94	17.81	27.51	32.06	34.26	11.74	15.30	19.05	11.78	14.66	19.07	13.29	15.43	19.86	19.44	20.08	23.16	19.32	21.52	24.25	20.67	21.61	24.77

Appendix-3 Mean percent wild coffee leaf damage by common coffee leaf insect pests through different seasons

Tree NO	Wet season (Aug, Mar and Apr)				Transition (Sep, Oct and Nov				Dry (Dec, Jan and Feb			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	mean
1	26.54	25.66	24.4	25.53	18.79	18.61	20	19.13	14.06	17.23	21.165	17.48
2	25.717	28.35	29.03	27.7	20.21	21.27	23.94	21.81	15.41	22.81	18.95	19.06
3	23.56	29.46	25.38	26.13	22.58	22.78	25.42	23.59	16.34	20.44	21.59	19.46
4	25.34	31.65	28.42	28.47	24.98	26.64	28.81	26.81	15.72	21.48	24.68	20.63
5	24.17	29.42	22.36	25.32	24.98	20.56	22.35	22.63	16.25	17.52	21.26	18.34
6	25	26.55	22.35	24.63	22.85	21.03	20.21	21.36	13.85	15.31	16.44	15.2
7	19.39	17.9	26.77	21.35	13.85	15.31	17.15	15.44	11.49	14.34	16.55	14.13
8	26.19	23.95	24.98	25.04	13.94	13.81	17.04	14.93	12.71	13.76	16.61	14.36
9	23.23	21.53	25.75	23.5	17.32	20.07	21.51	19.63	13.37	14.89	17.54	15.27
10	24.96	25.75	28.12	26.28	18.74	21.82	24.7	21.75	16.49	14.747	21.15	17.46
11	22.67	22.9	23.02	22.86	17.7	17.64	20.59	18.64	18.39	15.88	22.59	18.95
12	22.82	25.3	23.89	24	13.68	20.41	19.37	17.82	12.38	17.69	21.38	17.15
13	19.46	18.48	25.91	21.28	18.03	20.32	19.57	19.31	16.8	17.42	17.94	17.39
14	24.22	22.77	24.35	23.78	14.7	14.08	16.15	14.98	15.16	14.18	17.28	15.54
15	30.56	22.43	30.56	27.85	17.95	18.31	21.26	19.17	17.8	15.32	20.14	17.48
Mean	24.25	24.81	25.69	24.91	18.69	19.51	21.2	19.8	15.08	16.87	19.62	17.19

Appendix-4: Mean percent cultivated coffee leaf damage by common coffee leaf insect pests through different seasons

Tree No	Wet season (Aug, Mar and Apr)				Transition season (Sep, Oct and Nov)				Dry season (Dec, Jan and Feb)			
	T21	T22	**T23**	**Mean**	**T21**	**T22**	**T23**	**Mean**	**T21**	**T22**	**T23**	**Mean**
1	22.52	32.67	34.69	29.96	29.41	31.85	34.16	31.81	19.57	17.66	19.07	18.77
2	24.18	29.66	33.21	29.02	36.37	31.49	31.57	33.14	16.31	15.18	24.12	18.54
3	30.95	30.25	37.72	32.97	35.21	28.55	34.69	32.82	19.72	17.17	24.53	20.47
4	32.74	28.06	36.46	32.42	37.95	35.67	33.64	35.75	15.87	17.56	15.19	16.21
5	29.98	29.53	36.01	31.84	21.88	34.12	33.25	29.747	15.4	12.84	18.76	15.67
6	27.93	34.77	36.58	33.09	31.16	33.35	42.48	35.66	13.98	18.39	23.31	18.56
7	27.01	29.1	37.32	31.14	34.68	30.76	34.59	33.34	17.67	19.51	18.85	18.68
8	27.5	35.63	34.86	32.66	31.38	41.05	30.95	34.46	10.92	19.55	19.84	16.77
9	24.96	30.4	36.35	30.57	25.9	35.81	35.59	32.44	14.9	17.69	23.75	18.78
10	21.89	31.11	35.84	29.61	15.59	36.55	37.29	29.81	14.42	18.36	18.21	16.99
11	27.71	30.647	26.73	28.36	28.49	33.05	23.52	28.35	16.59	15.9	15.95	16.14
12	27.04	33.42	35.56	32.01	23.92	26.86	38.25	29.67	14.4	14.84	23.92	17.72
13	26.28	30.53	35	30.6	19.53	31.74	37.83	29.7	11.46	16.25	22.03	16.58
14	27.04	32.12	38.53	32.56	18.69	34.67	36.48	29.94	14.19	16.51	19.89	16.86
15	26.98	31.28	35.35	31.2	27.87	33.25	34.59	31.9	15.38	16.96	20.53	17.62
Mean	26.98	31.28	35.35	31.20	27.87	33.25	34.59	31.90	15.38	16.96	20.53	17.624

Appendix 5: Mean percent proportion of wild coffee leave damaged by most common coffee leaf insect pests at Manna

Month	LS				SLM				BLM			
	T1	T2	T3	Mean	T1	T2	T3	Mean	T1	T2	T3	Mean
Aug	43.94	50.14	78.11	57.76	37.89	38.68	15.40	30.66	17.08	11.17	06.49	11.58
Sep	46.58	69.32	82.55	66.15	37.82	24.85	13.30	25.32	16.77	05.83	04.15	08.92
Oct	75.63	88.03	88.92	84.19	20.17	09.15	10.53	13.28	04.20	02.82	01.26	02.76
Nov	78.26	95.35	93.27	88.96	08.69	03.49	06.73	06.30	02.48	01.16	00.00	01.21
Dec	77.89	93.44	87.74	96.36	21.05	05.74	12.26	13.02	01.05	00.83	00.00	00.63
Jan	76.47	95.04	84.87	85.46	22.69	04.96	15.13	14.26	00.84	00.00	00.00	00.28
Feb	80.74	87.42	87.74	85.30	17.78	11.95	10.85	13.53	01.48	00.01	00.01	01.50
Mar	56.37	66.46	77.00	66.61	36.91	25.00	14.44	25.45	06.71	08.54	08.56	07.94
Apr	54.33	68.98	82.44	68.58	31.79	21.39	07.80	20.33	13.87	09.62	09.76	11.08
Mean	65.58	79.35	84.74	76.60	26.09	16.13	18.83	18.02	07.16	04.44	03.36	05.10

Note:- LS, SLM and BLM represents leaf Skeletenizer, Serpentine leaf minor and Blotch leaf minor respectively.
- T1, T2 and T3 represent low, medium and high shade status respectively.

Appendix 6: Mean percent proportion of cultivated (plantation) coffee leave damaged by most common coffee leaf insect pests at Melko

Month	LS				SLM				BLM			
	T21	T22	T23	Mean	T21	T22	T23	Mean	T21	T22	T23	Mean
Aug	52.79	59.07	61.38	57.75	45.96	40.00	38.05	41.34	01.24	00.93	00.57	00.91
Sep	63.59	57.77	64.51	61.96	37.77	39.17	35.04	37.33	02.64	03.06	00.45	02.05
Oct	64.54	67.97	65.17	65.89	34.52	30.47	34.46	33.15	01.01	01.56	00.37	00.98
Nov	81.25	71.07	75.21	75.84	18.75	28.93	24.79	24.16	00.00	00.00	00.00	00.00
Dec	90.22	88.89	86.26	88.46	09.78	11.11	13.74	11.54	00.00	00.00	00.00	00.00
Jan	91.26	95.45	92.02	92.91	06.80	03.64	05.52	05.32	01.94	00.91	02.45	01.77
Feb	73.47	80.67	86.17	80.10	20.41	13.33	09.04	14.26	06.12	06.00	04.79	05.64
Mar	71.00	75.14	83.50	76.58	20.23	11.60	10.50	14.11	08.67	13.26	06.00	09.31
Apr	65.32	77.17	81.19	74.56	23.70	09.23	10.89	14.61	10.98	13.59	07.92	10.83
Mean	72.61	74.80	77.27	74.89	24.21	20.83	20.22	21.76	04.73	04.37	01.84	03.50

Note: T21, T22 and T23 represents low, medium and high shade status of cultivated coffee population

Appendix 7: Mean percent infestation of wild and cultivated coffee by coffee berry moth

Type of coffee tree	Percentage of berry damaged per coffee tree															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean
Cultivated	11.36	14.75	09.09	04.84	10.17	07.02	14.03	03.57	16.28	09.52	15.38	15.38	15.87	13.95	10.53	11.45
Wild	13.95	03.07	08.77	01.96	08.16	10.34	05.77	06.67	07.94	03.77	10.61	06.78	05.77	07.94	02.08	06.61

Appendix 8: Summary of mean monthly rainfall distribution and temperature recorded at melko near by cultivated coffee and Manna sub site which is found near by wild coffee.

Month	Melko sub site			Manna (Yebu) sub site		
	Rain fall (mm)	Temperature		Rain fall (mm)	Temperature (^{0}C) at 2M	
		Min	Max		Min	Max
Jan	38.25	11.25	28.30	37.7	11.19831	29.0
Feb	26.85	12.35	28.65	29.4875	13.34696	30.5
Mar	70.00	13.40	29.10	104.7	13.42288	29.4
Apr	129.75	14.40	27.70	146.05	13.38823	28.8
May	226.50	14.50	25.85	230.1	13.32812	28.4
Jun	239.20	14.20	24.65	308.65	12.94639	26.7
Jul	241.25	14.00	23.05	313.325	12.82875	25.6
Aug	227.55	13.90	23.35	305.125	12.70915	25.5
Sep	152.20	13.55	24.30	256.175	12.76977	26.4
Oct	174.20	12.45	25.60	169.1625	12.61978	27.5
Nov	64.90	10.25	26.15	61.1125	12.41706	28.2
Dec	21.65	09.05	26.95	52.5875	12.67601	28.4
Average	134.36	12.77	26.14	167.8479	12.80428	27.9

Appendix 9: percentage fallen and left over coffee berry infested by coffee berry borer of cultivated and wild coffee plantation.

Fallen berry	Wild coffee plantation				Cultivated coffee plantation			
	T1	T2	T3	Mean	T21	T22	T23	Mean
	1	1	2	1	2	2	3	2
Left over berry	7	10	13	10	12	13	20	14

Note: T1= low shade status of wild coffee plantation
T2= medium shade status of wild coffee plantation
T3= high shade status of wild coffee plantation
T21= low shade status of cultivated coffee plantation
T22= medium shade status of cultivated coffee plantation
T23= high shade status of cultivated coffee plantation

Price (1997) also suggested that stable community has both stable populations and numbers of species present that remains roughly constant through time.