

**Review Article**

Coffee Berry Borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae): A Challenging Coffee Productions and Future Prospects

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Abstract: Coffee is the major commodity legally traded in the world from agricultural productions. Even though, it's economically important, its production and productivity is challenged by many factors, of which insect pests are the major. Among insect pests, coffee berry borer is the most challenging insect pest of coffee throughout the globe. It is the most important biotic constraints for commercial coffee production worldwide and major concern in eastern Africa. The infestations start when the adult females bore the berry and deposit eggs inside it. Hatched larvae start to feed on the inside the berry, which leads the reduction of yield and quality of the marketable product. On the other hand, almost all the lifecycle of the insect carried out inside the coffee berry and its cryptic nature, making it difficult to control. Additionally, global warming is particularly important for coffee because of its influence on occurrence of pests which often diminish production and quality of coffee. Increasing infestation of coffee berry borer and their management have significantly constrained economical production of coffee. The infestation of the pest is highly influenced by altitude, coffee production system, agroforestry practices, shade intensity levels and the natural enemies' diversity and populations. Many management options like cultural, insecticides, microbial and traps showed promising results under field conditions. But, using these options solely is unsustainable and ineffective for long term solutions. Then development of integrated management option for coffee berry borer is an issue in the future. And the compatibility of the promised options along with their application sequence also needs focus. The paper reviewed and identifies the research efforts should focus to increase the successfully developing an effective coffee berry borer management methods.

Keywords: *Coffea arabica*, Distribution, Quality, Damage

1. Introduction

Coffee is one of the major commodities which played significant source of income for more than 80 countries in the international agricultural trade [1]. The dominant coffee species are *Coffea arabica* L. and *Coffea canephora* Pierre ex A. Froehner which took the highest share in the coffee trade. But, more than 70% coffee production is covered by *C. arabica*. Many authors' reports agreed that *C. arabica* is originated in Ethiopia and where it's wild variety dominantly grown [2]. The economies of many countries depend upon coffee productions and businesses [3]. In Eastern Africa region coffee is a major cash and export crop. As an example, Fekadu *et al.* [4] reported that coffee contributed a higher

share to the Ethiopian economy in which it was a primary export commodity.

Jaramillo *et al.* [5] reported that the price of coffee highly increased between 2009 and 2011 years. This may be related with coffee productivity reduction in Eastern Africa and Latin America, the main coffee productions area. Even though, it's economic important, it affected by many production factors, of which insect pests influences both the yield and quality of the crop [4]. Major challenges that face production of *C. arabica* worldwide include: susceptibility to insect pests and diseases, low soil fertility and variability in climate and poor management practices [6]. Global warming is particularly important for coffee because of its influence on occurrence of droughts, and pests which often diminish production and

quality of coffee [7]. Mugo *et al.* [8] reported that the increasing infestation of coffee pests and their consequent management have significantly limited in coffee production.

Over 900 insect species have been reported on coffee in the world [9]. However, fewer than 20 of the arthropod insect pests constitute major constraints to coffee production [10]. In terms of economic importance, there are five coffee insect pests that are particularly important on Arabica coffee in East Africa. These include antestia bugs, coffee berry borer, green scales (*Coccus spp.* De Lotto), Kenyan mealy bugs (*Planococcus kenyae* Le Pelley) and coffee leaf miners (*Leucoptera meyricki* Ghesquiere and *Leucoptera coffeae* Washbourn) and other coffee pests have low economic damage [11]. But, in Ethiopia over 49 species of insect pests were reported [12]. Among which antestia bugs and coffee blotch miner are the major insect pests caused higher damage [13]. However, coffee berry borer, coffee thrips, green scale and coffee cushion scale are considered as potentially important insect pests in Ethiopia.

Even though coffee berry borer is the major insect pest affecting worldwide commercial coffee productions; it is a major concern in eastern Africa region [14-16]. The higher infestation of the pest was 96% in the region [17]. Previously, there were no information's of coffee berry borer infestations on coffee plantations at higher altitudes [18]. But, Jaramillo *et al.* [16] suggested that the probably *C. canephora* was the original host of the coffee berry borer. This coffee species is primarily produced at lower altitudes areas. Consequently, due to temperatures increment of coffee growing regions, the infestation of the pest now recorded at higher altitudes, where it *C. arabica* is dominant [16]. The objective of this paper is to identify the major achievements, the research gaps and put the future work on which the research should focus for the successful and effective coffee berry borer management options.

2. General Description and Biology of Coffee Berry Borer

2.1. The Taxonomic Classification and Biology Coffee Berry Borer

Coffee berry borers are categories of order Coleoptera, Scolytidae family and *Hypothenemus* genus. It has many synonyms name such as *Cryphalus hampei*, *Stephanoderes hampei*, *Stephanoderes coffeae* and *Hypothenemus coffeae* (Hagedorn) [19]. The most commonly used and accepted is *Hypothenemus hampei* (Ferrari, 1867) [19, 20].

The genus *Hypothenemus* has 181 species, of which only *Hypothenemus hampei* is known as an important pest [20]. The insect penetrates the coffee berry and reaches the endosperm where it builds galleries for its reproduction and then it commences egg laying. Barrera [21] reported that the female insect start oviposition after 2 days of her infestation. And the majority life cycle of the pest is spending inside the coffee berry [22].

2.2. Host Range of Coffee Berry Borer

Johnson *et al.* [23] reported that the majority of *Hypothenemus* genus feed on dead plant materials and not a significant crop pest. However, an economically important *Hypothenemus* species are the tropical nut borer (TNB), *H. obscures* and *H. hampei* [23]. And coffee is main host for the coffee berry borer. Additionally, Coffee berry borer adults have been recorded on plants other than the coffee [14]. In Haweii, Messing [24] evaluated different plant families and recorded the pest on *Leucanea leucocephala* (Lam.) from Fabaceae family. But, the pest was unable to use this plant as a host. Le pelley [25] reported that some of the plants on which the pests occurred include *Tephrosia sp.*, *Phaseolus lunatis*, *Hibiscus sp.*, and *Oxycanthus sp.* However, Sponagel [26] reported that the insects' life cycle is only known to be completed on coffee species. Additionally, its primary host is coffee plant and its reproduction didn't carry out on any other plants species [27, 23].

3. The Status and Distribution of Coffee Berry Borer

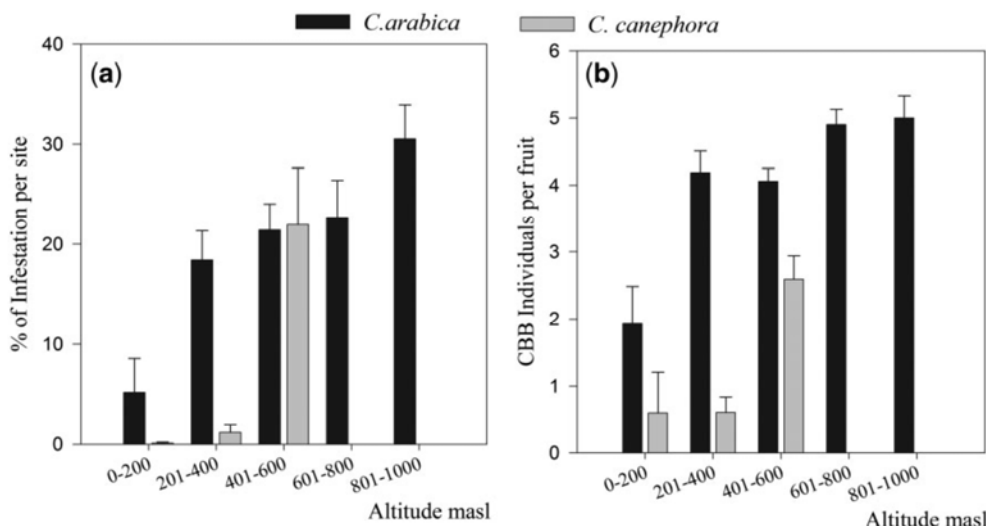
Coffee berry borer was first reported in exported coffee beans (Ferrari, 1867). It was collected from field in Mount Coffee, Liberia [28, 19]. In 1901 it recorded as a pest of *C. canephora* in the Republic of Congo and Gabon [29]. The pest was first detected in Brazil in 1913 [30]. The coffee berry borer expanded into Kenya in 1928, Ethiopia in 1968 and Colombia in 1988 [31, 32, 16]. Later coffee berry borer is recorded in almost all eastern and southern African countries. The pest becomes the most devastating insect pest on *C. arabica* and *C. canephora*. Coffee berry borer has spread to more than 80 coffee producing countries in the world [33, 20, 34]. Except China, Nepal and Papua New Guinea coffee berry borer is a serious pest of coffee worldwide [34, 11, 22]. But recently it reported that Papua New Guinea's coffee industry is infested [35].

Previously, coffee berry borer primarily attacks *C. canephora* which dominantly grown at lower altitudes while, *C. arabica* and forest coffee were less affected which commonly grown at higher altitude [36]. Eyasu *et al.* [37] study showed that the coffee berry borer is dominated at lower altitude coffee production areas and coffee produced by intensive cares. But with increasing temperatures, the coffee berry borer could be forced to migrate to higher altitudes where *C. arabica* dominantly grows. Study conducted in some coffee growing areas of Ethiopia showed infestation of coffee berries and populations of the pest have increased throughout southwestern Ethiopia [38]. As Esayas *et al.* [39] elucidated coffee berry borer covered a wide range of altitudes ranging from 1200 to 1770 m.a.s.l. Chemed *et al.* [40] reported that average incidence of 4.83 ± 0.44 , 7.15 ± 2.26 and $2.96 \pm 0.55\%$ of *H. hampei* at Berhane-Kontir, Yaya and Bonga, respectively. Fekadu *et al.* [14] also indicated that coffee berry borer is top prevalent coffee pests in Gedeo zone of southern Ethiopia.

Vega *et al.* [41] estimated that infestation levels of the

coffee berry borer were 60% in México and 50 – 90% in many countries. And the more severe infestation of the pest recorded in Puerto Rico in 2014. It caused severe damage especially at intermediate to high elevations [42]. The pest was considered as a serious threat for the survival of the coffee industry in the Island [42]. Marino *et al.* [42] used data for both *C. arabica* and *C. canephora* together and observed that infestation ranged from 0 to 95%. In 66% of sites sampled, the maximum number of individuals per fruit was greater than 10. Marino *et*

al. [42] found that almost double the number of individuals in sites above 201 m.a.s.l than at sites below 200 m.a.s.l. (Figure 1 (a)). These authors estimated that the infestation and coffee berry borer population per fruit were significantly higher in Arabica than Robusta coffee (Figure 1b). This indicates the pest likely more to infest and reproduce in coffee arabica than coffee canephora and will cause a major production and productivity reduction on coffee arabica dominant countries.



Source: Marino *et al.* [42].

Figure 1. Infestation and number of *H. hampei* per fruit on *C. arabica* and *C. canephora* (mean + S. E.) across altitude.

4. Coffee Production and Quality Damage

Coffee damage begins after the female insect colonizes and enters the coffee berry for feeding and reproduction (Figure 2a) [43]. The insect damage coffee beans before the farmers can harvest, and it is causing losses exceeding US \$500 million annually [33]. In India the main pest which reduces the production of coffee is caused by coffee berry borer [22]. Annually \$215-358 million losses were estimated by the pest in Brazil [44, 45]. The coffee industries in Puerto Rico, 1,200 coffee farms were destroyed and the total value of Puerto Rican coffee fell by 33% [46]. Additionally, 30% of the total cost of production is spent for the pest management [46]. And areas untreated intensively, the insect can destroy up to 80% of coffee production [5]. D/r Kenny said that if there is no control over pest, then Papua New Guinea stand to lose up to 80 percent of the crop. And it's going to cost the Papua New Guinea government at least K50-70 million to carry out the quarantine in the affected area [35]. These evidences clearly showed the importance of the pest and damage it caused is highly significant.

Therefore, coffee berry borer caused major economic losses and still a major challenge for coffee productions [30]. It caused severe losses in coffee production and quality by affecting developing berries, which provide a suitable habitat for the pest's reproduction and protection from predators and

adverse weather conditions [45]. The problem is facilitated by the female insect which attacks the immature and mature stages of coffee berries [43]. Females insect bore a hole into the coffee berry and then construct galleries in the seeds (beans) [47]. Upon hatching, larvae feed on the seeds, thus reducing and affects the yields and quality of the marketable beans (Figure 2b) [45].



a)



b)

Figure 2. Damaged coffee berries.

a) Damaged coffee beans b) Coffee berry borer reared in the beans; eggs (left), and eggs and larvae (right).

The coffee berry borer primarily causes three types of damages: first the pest causes premature fall of young berries, secondly it increased susceptibility of infested ripe berries to fungus or bacterial infection, and third it reduces yield and quality of the crop [48, 14, 15]. And finally, the attack by coffee berry borer leads total yield loss [36, 49]. Velmourougane *et al.* [50] reported that higher microbial contaminations recorded in coffee berry borer infested beans in both common coffee varieties. Similarly, Infonet Biovision [51] indicated that the pest facilitates the coffee bean to fungal infection and hence contamination with mycotoxins. And Vega *et al.* [20] found 14 bacterial species that degraded and detoxified caffeine.

Coffee berry borer caused 20 percent of losses and reduced the price by 30 to 40 percent [52]. And yield losses by pest can be high up to 80% – 96% [53]. Also Infonet Biovision [51] reported that 50 to 100% coffee losses recorded by this pest if the pest is not controlled. In Colombia, coffee berry borer infested 650,000 hectares and reduced national coffee production by 1.5 million bags which estimated US\$ 100 million [36]. In eastern Africa countries, due to the pest of up to 96% losses have been reported [54]. The pest is reported as factors to an on-going coffee productions decline [46]. In Ethiopia, Esayas *et al.* [39] reported that the borer inflicted up to 60% damage on dry left over coffee berries in the surveys conducted at different coffee growing areas of the country.

The nature of coffee berry borer is cryptic which it live and reproduce inside the berry and it leads to the pest difficult to control [33]. Additionally, the infestations or populations of berry borers are carried over from one coffee crop to the next by breeding in over-ripe berries and Buni that are left on the trees or have fallen to the ground [53]. These conditions enhance the reproduction of the pest and simultaneously hinder the development of suitable and effective management options.

5. Management Options of Coffee Berry Borer

To manage coffee berry borer in coffee producers in Brazil, it costs up to \$315 million each year and its costs of control is about 10% of production's costs [43, 55]. And Iscaro [3] indicated that if no action is taken against the pest, coffee

productions in the worldwide will encounter enormous harm and the economies of both nations would greatly suffer. So, the development of suitable and economically friend management strategies for coffee berry borer is therefore vital in order to empower small holder farmers, enhance the production and quality of the crop and protect the environment [49].

Even though a cultural practice increases the cost of productions, 80% of the infestation of the coffee berry borer reduced in Colombia [56, 57]. Ricardo Cure *et al.* [58] and Bagny Beilhe *et al.* [59] reported that the infestation of coffee berry borer in Colombia and Brazil was significantly reduced by 15-days intervals harvesting and sanitary practices. Similarly, these practices enhance the quality of coffee which fetches higher economic value. Furthermore, harvesting the fruit at its red ripe stage reduces the infestation on the pest as a result it enhances the quality of the product [37]. Bagny Beilhe *et al.* [59] study indicated that shade intensity, predator and tree diversity have impact on the infestation and damage level of the coffee berry borer. As they suggested, the pest will be regulated by maintaining optimum tree diversity and shade intensity levels which enhance the natural enemies' populations and diversity. Similarly, different insecticides were evaluated to manage pest which resulted different efficacy levels. As an example, an organochlorine group (endosulfan) 88% of the infestations reduced, while organophosphate group (pirimiphos-methyl, fenitrothion, chlorpyrifos and fenthion) 98% of the pest decreased (Figure 3).

Additionally, many microbial were tested under laboratory and field conditions. From these, *Beauveria bassiana* showed promising options under field condition. Furthermore many traps developed and the BROCAPR trap captured more than 10,000 adults per day (Table 1). On the other hand, parasitoids like *Prorops nasuta*, *Cephalonomia stephanoderi* and *Phymastichus coffea* were introduced many countries as classical biological control options. But this strategy was resulted ineffective and unsatisfactory [30, 60]. Rodríguez *et al.* [60] reported that the *P. coffea* was incompatible to the others management methods like *Beauveria bassiana* and insecticide. This may be confirming with using the single management options unable to control the pest below its economic threshold levels and looking the integrated of options.

Table 1. Capturing capacity of different coffee berry borer traps

No.	Types of trap	Capturing capacity	Average capturing/ day
1	BROCAPR trap	More than 10,000 adults per day	10,000
2	Artisanal traps (in Mexico)	Ranged from 83 to 1484 adults per week	112
3	Artisanal traps (in Brazil)	Ranged from 77 to 609 adults per week	49

Source: [56, 57, 61-67]

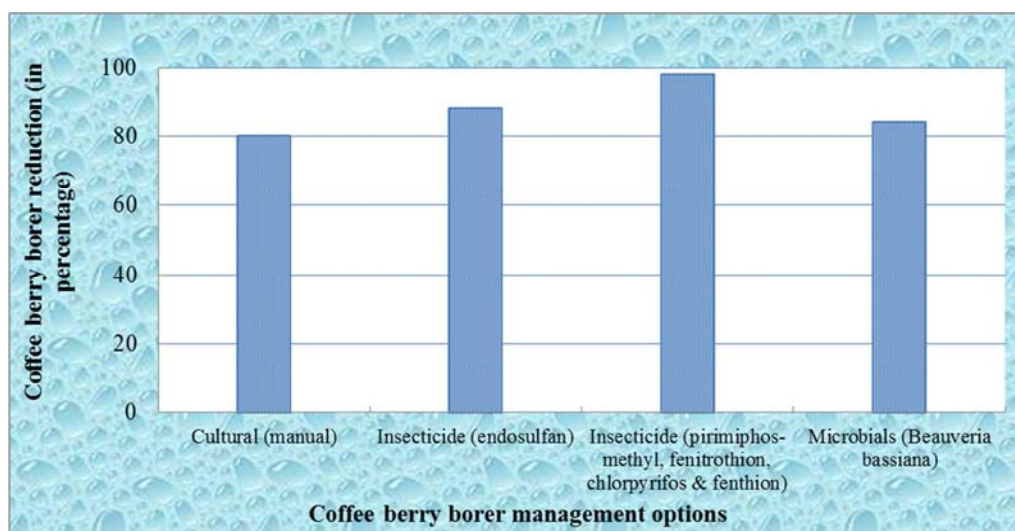


Figure 3. Effectiveness of different coffee berry borer management options.

6. Summary and Conclusion

Coffee is important cash crop in the international trade and a significant source of income for many tropical and sub-tropical countries. More than 70 percent share is from *C. arabica* which is originated in Ethiopia. Even though coffee is high valued commodity its productivity is very low. Insect pest is one of the major challenges that face production of coffee worldwide. Coffee losses due to pests estimated to be 13% but in Africa the yield losses can be higher up to 96% and at severe, up to 100% of berries attacked if the pest is not managed.

Coffee berry borer is the important pest for commercial coffee productions worldwide and major concern in eastern Africa region. Previously it is known lower altitudes coffee insect pests at where *C. canephora* is grown but recently it found at higher altitudes, where it infest *C. arabica*. The population growth of coffee berry borer is directly and exponentially related with temperatures ranged between 15 and 30°C. By two degrees celsius temperature increases would force the coffee berry borer to migrate to the higher altitudes. This indicates the bugs' can shift from lower elevation where *C. canephora* dominantly grows to the higher altitudes of the *C. arabica*. In the current time coffee berry borer is devastating almost all coffee growing countries. Due to cryptic nature and infestations of berry borers are carried over from one coffee crop to the next by breeding in over-ripe berries and Buni, it difficult to control it if ones it infest the coffee. But coffee will encounter dangerous harm and the economies of producing country would greatly suffer if the pest is not managed well.

However coffee berry borer is invading coffee productions in the world, it has minimum attention in Ethiopia. So future research focus on: the current status and distribution of the pest should considered in major coffee growing areas of Ethiopia and their natural enemies under different ecology and production systems, proper studies on biology, rearing and ecological requirements of coffee berry borer and identify

potential natural enemies so that they can be used in biological control, awareness creation for the importance of the pest is crucial for farmers, government and all persons involved in coffee productions and process, farmers need to monitor their crops regularly, as Ethiopia is the center of origin and diversity of Arabica coffee, there is a potential to find tolerant varieties against insect pests of coffee in Ethiopia, bio pesticides based on botanicals and microbial control agents are one of the potential options for coffee pest management and development of effective management strategies for coffee berry borer is therefore vital in order to enhance the production and quality of the crop. Different management options like cultural, insecticides, microbial and traps showed promising results under field conditions. But, using these options solely their drawbacks overweighed their positive part. Then development of integrated management option for coffee berry borer is an issue in the future. And the compatibility of the promised options along with their application sequence also needs focus.

References

- [1] DaMatta, F. M. 2004. Ecophysiological constraints on the production of shaded and unshaded coffee. *A Review. Field Crop Research*. 86: 99-114.
- [2] Koebler, J. 2013. Buzzkill? How Climate Change Could Eventually End Coffee. USNews.com, *US News and World Report*, 27 March, 2013: <http://www.usnews.com/news/articles/2013/03/27/buzzkill-how-climate-change-could-eventually-end-coffee>.
- [3] Iscaro, J. 2014. The Impact of Climate Change on Coffee Production in Colombia and Ethiopia. *Global Majority E-Journal*. 5 (1): 33-43.
- [4] Fekadu Gemechu, Melesse Maryo and Girmaye Benti. 2016. The prevalence and impact of coffee arthropod pests in the gedeo indigenous agro forestry systems, Southern Ethiopia. *International Journal of Biodiversity and Conservation*. 8 (10): 233-243.

- [5] Jaramillo, J., Muchugu, E., Vega, F., Davis, A., Borgemeister, C. and Chabi-Olaye, A. 2011. Some Like It Hot: The Influence and Implications of Climate Change on Coffee Berry Borer (*Hypothenemus hampei*) and Coffee Production in East Africa. *Plos One*. 6 (9): 1-14.
- [6] Musoli, P. C., Hakiza, G. J., Birinkunzira, J. B., Kibirige-Sebunya and Kucel, P. 2001. Coffee (*Coffea spp.*). In Mukiibi, J. K. (Eds.) *Agriculture in Uganda- Vol. II*. Pp. 376-436. Fountain Publishers, CTA/NARO.
- [7] Gichimu, B. M. 2008. Coffee arabica Breeding: Challenges Posed by Climate Change. Coffee Research Foundation Kenya. Available from: <http://www.eafca.org/www/downloads/AFCCE10/presentation/s/Arabica%20Coffee%20Breeding%20Challenges%20Posed%20by%20Climate%20Change.pdf>.
- [8] Mugo, H. M., Irungu, L. W. and Ndegwa, P. N. 2011. The Insect Pests of Coffee and their distribution in Kenya. *International Journal of Science and Nature*. 2 (3): 564 -569.
- [9] Kimani, M., Little, T. and Janny, G. M. 2002. *Introduction to Coffee Management through Discovery Learning*. CABI Bioscience.
- [10] Odour, G. I., and Simons, S. A. 2003. Biological control in IPM for Coffee. In: Neuenschwander, P., Borgemeister, C. and Langewald, J. (Eds.). *Biological Control in IPM Systems in Africa*. Pp. 347-362. CAB International Publishing, Wallingford, UK.
- [11] Nahayo, A. and Bayisenge, J. 2012. Biological control of coffee antestia bugs (*Antestiopsis lineaticolis*) by using *Beauveria bassiana*. *New York Science Journal*. 5 (12): 106-113.
- [12] Chemed Abdeta, Emanu Getu, Emiru Seyoum, Hindorf H. and Teshale Berhanu. 2015. Coffee leaf damaging insects' occurrence in the forest coffee ecosystem of southwestern Ethiopia. *African Journal of Plant Science*. 9 (2): 75-81.
- [13] Esayas Mendesil, Million Abebe and Chemed Abdeta. 2008. Review of Research on Coffee, Tea and Spices Insect pests in Ethiopia. In Tadesse Abraham (Ed.) *Increasing Crop Production through Improved Plant Protection - Vol. II*. Pp. 117-140. PPSE and EARO, Addis Ababa, Ethiopia.
- [14] Damon, A. 2000. A review of the biology and control of the Coffee Berry Borer, *Hypothenemus hampei* (Coleoptera: Scolytidae). *Bulletin of Entomological Research* 90, 453-466.
- [15] Jaramillo, J., Borgemeister, C. and Baker, P. 2006. Coffee Berry Borer *Hypothenemus hampei* (Coleoptera: Curculionidae): Searching for sustainable control strategies. *Bulletin of Entomological Research* 96: 223-234.
- [16] Jaramillo, J., Chabi-Olaye, A., Kamonjo, C., Jaramillo, A., Vega, F., Poehling, H. and Borgemeister, C. 2009a. Thermal Tolerance of the Coffee Berry Borer *Hypothenemus hampei*: Predictions of Climate Change Impact on a Tropical Insect Pest. *Plos One*. 4 (8): 1-11.
- [17] Mugo, H. M. and Kimemia, J. K. n.d. The Coffee berry borer, *Hypothenemus hampei* Ferrari (Coleoptera: Scolytidae) in Eastern Africa region: the extent of spread, damage and management systems: http://www.ico.org/event_pdfs/cbb/presentations/Kimemia%20Mugo%20CBB-%20ICO%20Paper.pdf. Accessed on May 26, 2017.
- [18] Davis, A. P., Govaerts, R., Bridson, D. M. and Stoffelen, P. 2006. An annotated taxonomic conspectus of the genus *Coffea* (Rubiaceae). *Bot J Linn Soc*. 152: 465-512.
- [19] Wood, S. L. 2007. *Bark and ambrosia beetles of South America (Coleoptera, Scolytidae)*. Provo, UT: Brigham Young University.
- [20] Vega, F. E., Infante, F. and Johnson, A. J. 2015. The genus *Hypothenemus*, with emphasis on *H. hampei*, the coffee berry borer. In: Vega, F. E. and Hofstetter, R. W. (Eds.) *Bark beetles: biology and ecology of native and invasive species*. Pp. 427-494. Academic Press, San Diego.
- [21] Barrera-Gaytan, J. F. 1994. Population dynamics of the Coffee Berry Borer, *Hypothenemus hampei* (Coleoptera: Scolytidae) and biological control using the parasitoid *Cephalonomia stephanoderis* (Hymenoptera: Bethyridae) in Chiapas Mexico. *Doctoral Dissertation*.
- [22] Soundari, K., Rekha, D., Senthilkumar, G. and Panneerselvam, A. 2016. Biocontrol of coffee berry borer, *Hypothenemus hampei*: Current focus. *Journal of Pharmacognosy and Phytochemistry*. 5 (3): 47-49.
- [23] Johnson, A., Bateman, C. and Hulcr, J. 2017. Draft guide to Identification of Coffee berry borer from similar bark beetles in Papua New Guinea (Version 0.1). http://www.ambrosiasymbiosis.org/wpcontent/uploads/2016/08/Identification_of_CBB_from_similar_beetles_v0p1_.pdf. Accessed on May 22, 2017.
- [24] Messing, R. H. 2012. The coffee berry borer (*Hypothenemus hampei*) invades Hawaii: Preliminary investigations on trap response alternate hosts. *Insects*. 3: 640-652.
- [25] Le Pelley, R. H. 1968. *Pests of coffee*. London: Longmans, Green and Co. Ltd.
- [26] Sponagel, K. W. 1994. La broca del Café *Hypothenemus hampei* en Plantaciones de Café Robusta en la Amazonía Ecuatoriana. Ph. D. Thesis, Universidad de Giessen, Giessen, Germany. p. 279.
- [27] Vijayalakshmi, C., Tintumol, K., and Saibu, U. 2013. Coffee Berry Borer, *Hypothenemus Hampei* (Ferrari): A Review. *International Journal of Innovative Research and Development*. 2 (13): 358-361.
- [28] Hopkins, A. D. 1915. Classification of the Cryphalinae, with descriptions of new genera and species. *United States Department of Agriculture, Contributions from the Bureau of Entomology, Report No. 99*.
- [29] Fleutiaux, E. 1901. Un ennemi du café du Ronilon (Congo). *La Nature – Revue des sciences et de leur application à l'art et à l'industrie* 29: 4.
- [30] Infante, F., Pérez, J. and Vega, F. E. 2014. The coffee berry borer: the centenary of a biological invasion in Brazil. *Braz. J. Biol.* 74 (3): 125-126.
- [31] Davidson, A. (1968). *Research in Agricultural Entomology in Ethiopia*. IAR, Addis Ababa, Ethiopia.
- [32] Vega, F. E., Mercadier, G. and Dowd, P. F. 1999. Fungi associated with the Coffee Berry Borer *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae). *Colloque Scientifique International Sur Le Café*. Pp. 229-238.

- [33] Vega, F. E., Infante, F., Castillo, A. and Jaramillo, J. 2009. The coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae): a short review, with recent findings and future research directions. *Terrestrial Arthropod Reviews*. 2: 129–147.
- [34] Burbano, E., Wright, M., Bright, D. E. and Vega, F. E. 2011. New record for the coffee berry borer, *Hypothenemus hampei*, in Hawaii. *Journal of Insect Science*. 11: 117. Available online: insectscience.org/11.117.
- [35] Eric Tlozek. 2017. Papua New Guinea coffee industry under threat from berry borer beetle: <http://www.abc.net.au/news/2017-05-30/png-coffee-industry-under-threat-from-berry-borer-beetle/8558142>. Accessed on June 10, 2017.
- [36] Rutherford, M. A. and Phiri, N. 2006. Pests and Diseases of Coffee in Eastern Africa: A Technical and Advisory Manual. Pp. 8-11. CAB International.
- [37] Eyasu Asfaw, Esayas Mendesil and Ali Mohammed. 2019. Altitude and coffee production systems influence extent of infestation and bean damage by the coffee berry borer. *Archives of Phytopathology and Plant Protection*. 52 (1-2): 170-183. <https://doi.org/10.1080/03235408.2019.1594541>.
- [38] EARO. 2000. Jimma Agricultural Research Centre progress report for the period 1998. EARO, Jimma, 133 pp.
- [39] Esayas Mendesil, Bekele Jembere and Emiru Seyoum. 2004. Population dynamics and distribution of coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) southwestern Ethiopia. *SINET: Ethiopian Journal of Sciences*. 27: 127-134.
- [40] Chemedi Abedeta, Emanu Getu, Emiru Seyoum and Holger Hindorf. 2011. Coffee Berry Insect Pests and their Parasitoids in the Afromontane Rainforests of Southwestern Ethiopia. *East African Journal of Sciences*. 5 (1): 41-50.
- [41] Vega, F. E., Kramer, M. and Jaramillo, J. 2011. Increasing Coffee Berry Borer (Coleoptera: Curculionidae: Scolytinae) female density in artificial diet decreases fecundity. *Journal of Economic Entomology*. 104 (1): 87-93.
- [42] Marino, Y. A., Vega, V. J., Garcia, J. M., Verle Rodrigues, J. C., Garcia, N. M. and Bayman, P. 2017. The Coffee Berry Borer (Coleoptera: Curculionidae) in Puerto Rico: Distribution, Infestation and Population per Fruit. *Journal of Insect Science* 17 (2): 1-8.
- [43] Baker, P. S. 1999. The Coffee berry borer in Columbia. Final report of the DFID- Cencafe- CABI Bioscience IPM for coffee project (CNTR 93/1536A).
- [44] Oliveira, C. M., Auad, A. M., Mendes, S. M. and Frizzas, M. R. 2013. Economic impact of exotic insect pests in Brazilian agriculture. *Journal of Applied Entomology*. 137 (1-2): 1-15.
- [45] Vega, F. E., Simpkins, A., Rodriguez-Soto, M. M., Infante, F. and Biedermann, P. H. 2017. Artificial diet sandwich reveals subsocial behaviour in the coffee berry borer, *Hypothenemus hampei* (Coleoptera: Curculionidae: Scolytinae). *Appl. Entomol.* 141: 470–476.
- [46] United States Agency for International Development (USAID). 2010. Kenya coffee industry value chain analysis. Profiling the actors, their interactions, costs, constraints and opportunities. Retrieved from <http://www.usaid.gov/>.
- [47] Bustillo, A. E., Cárdenas, R., Villalba, D., Benavides, P., Orozco, J. and Posada, F. 1998. Manejo Integrado de la Broca del Café, *Hypothenemus hampei* (Ferrari) en Colombia, 1st ed.; Cenicafe: Chinchiná, Colombia. 134pp.
- [48] Decazy, B., Ochoa, H. and Lotode, R. 1989. Indices de distribution spatiale et méthode d'échantillonnage des populations du scolyte des drupes du caféier, *Hypothenemus hampei* Ferr. *Café Cacao The'*. 33: 27-41.
- [49] Njihia, T. N. 2015. Chemical ecology of the coffee berry borer, *Hypothenemus hampei* Ferrari (Coleoptera: Scolytidae): The role of two spiroacetals in the insect- Host communication system. Master of Science (Plant Health Science and Management), Jomo Kenyatta University of Agriculture and Technology.
- [50] Velmourougane, K., Bhat, R. and Gopinandhan, T. N. 2010. Coffee Berry Borer (*Hypothenemus hampei*) - A Vector for Toxigenic Molds and Ochratoxin A Contamination in Coffee Beans. *Foodborne Pathogens and Disease*. 7 (10): 1279-1284.
- [51] Infonet Biovision. n.d. The coffee berry borer (*Hypothenemus hampei*): <http://www.infonet-biovision.org/PlantHealth/Crops/Coffee>. Accessed on May 27, 2017.
- [52] Agricultural Research. 2004. Stopping the Coffee Berry Borer from Boring into Profits: <https://agresearchmag.ars.usda.gov/2004/nov/coffee>. Accessed on June 10, 2017.
- [53] Njoga coffee. 2016. Urgent Warning of Coffee Berry Borer Outbreak to Kenyan Farmers. <https://www.njogacoffee.com/blogs/news/urgent-warning-of-coffee-berry-borer-outbreak-to-kenyan-farmers>. Accessed on May 27, 2017.
- [54] Magina, F. L. 2005. A review of coffee pest management. www.aaec.vt.edu/ipmcrspuganda.
- [55] O'brien, D. 2015. How coffee berry borers survive on caffeine: <https://phys.org/news/2015-12-coffee-berry-borers-survive-caffeine.html#jCp>. Accessed on May 26, 2017.
- [56] (Bustillo, A. E., Cardenas, R., Villalba, D. A., Benavides, P., Orozco, J. and Posada, F. J. 1998. Manejo integrado de la broca del café *Hypothenemus hampei* (Ferrari) en Colombia. Centro Nacional de Investigaciones de Café (Cenicafe). Chinchina, Colombia. 134 pp.
- [57] Bustillo Pardey, A. E. 2006. Una revision sobre la broca del café, *Hypothenemus hampei* (Coleoptera: Curculionidae: Scolytinae), en Colombia. *Revista Colomb. Entomol.* 32: 101-116.
- [58] José Ricardo Cure, Daniel Rodríguez, Andrew Paul Gutierrez & Luigi Ponti. 2020. The coffee agroecosystem: bio-economic analysis of coffee berry borer control (*Hypothenemus hampei*). *Scientific Report*, 10: 12262. <https://doi.org/10.1038/s41598-020-68989-x>.
- [59] Bagny Beilhe, Leï., Roudine, S., Quintero Perez, José. Alcides., Allinne, Clé., Daout, D., Mauxion, Ré., Carval, D., Pest-regulating networks of the coffee berry borer (*Hypothenemus hampei*) in agroforestry systems, *Crop Protection* (2019), doi: <https://doi.org/10.1016/j.cropro.2019.105036>.

- [60] Daniel Rodríguez, José Ricardo Cure, Andrew Paul Gutierrez and José Miguel Cotes. 2017. A coffee agro ecosystem model: III. Parasitoids of the coffee berry borer (*Hypothenemus hampei*). *Ecological Modeling*, 363: 96-110. <http://dx.doi.org/10.1016/j.ecolmodel.2017.08.008>.
- [61] Mansingh, A. 1991. Limitations of insecticides in the management of the coffee berry borer. *J. Coffee Res.* 21: 67-98.
- [62] Bustillo Pardey, A. E. 2002. El manejo de cafetales y su relacion con el control de la broca del café en Colombia. *Boletín Tecnico Cenicafe*. No. 24, 40 pp.
- [63] Bustillo Pardey, A. E. 2005. El papel del control biológico en el manejo integrado de la broca del café, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae: Scolytinae). *Rev. Acad. Colomb. Cienc.* 110: 55-68.
- [64] Dufour, B. 2002. Importance of trapping for integrated management (IPM) of the coffee berry borer, *Hypothenemus hampei* Ferr. *Recherche et Cafeiculture*, pp. 108-116.
- [65] Barrera, J. F., Herrera, J., Chiu, M., Gomez, J. and Valle-Mora, J. 2008. La trampa de una ventana (ECOIAPAR) captura mas broca del café *Hypothenemus hampei* que la trampade tres ventanas (ETOTRAP). *Entomol. Mexicana* 7, 619-624.
- [66] Uemura-Lima, D. H., Ventura, M. U., Mikami, A. Y., da Silva, F. C. and Morales, L. 2010. Responses of coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae), to vertical distribution of methanol: ethanol traps. *Neotrop. Entomol.* 39: 930-933.
- [67] Infante, F. 2018. Pest Management Strategies against the Coffee Berry Borer (Coleoptera: Curculionidae: Scolytinae). *Agricultural and Environmental Chemistry*. DOI: 10.1021/acs.jafc.7b04875.