Journal of Integrated Pest Management OPEN ACCESS

CASE STUDY

Implementing an Integrated Pest Management Program for Coffee Berry Borer in a Specialty Coffee Plantation in Colombia

Luis F. Aristizábal,[1,2] Olga Lara,[3] and Steven P. Arthurs[1]

[1]Mid-Florida Research and Education Center, University of Florida, Apopka, FL 23703.
[2]Corresponding author, e-mail: larist@ufl.edu.
[3]Inversiones Perla S. A., owners Neiva, Huila, Colombia.

J. Integ. Pest Mngmt. 3(1): 2012; DOI: http://dx.doi.org/10.1603/IPM11006

ABSTRACT. Efforts to implement an integrated pest management (IPM) program for coffee berry borer *Hypothenemus hampei* (Ferrari) in a 110-ha coffee plantation in the Huila region of Colombia are discussed. Hands-on training was provided for farm staff and harvest workers managing production in >80 coffee lots. Participants attended workshops describing pest management strategies, based on prior research and recommendations of the National Coffee Research Center in Colombia (Cenicafé). The training program focused on cultural practices, i.e., efficient harvesting of mature berries to eliminate coffee berry borer habitats, along with establishing a comprehensive monitoring program to reduce chemical insecticides and encouraging use of a biological-based insecticide. Participants implemented postharvest techniques by screening harvested berries and pulp pits to physically exclude adult coffee berry borers. The rationale was that adopting new practices would enable growers to transition away from chemical insecticides. Results over 3 yr showed widespread adoption of cultural, physical, and biological control methods. Overall, the IPM program was considered successful because problems associated with insect damage on the coffee crop decreased, despite reductions in endosulfan/chlorpyrifos use, which declined from 250 liters in 2002 to 75 liters in 2003, and 0 liters in 2004. Concurrently, *Beauveria bassiana* increased from 20 kg in 2002 to 80 kg in 2004. Harvest workers improved their efficiency at removing potential coffee berry borer breeding sites (leaving only 6.5 mature berries per tree in 2004, down from 22.2 in 2002). The quality of parchment coffee beans increased (insect damage was 2.3% in 2002, 1.7% in 2003, and 0.7% in 2004) whereas the proportion of the harvest sold as high quality 'specialty' coffee increased from 50% to 86% over the same period.

Key Words: *Hypothenemus hampei*, IPM, Colombia, coffee plantations, specialty coffee

The coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae: Scolytinae), long has been considered one of the most serious pests in coffee plantations worldwide (Le Pelley 1968, Jaramillo et al. 2006, Vega et al. 2009). Infestations of this small beetle are difficult to combat; most of the insect's lifecycle is completed inside coffee berries, making insecticide penetration and contact difficult (Baker 1999, Damon 2000). Female beetles bore holes into developing berries attached to the tree through the blossom scar and create 'galleries' where they remain and deposit their eggs. The developing larvae feed on the bean or endosperm of the seed, reducing yields as well as the quality of coffee and its price (Duque and Baker 2003). The already mated beetle progeny emerge from mature coffee berries to find new habitats for oviposition, with up to 150 coffee berry borers emerging from a single berry (Damon 2000).

Colombia produces the highest yield of *Coffea arabica* L. among all producer countries, with nearly 892,000 ha yielding an average of 552,000 tons of coffee in 2010. Most of this coffee is grown at high elevations often under different levels of shade (Wintgens 2004). Since first detected in 1988, coffee berry borer has become the major economic insect pest and now is found in all important coffee growing regions in the country (Bustillo 2002). Normally, coffee fruit becomes susceptible to coffee berry borer attack when it has >20% dry weight, occurring between 100 and 150 d of development, depending on the altitude (Montoya and Cardenas 1994, Baker 1999). To prevent significant economic loss, coffee growers routinely treat trees with chemical insecticides, such as endosulfan (Damon 2000).

In response to the threat of crop damage, the National Coffee Research Center in Colombia (Cenicafé) developed an integrated pest management (IPM) program for coffee berry borer (Bustillo et al. 1998, Aristizábal et al. 2002, Bustillo 2002). The program involves monitoring and development of cultural and biological techniques than can be used to supplement (or replace) traditional insecticides. A critical part of this effort has been to implement and evaluate these programs among the smallholder coffee growers (Baker 1999, Bentley et al. 2002; Aristizábal et al. 2004). This challenge is most acute in areas that produce high quality 'specialty coffees' because more limited insect damage to the parchment (processed) coffee is tolerated by processors.

Herein, we discuss a case study to implement IPM approaches for coffee berry borer in a large coffee plantation. Surveys were conducted among farm staff and harvest workers to determine IPM training needs. Also, information was collected regarding pest management practices, coffee berry borer infestation levels, and the amounts of pesticides used before and after conducting training workshops for farm workers.

Study Methods and Approach

Study Location. Established as a family enterprise since the 1920s, 'La Virginia' farm located in the Algeciras municipality, Huila Department of Colombia (Fig. 1A), comprises 110 ha of plantations and produces >300,000 kg of parchment coffee annually. The high elevation of the region (1,600 m above sea level) ensures seasonally mild temperatures (average 19°C) with ≈2,200 mm of annual rainfall and high relative humidity (average 80%). The coffee cultivar 'Caturra' is produced over a 5-yr production cycle with a planting density of 6,600 trees per ha. Production of coffee is managed on ≈85 individual lots at any one time with another 25 lots in various stages of renewal after felling. This method, termed 'zoqueo', in which trees are regrown (or if needed replanted), is part of the national program of renovation established by National Coffee Growers Federation in Colombia to maintain young and productive plantations and keep trees at a manageable size. The farm has ≈25 employees with another 400 contract workers hired for harvesting work. Because of the favorable agroecological conditions and experienced management, since the late 1990s, 'La Virginia' farm has produced high quality coffee marketed as 'Glorious Coffee', a state specialty coffee.

Project Justification. Since its arrival in Colombia, the coffee berry borer had become a serious pest in this region. Environmental conditions coupled with existing cultivation practices supported the

Fig. 1. (A) La Virginia farm (Algeciras- Colombia), (B) Harvesting mature coffee (Cenicafé photo), (C) Monitoring for coffee berry borer, (D) Examining coffee berry borer development in green coffee, (E) Degree of coffee berry borer position inside berry (Cenicafé photo, Gonzalo Hoyos), (F) Coffee berry borer infected with *Beauveria bassiana* (Cenicafé photo), (G) silos covered to prevent movement of coffee berry borer, (H) coffee lot after zoqueo (Cenicafé photo).

spread of damaging populations of coffee berry borer. Farm workers began using ever increasing quantities of insecticides (mainly endosulfan); however, this approach created logistical problems, including concerns regarding the safety of workers and potential for insecticide resistance. In an attempt to promote more biorational coffee berry borer management, education and hands-on training was provided on nonchemical strategies to identify and control coffee berry borer infestations and limit the spread of this pest between coffee lots. The methodology used for training workers in the field was 'learning by doing', which involved practicing effective harvesting techniques (Aristizábal et al. 2002, 2004; Bentley et al. 2002). Several workshops were conducted for farm managers and harvest workers based on prior research and recommendations of Cenicafé (e.g., Bustillo et al. 1998, Baker 1999, Aristizábal et al. 2002, Bustillo 2002), adjusted or tailored to the prevailing conditions at La Virginia farm. Information was provided on the identification, biology, and behavior of the coffee berry borer along with the various management strategies discussed in the next section. The lead author initiated a coffee berry borer monitoring program that involved training a team of 12 scouts. The rationale was that the adoption of IPM practices would enable growers to transition away from chemical insecticides, without resulting in unacceptable damage caused by the coffee berry borer. Because of the quality requirements of the specialty coffee label, an important consideration was the need to maintain $<2\%$ insect damage in dried parchment coffee, the marketed product.

Basis of IPM Program. Seasonal rainfall occurs over two main periods (April and May and September through December) in the southeast Huila Department, which creates a mixed and continuous flowering and production cycle within the coffee plantation. These weather patterns create favorable habitat for the coffee berry borer throughout the majority of the year, requiring management of coffee berry borer on a routine basis (Arcila et al. 1993). Farm staff and harvest workers were educated about the importance of effective cultural practices (regular and efficient harvesting) as a major component of coffee berry borer management (Saldarriaga 1994, Bustillo et al. 1998, Diaz and Marin 1999, Benavides et al. 2002, Aristizábal et al. 2011). In this process, mature and over ripe berries, which serve as the source for new coffee berry borer infestation, are picked by harvest workers at regular intervals (e.g., every two or 3 wk) throughout the year (Fig. 1B). Although expensive in terms of labor costs, an efficient collection of the mature and older dried berries can remove 80% or more of the coffee berry borer population (Bustillo et al. 1998). However, the effectiveness of this approach depends on how rigorously these berries are removed. Bustillo et al. (1998) estimated that at low to moderate coffee berry borer densities ($<$5% infestation) the manual removal of berries is most effective when $\leq$5 mature berries per coffee tree remain after harvesting; is intermediately effective when 6–10 berries remain; and relatively ineffective when $>$10 berries are left on coffee trees. Four-hour training exercises were routinely conducted for farm staff and harvest workers in cultural control to evaluate effective harvesting techniques.

Regular monitoring for coffee berry borer is necessary to help evaluate the effectiveness of cultural control practices and to make informed management recommendations. A monitoring plan was established on $>$80 coffee lots, each $\approx$1 ha (ranging from 0.5 to 2 ha), throughout La Virginia to determine the location of coffee berry borer infestations and developmental stage inside the berry. To determine the location of coffee berry borer infestations, a team of local students was hired as scouts and trained to sample each coffee lot once per month according to previous methods (Bustillo et al. 1998). Scouts made a zig-zag path throughout lots, and sampled trees (selected haphazardly) every 10–15 m. Thirty trees were sampled in lots $\leq$1 ha, whereas 60 trees were selected in larger (1- to 2-ha) lots. For each sampled tree, a representative branch in the middle was selected and all developing (green) berries examined for coffee berry borer entry holes (Fig. 1C).

In addition, 100 infested berries with an estimated $>$100-d development per plot were removed, cut open, and examined for the position of the coffee berry borer inside (Fig. 1D). Salazar et al. (1993) showed that coffee berry borers preferentially oviposit on berries with $>$20% dry weight ($>$120-d development). In an AB position (Fig. 1E), the coffee berry borer had not penetrated deep enough to damage the developing endosperm and was still vulnerable to insecticides, whereas in a CD position the endosperm was found damaged and beetles were relatively protected from applied insecticides. Bustillo et al. (1998) showed that good control ($>$90% mortality of coffee berry borer) can be achieved within 24 h of penetration, but the effectiveness of insecticide sprays declines significantly as the beetle bores deeper into the developing berries. In general, coffee berry borer infestations of $>$2% berries with $>$50% of beetles in the AB position were considered good targets for insecticidal control provided they could be applied within 3 d of monitoring. Through the establishment of a routine monitoring plan for the whole farm, the managers were provided with regular and reliable information to help prioritize harvesting schedules or make recommendations of insecticidal applications to specific plots, rather than treating larger areas.

Despite its relatively recent introduction in Colombia, a number of natural enemies may help regulate coffee berry borer populations, including arthropod predators, competitors, bacteria, protozoa, and the entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin (Bustillo et al. 2002, Vega et al. 2009). Cenicafé earlier developed a pilot program for mass producing *B. bassiana* as a bioinsecticide, which led to the commercial production and distribution of $>$1,000 tons of the material. Under optimum environmental conditions, applications of *B. bassiana* cause $>$80% mortality of adult female coffee berry borer (Fig. 1 F), although control is often more variable (Bustillo et al. 1998, Baker 1999, Posada et al. 2003). At La Virginia, pest control operators started using *B. bassiana* in conjunction with monitoring in place of chemical insecticides. A product obtained through Bioprotección (Chinchiná, Caldas, Colombia) with a concentration of 2.5×10^{10} spores per g, was applied at a concentration of 2 g per liter with 1% emulsifiable oil added as an adjuvant.

Since 1989, three species of exotic parasitoids, *Cephalonomia stephanoderis* Betrem, *Prorops nasuta* Waterston (Hymenoptera: Bethylidae), and *Phymastichus coffea* La Salle (Hymenoptera: Eulophidae), have been mass produced and introduced into coffee plantations in Colombia and elsewhere to combat coffee berry borer (Bustillo et al. 1998, Aristizábal 2002, Orozco 2002). However, because of the high cost of mass rearing, full-scale parasitoid releases (typically involving seasonal releases of 250,000 wasps per lot) were not conducted at La Virginia. However, an initial introductory release comprising a total of 500,000 *P. nasuta* was made throughout infested lots in 2003; however, follow up releases were not made and their establishment and impact was not specifically evaluated.

Postharvest pest control is an important component of an integrated control strategy for coffee berry borer. Previous studies have shown that coffee berry processing areas are sources of infestations as adult coffee berry borer escape from the harvested materials (Castro et al. 1998, Salazar et al. 2003). To address this problem, farm staff constructed covers for the silos used to collect harvested berries as well as the pulp pits (Fig. 1G). The covers employed transparent plastic smeared with grease, an effective method to trap coffee berry borer.

A major problem with coffee berry borer arises from the annual process of renovation 'zoqueo' that involves $\approx$20% of the area in production. In this process, entire lots are cut down up to nearly 0.3 m from the tree base after five or 6 yr of production (Fig. 1H). However, because coffee berry borer management traditionally is not conducted on felled trees (which are not removed), an unintended consequence of this practice is the generation of large numbers of coffee berry borer. Baker (1999) and Castaño et al. (2005) estimated that up to 1.5 million coffee berry borer per ha can be produced in zoqueo areas, that presumably can reinfest neighboring coffee lots. To address this problem, several tactics were employed. Firstly, farm workers left a number of unfelled trap trees around the perimeter and middle of the plot for the first two months. The trap trees and the first five rows of adjacent plots were monitored and sprayed with *B. bassiana* as needed. In addition, harvest workers revisited zoqueo plots for additional collection and removal of mature berries on one or more occasions after trees were felled.

On-site Assessments. At the beginning of the study in 2002, we interviewed farm staff (25 employees) to assess their knowledge of coffee berry borer and the existing practices for managing this pest. A questionnaire regarding current coffee berry borer management practices (after Aristizábal et al. 2002) was conducted to establish a training plan for staff and contract harvest workers. We also conducted on-site visits to better understand the training needs. For example, we observed pest control operators to determine if equipment was calibrated properly and insecticides applied according to recommended practices (e.g., Bustillo et al. 1998, Baker 1999, Aristizábal et al. 2002, Bustillo 2002). We also collected information as to how well the new program worked over a 3-yr period. For example, we looked for improvements in cultural coffee berry borer management by harvest workers. To do this, every other month, the coffee berry borer monitoring team counted the total number of mature and old, dried up berries remaining on entire trees in every coffee lot (15 haphazardly-selected trees per lot were sampled). Trees were sampled shortly after a harvest crew had passed through the block as part of the routine harvesting schedule. We also compiled monitoring data from 10 major areas of the farm to look for coffee berry borer population trends and obtained information of the amounts and costs of chemical and biological insecticides used each year. Finally, we obtained the official written report on the yield and final quality of harvested coffee from the owner of La Virginia or the local cooperative outlet where the coffee was sold.

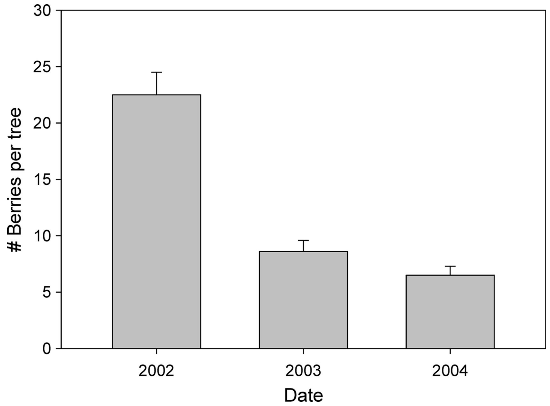

Fig. 2. Harvesting efficiency before training (2002) and after training (2003 and 2004) for harvest workers. Data show the number ± SEM mature and dry berries remaining per tree from 11 regions (81 coffee lots) after picking.

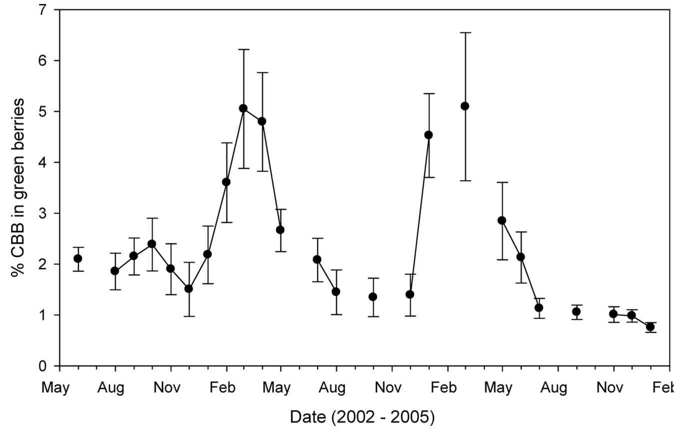

Fig. 4. Coffee berry borer populations between June 2002 and January 2005. Figure shows the mean ± SEM percent infested and damaged berries monitored from 11 areas (81 coffee lots). Line breaks denote months where no data were collected.

Major Findings. At the start of the project in 2002, coffee berry borer management primarily consisted of applications of endosulfan applied via Motax backpack sprayer on a calendar basis two or three times a year. Monitoring for coffee berry borer was infrequent and so sprays sometimes were applied on all coffee lots in production. Relatively little *B. bassiana* was used. We observed improper pesticide calibration. For example, nozzles on low-volume backpack sprayers (Motax 33; Micron Sprayers Ltd, Herefordshire, UK) should output 140 ml/min; however, up to 250 ml/min was observed resulting in inefficient insecticide application. Some equipment was damaged, thus the recommended volume application rate of 60 liter per ha was not always achieved. Another problem with the initial insecticide program was that when monitoring was done, control decisions typically were made at least two or 3 wk after the information was collected; thus it was no longer necessarily accurate. Postharvest controls (physical exclusion) were not practiced in 2002, whereas coffee berry borer control in non-producing lots also often was not done.

By 2003, the situation had changed considerably. After ≈400 harvest workers were trained (groups of 25 workers were trained in 4-h sessions), cultural controls improved significantly. For example, harvesting efficiency was much higher in the second and third years, based on the number of mature and dry berries counted on trees (Fig. 2). On some occasions where scouts became aware of potential problems, a second sanitary collection of berries after harvesting, called 'repase' (passing over again), also was conducted. The decline in mature coffee berries left on trees would ensure that fewer coffee berry borers could reproduce successfully within fields.

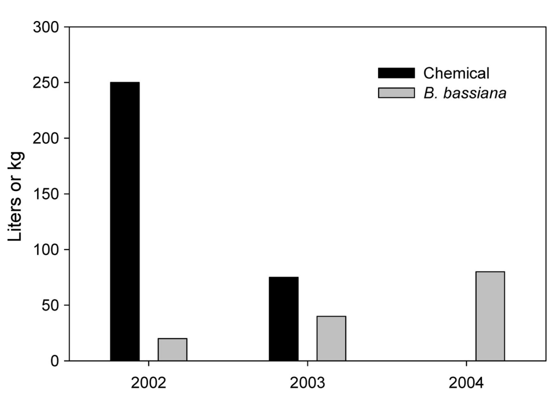

Fig. 3. Quantities and categories of insecticides used at La Virginia farm (Algeciras – Colombia) over 3 yr.

A large reduction in the use of chemical insecticides during the project was observed (Fig. 3). The coffee berry borer monitoring program ensured that fewer coffee lots required insecticide applications. The use of endosulfan also was restricted by the Colombian authorities, and was replaced with slightly less persistent alternatives. Overall, use of insecticides declined from 250 liters (endosulfan) in 2002 to 75 liters (chlorpyrifos) in 2003, with no chemical insecticides used in 2004. Concurrently, the use of *B. bassiana* increased from only 20 kg in 2002 to 40 kg in 2003 and 80 kg in 2004. The costs of coffee berry borer control (insecticides, bioinsecticides, application costs, and monitoring) declined nearly threefold between 2002 and 2004, from U.S. $6,062 in 2002, to $3,453 in 2003, and $2,177 in 2004. A majority of the increased efficiency was because of smaller area of coffee crops that were treated with insecticides. We also observed improvement in applicator technique and spray equipment as awareness of the earlier problems increased. Finally, the farm workers implemented postharvest control measures (physical exclusion) and improved management of coffee berry borer renovation areas (zoqueo lots). Both these tactics presumably reduced the number of coffee berry borer on the farm.

Overall, we consider that the IPM program for coffee berry borer was successful because problems associated with insect damage on the coffee crop decreased, despite the dramatic decline in the insecticide (chemical) use during this period (Fig. 4). Populations of coffee berry borer peaked (up to 5% of berries infested on average) in February, March, and April in 2003 and 2004 after the main harvesting periods, but remained <2% for the remaining periods, and were lowest (≈1%) toward the end of the study period. More importantly, the quality of harvested product actually increased three-fold (based on proportion of parchment coffee with coffee berry borer damage) from 2002 to 2004 (Table 1). This better quality may have been caused partly by fewer coffee berry borers penetrating into the endosperm. The proportion of coffee beans sold as 'specialty coffee', increased by 72% (from 50% to 86%) during the same period. There was also a slight decline in overall yield between 2002 and 2004, which was, at least in

Table 1. Overall coffee production and final pest damage at La Virginia farm (Huila Department, Colombia) following implementation of an IPM program for CBB in 2002

Year	Production area (ha)	Yield per ha (kg)	% Damage in parchment coffee	% Sold as 'specialty'
2002	87	4,391	2.3	50
2003	78	3,603	1.7	70
2004	80	3,938	0.7	86

part, likely caused by the smaller area in production (87 ha in 2002 versus 80 ha in 2004).

Recommendations. The coffee berry borer remains a serious problem for coffee farmers worldwide, as underscored by the discovery of this pest by the Hawaiian Department of Agriculture in September 2010 (http://hawaii.gov/hdoa/pi/ppc/coffee-berry-borer-folder/coffee-berry-borer-information-page). Our case study provides evidence that coffee berry borer potentially can be controlled using an integrated approach with minimal input of broad-spectrum insecticides. However, establishing and maintaining an effective IPM program for coffee berry borer is not a straightforward task. Some general recommendations arising from this case study include the need to convince the owners and managers of the coffee farm of the benefits of an IPM program, given the investment needed. Efficient cultural control techniques remain expensive and dependent on hiring experienced (skilled) field labor for harvesting duties. Monitoring procedures also are laborious (especially when the stage of development of the coffee berry borer inside the berries also is tracked) and require experienced scouts and good coordination between various farm workers. However, the expenditure of these approaches needs to be weighed against the benefits of reduced amounts of insecticides needed. There are other logistical advantages of implementing cultural control and monitoring methods, such as the lack of special equipment needed and avoiding restricted entry intervals associated with chemical pesticides. In our case, farm workers appreciated the ability to quickly respond to coffee berry borer hotspots before they spread to other lots. Additional field research is warranted for refinement of the IPM program. For example, the use of alcohol-baited traps for adult coffee berry borer as well as the control of immature coffee berry borer stages in berries fallen on the ground, may allow additional improvements in efficacy to be achieved.

Acknowledgments

We are indebted to the staff and workers at La Virginia farm, students at El Paraiso Villa High School, employees from Inversiones Perala S. A., and Alex Bustillo for technical assistance and guidance. We thank Arshad Ali and Barbra Resnick for improving an earlier draft of the manuscript.

References Cited

Arcila, J., A. Jaramillo, V. Blandión, and A. E. Bustillo. 1993. La floración del cafeto y su relación con el control de la broca del café. Avances Técnicos Cenicafé No. 193: 1–6.

Aristizábal, L. F. 2002. Revisión sobre el estado actual de la investigación de parasitoides para el control de la broca del café en Colombia (Ferrari), pp. 80–114. *In* Memorias Curso Internacional Teórico–Práctico. Sección II. Parasitoides y otros enemigos de la broca del café. Cenicafé, Chinchiná, 18–22 March 2002.

Aristizábal, L. F., H. M. Salazar, and C. G. Mejía. 2002. Cambios en la adopción de los componentes del manejo integrado de la broca del café, Hypothenemus hampei (Coleoptera: Scolytidae), a través de metodologías participativas. Rev. Colomb. Entomol. (Colombia) 28: 153–160.

Aristizábal, L. F., A. E. Bustillo, M. Jiménez, and H. I Trujillo. 2004. V encuentro de caficultores experimentadores. Manejo integrado de la broca del café a través de investigación participativa. Convenio Colciencias-Federacafé-Cenicafé. Fundación Manuel Mejia, Chinchiná, 21–22 September 2004.

Aristizábal, L. F., M. Jiménez, A. E. Bustillo, and S. P. Arthurs. 2011. Monitoring cultural practices for coffee berry borer *Hypothenemus hampei* (Coleoptera: Curculionidae: Scolytinae) management in a small coffee farm in Colombia. Fla. Entomol. 94: 685–687.

Baker, P. S. 1999. The coffee berry borer in Colombia. Final report of the DIFI-Cenicafé-CABI Bioscience IPM for coffee project. Chinchiná, Colombia.

Benavides, P., A. E. Bustillo, E. C. Montoya, R. Cardenas, and C. G. Mejía. 2002. Participación del control cultural, químico y biológico en el manejo de la broca del café. Rev. Colomb. Entomol. 28: 161–166.

Bentley, W. J., S. P. Baker, L. F. Aristizábal, O. Campos, W. Chilan, A. Garcia, R. Munoz, A. Jarquin, A. Larco, C. G. Mejia, et al. 2002. Manual for collaborative research with smallholder farmers. "What we learned from the CFC-IPM coffee project". CABI Commodities. Egham, Surrey, United Kingdom.

Bustillo, A. E. 2002. El manejo de los cafetales y su relación con el control de la broca del café en Colombia. FNC-Cenicafé, Chinchiná, Colombia. Boletin Tecnico 24: 1–40.

Bustillo, A. E., R. Cárdenas, D. A. Villalba, P. Benavides, J. Orozco, and F. J. Posada. 1998. Manejo integrado de la broca del café *Hypothenemus hampei* (Ferrari) en Colombia. *In* H. Ospina (ed.), Cenicafé, Chinchiná, Colombia.

Bustillo, A. E., R. Cárdenas, and F. J. Posada. 2002. Natural enemies and competitors of *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) in Colombia. Neotrop. Entomol. 31: 635–639.

Castaño, A., P. Benavides, and P. S. Baker. 2005. Dispersión de *Hypothenemus hampei* en cafetales zoqueados. Rev. Cenicafé 56: 142–150.

Castro, G. L., P. Benavides, and P.A.E. Bustillo. 1998. Dispersión y mortalidad de *Hypothenemus hampei*, durante la recolección y beneficio de la broca del café. Manejo Integrando de Plagas (Costa Rica). 50: 19–28.

Damon, A. 2000. A review of the biology and control of the coffee berry borer, *Hypothenemus hampei* (Coleoptera: Scolytidae). Bull. Entomol. Res. 90: 453–465.

Diaz, Y., and H. F. Marin. 1999. Evaluación de los frutos del café dejados después de las recolecciones durante un ciclo productivo del cultivo en dos municipios del Departamento de Caldas. Tesis Ingeniero Agrónomo, Facultad de Ciencias Agropecuarias. Universidad de Caldas, Manizales, Colombia.

Duque, H., and P. S. Baker. 2003. Devouring profit; the socio-economics of coffee berry borer IPM, Chinchiná, Colombia. The Commodities Press, CABI, Cenicafé, Colombia.

Jaramillo, J., C. Borgemeister, and P. Baker. 2006. Coffee berry borer *Hypothenemus hampei* (Coleoptera: Curculionidae): searching for sustainable control strategies, Bull. Entomol. Res. 96: 223–233.

Le Pelley, R. H. 1968. Pests of coffee. Longmans, Green and Co., Ltd., London, United Kingdom.

Montoya, S., and R. Cardena. 1994. Biología de *Hypothenemus hampei* (Ferrari) en frutos de café de diferentes edades. Rev., Cenicafé 45: 5–13.

Orozco, J. 2002. Parasitoides de origen africano para el control de la broca del café, pp. 71–79. *In* Memorias Curso Internacional Teórico–Práctico. Sección II. Parasitoides y otros enemigos de la broca del café. 18–22 March 2002, Cenicafé, Chinchiná, Colombia.

Posada, F.F.J., E.H.M. Salazar, F. F. Aristizábal, C. G. Mejía, and Q. M. Jiménez. 2003. Taller con caficultores experimentadores para evaluar *Beauveria bassiana* en el control de *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae). Rev. Colomb. Entomol. (Colombia) 29: 63–70.

Salazar, M. R., J. Arcila, N. Riaño, and A. E. Bustillo. 1993. Crecimiento y desarrollo del fruto del café y su relación con la broca. Avances Técnicos Cenicafé No. 194: 1–4.

Salazar, E.H.M., L. F. Aristizábal, and C. G. Mejía. 2003. Investigación participativa con caficultores en relación con el manejo integrado de la broca del café *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae) durante el proceso de beneficio. Rev. Colomb. Entomol. (Colombia) 29: 57–62.

Saldarriaga, A. G. 1994. Evaluación de prácticas culturales en el control de la broca del café *Hypothenemus hampei* (Ferrari 1867) (Coleóptero: Scolytidae). Tesis Ingeniero Agrónomo, Medellín, Universidad Nacional de Colombia.

Vega, F. E., F. Infante, A. Castillo, and J. Jaramillo. 2009. The coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae): a short review, with recent findings and future research directions. Terr. Arthropod Rev. 2: 129–147.

Wintgens, J. N. 2004. Coffee: growing, processing, sustainable production. Wiley-VCH, Weinheim, Federal Republic of Germany.

Received 8 February 2011; accepted 18 November 2011.