The coffee berry borer: the centenary of a biological invasion in Brazil

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One of the most important biological invasions of a tropical agroecosystem in the Americas commenced in 1913 in Brazil. Indigenous to Central Africa, the coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Curculionidae), was introduced to the state of São Paulo in coffee seeds imported from the Democratic Republic of the Congo (Berthet, 1913). As growers were not familiar with this insect, it was not until 1924, when damage had become widespread, that the insect was recognised to be the same species infesting coffee plantations in Africa (Da Silva, 2006).

This ca. 2 mm long beetle is the most devastating insect pest of coffee worldwide. The insect spends most of its life cycle concealed inside the coffee berry, making it quite difficult to control (Vega et al., 2009). Females bore into the berry and oviposit in galleries within the seed; total progeny can reach up to 300 individuals within a single berry (Jaramillo et al., 2009). Upon hatching, larvae consume the seed, thus reducing quality and yields of the marketable product. In Brazil alone, this insect causes losses estimated at $215-358 million annually (Oliveira et al., 2013). Subsequent to its introduction to Brazil, the insect has invaded all coffee-growing areas in the Americas and the Caribbean and has now been reported in nearly all coffee-producing countries worldwide (Vega et al., 2009). The term "invasive" that denotes the uncontrolled spread of an organism outside its native range, is well suited for the coffee berry borer, based on its widespread geographic distribution.

Of the ca. 1,603 coffee berry borer-related papers published worldwide in the past one hundred years (Figure 1), only 602 are peer-reviewed, for an average of six papers per year. These data reveal the scant amount of scientific information published on an insect pest that directly affects 20 million coffee-growing families, equivalent to over 100 million people, in ca. 80 coffee-producing countries (Vega et al., 2009). In contrast, 1,654 peer-reviewed papers on another tropical invasive species, the Mediterranean fruit fly, *Ceratitis capitata* (Weidemann) (Diptera: Tephritidae), were published in 22 years (1990-2012), equivalent to 75 peer-reviewed papers per year. Approximately 31% of all coffee berry borer-related papers deal with biological control based on parasitoids and fungal entomopathogens, indicating the continued emphasis placed on these natural enemies even though their impact in reducing population levels has been variable (Vega et al., 2009). Similarly, the repeated attempts to trap the insect (3% of papers) using an ethanol-methanol attractant should not be considered an effective pest management option, bearing in mind that field populations of the coffee berry borer can reach 11 million individuals per hectare (Baker and Barrera, 1993) and that the total number of trapped insects has been reported at ca. 2000 per day (Dufour and Frérot, 2008).

Rather than continuing to focus on the same and repeatedly tested pest management methods (i.e., parasitoids, fungal entomopathogens, trapping), novel and modern research approaches to deal with a 100-year-old invasion are needed. For example, there are promising underexplored research areas involving the development of coffee berry borer attractants and/or repellents that could lead to more effective pest management strategies (Vega et al., 2009). Similarly, a better understanding of the microbiota associated with the coffee berry borer might reveal novel pest management options, including interference with *Wolbachia* (an α-proteobacterium responsible for female-biased sex ratios) (Vega et al., 2002). The recent identification of a bacterial gene [*HhMAN1*] from the *H. hampei* genome, suggests the presence of symbiotic bacteria in the intestinal flora, which allow the insect to use galactomannans present in the coffee seeds (Acuña et al., 2012). We presume that the presence of symbionts might be responsible for allowing *H. hampei* to occupy a unique ecological niche inside the coffee seeds. Future studies might reveal a possible role for other microorganisms in breaking down caffeine, an alkaloid present in the seed and known to be toxic to other insects. Thus, an in-depth study of the microbiota associated to the coffee berry borer might reveal mechanisms that could be manipulated to negatively affect specific microorganisms that are essential for the survival of the coffee berry borer.

The coffee berry borer continues to cause major economic losses and remains a major challenge for tropical entomologists and coffee growers. The historical analysis of the scientific literature reveals a paucity of coffee berry borer papers published when compared to another major insect pest, the Mediterranean fruit fly. It is imperative for coffee-producing countries to critically reassess research programmes aimed at managing this insect. Understanding the historical attempts to manage the coffee berry borer and identifying the most promising strategies for reducing losses could finally result in a major breakthrough that would improve the livelihoods of coffee growers worldwide.

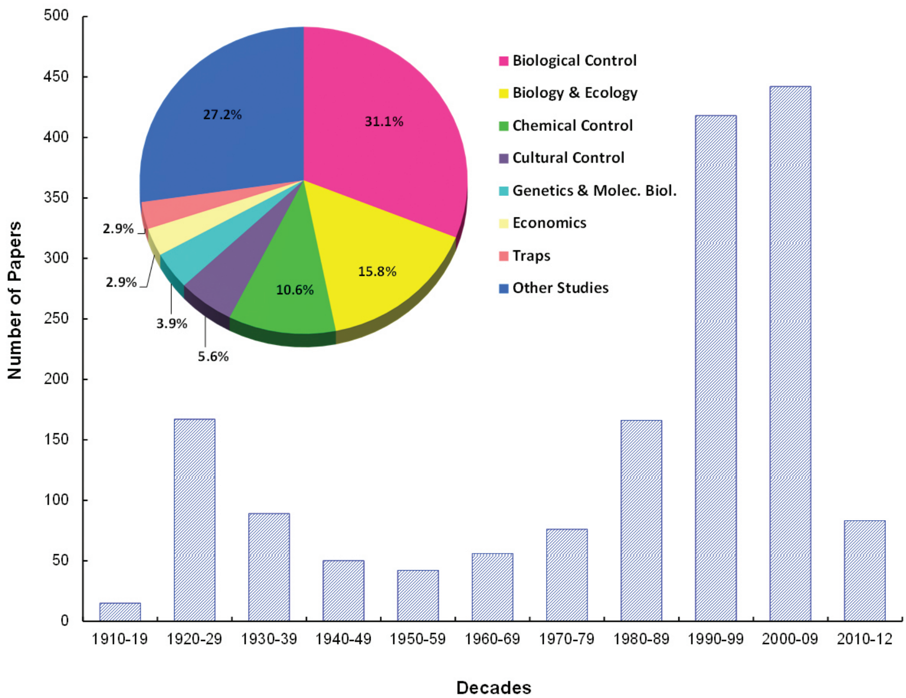

Figure 1. Main topics of peer and non-peer reviewed coffee berry borer-related papers published from 1910 to 2012 (n=1,603) based on the following databases: AGRICOLA, AGRIS, BIOSIS Previews and Biological Abstracts, CAB Abstracts, Food Science and Technology Abstracts, Medline, Web of Science, Wildlife & Ecology Studies Worldwide, and Zoological Record.

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