

Bio-Ecological and Management Studies of Coffee Berry Borer, *Hypothenemus Hampei Ferrari* (Coleoptera: Scolytidae) in Ethiopia

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Abstract: In Ethiopia, coffee is important to the economy of the country and also millions of the population relying on for their livelihood. Besides its importance, coffee production has constraints with number of biotic factors of which insect pests are the major ones. The present review was designed to summarize studies conducted on bio ecology and management of coffee berry borer in the country. The coffee berry borer, *Hypothenemus hampei* is a small black beetle that attacks the fruits of *C. arabica*. The first occurrence of coffee berry borer in Ethiopia was reported by Davidson. *H. hampei* is a pest of immature and mature coffee berries, causing no damage to the leaves, branches or stem. Attack by *H. hampei* begins at the apex of the coffee berry. The female beetle bores through the berry into the bean and lays eggs in the tunnel. Total number of eggs laid per female ranged from 20 to 40 eggs with a mean of $32 + 0.3$ eggs. Large-scale coffee plantations, research centers and small-scale farmers' showed a considerable variation in the level of damage. Creating an atmosphere that is not conducive to borer breeding and reducing primary sources of infestation are very important to reduce pest attack. Shade tree regulation and pruning can reduce the populations and also exposing them to attack by the natural enemies. Insect traps play an important role in monitoring and minimizing the borer. *Beauveria bassiana* which are efficient are considered to be good candidate on selecting biopesticides agents. In general, vigorous research needs to be taken to update the biology and management of coffee berry borer especially biological method. As Ethiopia is the centre of origin and diversity of Arabica coffee, there is a potential to find natural enemies and tolerant varieties against the pest.

Keywords: *Coffea arabica*, coffee pests, *Hypothenemus hampei*, entomopathogenic fungi

1. INTRODUCTION

Coffee (*Coffea arabica* L.) provides Ethiopia with its most important agricultural commodity, contributing around one quarter of its total export earnings (Minten *et al.*, 2014). In Ethiopia, coffee is produced within specific agro-ecological zones, over numerous geographical and political boundaries. At least 80% of Ethiopia's coffee comes from forests, forest-like habitats, or farms with shade (canopy) cover, representing land coverage of around 19,000 km² with around another 4,000 km² (c. 20%) grown in small plots in partial shade or full sun (Moat *et al.*, 2017). Ethiopia is the largest producer of coffee in Africa and is the fifth largest coffee producer in the world next to Brazil, Vietnam, Colombia and Indonesia, contributing about 4.2 percent of total world coffee production (Belay *et al.*, 2016).

Coffee has economical, environmental as well as social significance to producer countries (USDA, 2013). Despite the fact that Ethiopia is the center of origin and diversity for Arabica coffee, production and productivity is very low. The national average yield of coffee is between 600-700 kg ha⁻¹ as compared to the research result (production potential), which ranges from 1,800-2,500 kg ha⁻¹ (Tesfu, 2012). Even in modern plantation like Bebeke, Limu and Tepi coffee plantations, productivity hardly exceeds 430 kg ha⁻¹. This is due to poor adaptability of most of the released coffee berry disease resistant varieties at low lands of Bebeke and Tepi, labor shortage, harvest losses and inadequate or improper crop management practices (Baye *et al.*, 2008). In addition, insect pests are also among the major factors considered to limit coffee production both in terms of quality and quantity in the country (Million and Bayissa, 1986; Million, 1987; 2000).

In agricultural systems, particularly that of coffee, herbivorous insects can have significant impacts on plant productivity and can become a constant problem for farmers. From these coffee berry borer

(CBB), *H. hampei* Ferrari, one of the most economically important insect pest in coffee plantations in eastern Africa (Vega *et al.*, 2015). The coffee berry borer is the most serious pest of coffee in many of the major coffee-producing countries in the world. The scolytid beetle feeds on the cotyledons and has been known to cause serious attack of berries in a heavy infestation. Crop losses can be very severe and coffee quality from damaged berries is poor (Baker, 2016). The objectives of this review were to summarize the basic and applied studies of coffee berry borer and to identify the gap of research in Ethiopia and forward future direction.

2. COFFEE BERRY BORER (*HYPOTHENEMUS HAMPEI*)

2.1. Origin and Morphological Description

Coffee berry borer was first reported in coffee fields in Gabon in 1901, and later in Kenya in 1928 (Vega *et al.*, 1999). Although, the pest origin has not been confirmed yet, it is mostly believed to be native to Africa (Le Pelley, 1968). *H. hampei* has since spread to almost all the 80 coffee producing countries in the world (Vega *et al.*, 2009). The eggs of the borer is elliptical or ovoid in shape, milky-white and shiny when first laid, 0.5-0.8 mm long, 0.25-0.35 mm wide. Larvae - there are two larval instars for the female and one for the male. White, legless, vermiform body with fine but sparse hairs, brown hypognathous head, 3-segmented thorax and 9-segmented abdomen. Well-developed mouth parts. Pupae - white, becoming yellow after 10 days of development. Mandibles, eyes, antennae, elytra and membraneous wings are differentiated and easily visible (Johannson, 1984). The female adult beetle is 1.5–2.0 mm long × 1 mm wide; the adult male is smaller, but this can vary somewhat from place to place. When first emerging, the beetle is brown, but as it matures over the next few days it becomes black, with a reddish tinge to the thorax. The pupae are a similar length to the adult and the larvae are a little smaller, having a white body and brown head (Waller *et al.*, 2007).

2.2. Biology and Life cycle

Having a preference for older berries, the life cycle may not be completed before harvest and there is therefore a danger of spreading the beetle within green beans. The female beetle bores through the berry into the bean and lays eggs in the tunnel. Over a period of 3–7 weeks, up to 60 eggs may be laid, which hatch in 5–9 days (Waterhouse and Norris, 1989). The larvae feed on the bean for 10–16 days. The females molt twice before pupation and the pupal stage lasts for 4–9 days. The female becomes sexually mature soon after emergence, is fertilized by the male within the berry and is capable of laying eggs 3–4 days later. Males cannot fly and are capable of fertilizing up to 30 females during their lifespan (Wrigley, 1988).

According to Esayas (2002) studies in Ethiopia, oviposition started at about 7 -1 2 days after the emergence of female borer. Total number of eggs laid per female ranged from 20 to 40 eggs with a mean of 32 ± 0.3 eggs. Egg viability ranged from 88 to 96 percent with an average egg viability of 95 %. The incubation period of egg ranged from 5 to 10 days with mean of 6.5 ± 0.3 days. There are two larval instars for the female and one for the male. The average larval period of the female and male is 16 ± 0.3 and 12.5 ± 0.3 days, respectively. The total larval period ranged from 12 to 21 (17 ± 0.5) days. The average pupal period ranged from 5 to 9 days with mean of 6.2 ± 0.3 days. Complete development period (egg to adult) took 24 to 43 days with mean of 31.7 ± 0.8 days. Longevity of the female ranged from 40 to 95 days, with mean of 76 ± 0.8 days. On the other hand, the longevity of the male ranged from 25 to 45 days, with mean of 40 ± 0.6 days.

2.3. Feeding Behavior, Damage and Economic Importance

H. hampei is a pest of immature and mature coffee berries, causing no damage to the leaves, branches or stem. Attack by *H. hampei* begins at the apex of the coffee berry from about eight weeks after flowering. A small perforation about 1 mm diameter is often clearly visible though this may become partly obscured by subsequent growth of the berry or by fungi that attack the borer. During active boring by the adult female, she pushes out the debris, which forms a deposit over the hole. This deposit may be brown, grey or green in colour (Damon, 2000; Esayas, 2002). Infestation is confirmed by cutting open the berry. If the endosperm is still watery, the female will be found in the mesoderm between the two seeds, waiting for the internal tissues to become more solid. If the endosperm is more developed, the borer will normally be found there (Damon 2000). Adult female *H. hampei* bore galleries into the endosperm of the coffee seed, causing three types of economic losses: (i) boring and feeding activities

of adults and progeny cause a reduction in yield and quality of the final product (Moore & Prior, 1988); (ii) due to physical damage, attacked mature berries become vulnerable to infection and further pest attack (Waterhouse & Norris, 1989); and (iii) when insufficient mature berries are available, i.e. at the beginning of the season or where frequent harvesting is practiced, the hard, green berries are attacked. According to Esayas (2002) report Damage due to the borer may vary according to the level of infestation and incidence. Sometimes small perforation may be observed without significant damage of the berry. On the other hand, during high infestation the whole of the bean may be totally damaged make it worthless. Under natural infestation, one to six entrance hole per damaged berry were observed. Most of the damaged berries contained of 2 to 3 entrance hole, but few of them showed 5 and 6 entrance holes per damaged berry.

In Eastern Africa countries, yield losses reported as high as 96% have resulted from coffee berry borer attack on coffee (Magina, 2005). In Kenya, infestation levels of up to 80% have been reported (Masaba *et al.*, 1985) and the pest is reported to contribute to an on-going decline in coffee production in the country. So as to manage these pests, particularly the coffee insect pests, researchers in the past have tried to identify and develop effective, economic acceptable and sustainable pest control strategies. In Ethiopia the pest also causes significant damage both on left over the tree and fallen berries (Chemedo *et al.*, 2011).

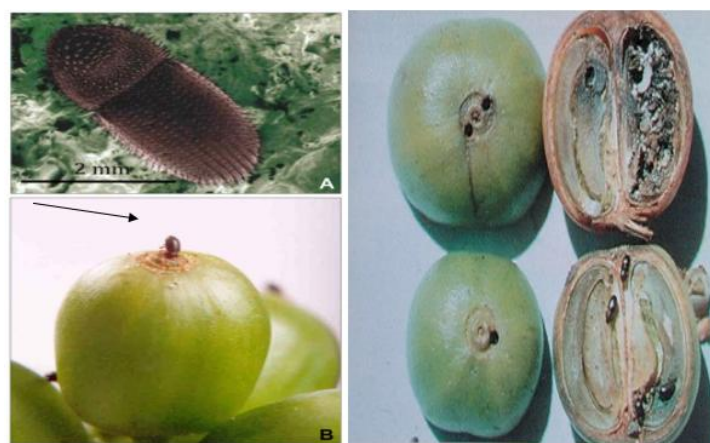


Figure1. Female of the CBB (a), female *H. hampei* penetrating a coffee berry (b) and galleries in berry (c)

Photo courtesy of John Frank, FAO Consultant

3. COFFEE BERRY BORER IN ETHIOPIA

3.1. Population Distribution and Level Of Damage

The first occurrence of coffee berry borer in Ethiopia was reported by Davidson (1968). The result of study by Fikadu *et al.*, (2016) in Gedeo zone of Southern Ethiopia indicated that the highest, severe level was recorded by coffee berry borer, *H. hampei*, in Yergachefe, Wonago, Dilla zuria, Kochere and Gedeb weredas. For instance, the damage caused by the borer outweighs the other pests as a single insect can lead the whole berry die. There was no statistically significant difference in the damage of coffee plant among studied coffee landraces and across the study sites (Fekadu *et al.*, 2016). Coffee berry borer covered a wide range of altitudes ranging from 1200 to 1770 m.a.s.l. (Chemedo *et al.*, 2011). It was recorded in large-scale coffee plantations, research centers and small- scale farmers' holdings at a considerable variation in the level of damage. The highest mean percent infestation was recorded at Tepi (60%). In general, at Yeki and Godere districts, where most of large-scale coffee plantations are found and at research centers like Melko, Metu and Tepi the level of infestation was considerably higher. On the other hand, in small-scale farmers', the infestation was very low (<5%). On the other hand, according to Eyasu *et al.* (2019) study results showed significantly highest proportion of damaged berries (37.5%), number of holes per berry (10.88) and number of adult CBB per berry (7.55) on dried leftover berries at low-altitudes. The study also showed that, this pest caused significantly highest damage in plantation coffee management system than garden coffee. Results of this study highlight proper harvesting at red ripe stage in order to minimize incidence of coffee berry borer. The authors were also recommended that the importance to design integrated management strategies to mitigate the borer damage especially in lowland plantation coffee production systems (Eyasu *et al.*, 2019).

3.3. Loss Assessment

The borer, feed and reproduce inside the berry where both the adults and larvae cause a direct damage on the berry and affect the quality and also cause abscission of berries (Vega *et al.*, 2009). Surveys conducted at various coffee growing areas of the country showed that the borer inflicted up to 60% damage on dry left over coffee berries (Esayas *et al.*, 2004). Unlike in other countries where it attacks green, ripe and dry berries (Le Pelley, 1968; Baker, 1999), in Ethiopia, it attacks only dry left over and fallen berries. Damage on green berries was almost negligible (<1%). However, it is important that the pest be monitored following the crop phenology to detect any deviation in its feeding behavior.

4. MANAGEMENT OF COFFEE BERRY BORER

4.1. Preventative Measures

All preventive methods consist in creating an atmosphere that is not conducive to pest breeding, or which limits their spread by reducing primary sources of infestation. They fall into two groups:

4.1.1. Manual and Cultural Control

Shade tree regulation and pruning can reduce the populations of the borer by creating unfavorable environmental conditions, and also exposing them to attack by the natural enemies of the borer (Crowe and Tadesse, 1984). Coffee berries should be collected as soon as they ripen (picking should be carried out at least every two weeks during fruiting peaks and every month at other times).



Figure3. Ripe coffee berry collection (A), Coffee berry dry processing method at household (B)

All over-ripen or dry leftover and fallen berries should be collected after harvest and destroyed in order to deprive the borer the opportunity for breeding and leave little host for immigrating borers (Crowe and Tadesse, 1984; Million, 1987; Esayas *et al.* 2004). Cultural control is as yet the safest, simplest and most accessible control method, especially for the thousands of small producers. It is labour intensive, however, depending upon cheap or free family labour in order to be cost effective.

4.1.2. Trapping

This technique consists of diffusing attractants in coffee trees to attract pests into a trap. The attractants may be pheromones, or simple chemical substances (FAO, 2005).



Figure4. Coffee berry borer traps developed by FAO

Few countries have developed a trap into which CBB are attracted by a mixture of ethanol and methanol where they die. This method leads to catches of hundreds of thousands of insects in a few weeks. Use traps to detect, monitoring and destroy populations of the insect (FAO, 2005). Traps will not control or eradicate CBB but can be used as a monitoring tool to determine when CBB may be vulnerable to spraying and to help indicate when to start sampling. Visual inspection or sampling is better than trapping for detection, determining infestation estimates, and finding “hot spots” because traps may not catch CBB until populations are high (Anderea *et al.*, 2015). According to Yonas (2017) the efficiency of the attractant Ethanol to Methanol (E:M) mixtures at Tepi-Baya II, Limu-Goma II and Mizan-Aman showed no significant difference, but all were significantly ($P < 0.001$) different from the control. The percentage of captured CBB with E: M, (1:1, 1:2 and 1:3) at Tepi-Baya II were 427, 413 and 416 at Limu-Goma II, 97, 115 and 90 and at Mizan-Aman; 139, 122 and 98, respectively. The outcome of the research work indicated that CBB population should be checked before the pest brings a devastating effect by the application of mechanical trapping and biopesticides in combination (Yonas, 2017).

4.2. Botanical Methods

With neem oil enriched with azadirachtin to 0.2%, 65% mortality was observed after three applications and a repellent effect was noted, with up to 80% of the berries showing signs of having been rasped superficially. Similar results were obtained using African palm oil (instead of neem oil) enriched with azadirachtin. Both substances were comparable in effect with endosulfan, but with the repellent effect of 40–50% shorter duration, therefore requiring twice as many applications. The main problem mentioned was the rapid biodegradation of azadirachtin in the field, giving a persistence of only a few days, resulting in a period of continued feeding after application (Schmutterer, 1990).

4.3. Biological Control

4.3.1. Entomopathogenic Fungi

Beauveria bassiana exclusively attacks adult *H. hampei* and infection can be detected by a blob of white, cotton-wool like mycelium, growing away from the body of the insect, appearing at the entrance of the tunnel (perforation) bored into the coffee berry. Wherever berry borer is found, the entomopathogenic fungus *B. bassiana* is also present as a natural infection, especially on the ground in cool conditions with high relative humidity and heavy shade. Conidia of the fungus adhere to the cuticle of *H. hampei*, where they germinate and penetrate the cuticle, proliferating internally to destroy the insects (Waller, 2007).

According to Yonas and Tesfaye (2017) study in Ethiopia, the isolates of *B. bassiana* which are efficient in all criteria are considered to be good candidate on selecting biopesticides agents. Moisture content of the harvested spore is expected to be lower to maintain the viability and improved shelf life. The use of high quality standards for spores increases the likelihood of success when applied in the field. The shorter mean mortality time and high. Mortality of coffee berry borers dipped into spore suspensions of 1×10^7 ml⁻¹ showed high mortality with 13 of the isolates reaching 100% mortality even though there was discrepancies on number the mortality of the coffee berry borers at different hours (days) intervals. It is indicated that the two isolates B7A and C3C scoring as the better isolates for biocontrol agents. This information provides a better picture to determine which isolates should be considered for subsequent mass production, formulation and possible commercialization. The use of high quality standards for spores increases the likelihood of success when applied in the field. The shorter mean mortality time and high germination potential for the isolates that selected for mass production were the main criteria. A possible reason was that the higher proportion of viable spores. Vega *et al.* (2012) stated that effectiveness of *B. bassiana* under field conditions depends of several factors, including the strain, concentration, virulence, weather conditions, and application efficiency.

4.3.2. Parasitoids

H. hampei is indigenous to central Africa, where three important natural enemies have been known for more than 40 years. Two of these are Bethyloid wasps: *Prorops nasuta* Waterston and *Cephalonomia stephanoderis* Betrem, and a Braconid: *Heterospilus coffeicola* Schmiedeknecht. *Prorops nasuta* acts as both parasite and predator, the adult feeding on eggs and young larvae while the larvae attack fully-grown larvae and pupae. Various insects, native to areas where coffee is an exotic crop. In Uganda, *H. hampei* was reported to be brought under control during April by *Prorops nasuta* Waterston

(Hymenoptera: Bethyridae), ovipositing on the full-grown larvae. During these explorations, it has become clear that in some parts of Ethiopia, *H. hampei* is not a problem possibly due to an efficient parasitoid and/or predator complex, resistant strains of coffee or the exceptionally clean harvest, reducing pest carry over during the inter-harvest period (Damon, 1999). Very recently, *H. hampei* was found in the south and south-east of Ethiopia associated with three unidentified parasitoids, two attacking the larval stage and one the adult stage (Abebe, 1998).

4.4. Chemical Control

Although there are several insecticides that are effective against berry borer, the beetle is protected to some extent from their effect by spending much of its life cycle within the berry. Spraying may do more harm than good, by destroying natural enemies. Insecticides can be effective if they are applied when the female is at entry tunnel before she penetrates the endosperm. They are not effective at controlling mature infestations, especially on fallen berries (Baker, 1999). Spraying can be done but is usually not needed if the above measures are carried out rigorously. Chemicals that can be used are Cypermethrin, Deltamethrin and Chlorpyrifos (Kuit consultancy).

5. SUMMARY AND CONCLUSION

In this review it was tried to compile about the origin, the biology and life cycle, damage, economic importance, population distribution, dynamics and different management methods of coffee berry borer in Ethiopia. Different management methods for the borer were also reviewed. Coffee berry borer is one of the major insect pests where coffee is grown. It is a pest of immature and mature coffee berries, causing no damage to the leaves, branches or stem. In Africa, yield losses as high as 96% attack on coffee tree leading to yield reduction and poor quality of coffee beans. Due to the extended oviposition period of the female, all life stages of the borer can be found in the berry. It feeds on and reproduces in the endosperm of the seed of the coffee berry. According to different survey findings in Ethiopia the pest also causes significant damage both on left over the tree and fallen berries. Population dynamics of coffee berry borers were found to occur almost throughout the year with fluctuating numbers. Surveys showed the borer inflicted up to 60% damage on dry left over coffee berries in this country, it attacks only dry left over and fallen berries. Different management methods were reviewed which includes prevention methods, manual, cultural and trapping, botanicals, parasitoids and entomopathogenic fungi.

6. GAPS AND FUTURE DIRECTION IN ETHIOPIA

- Studies on current status of coffee berry borer population dynamics and its natural enemies under different ecology and production systems in Ethiopia
- Biological control ought to be very promising management because coffee trees provide ideal condition for natural enemies.
- As Ethiopia is the centre of origin and diversity of Arabica coffee, there is a potential to find resistant/tolerant varieties against the pest
- Biopesticides based on botanicals and microbial control agents are one of the potential options for this pest management.
- Development of IPM for coffee berry borer insect pest is prospect

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