Losses of Brazilian bees: an overview of factors that may affect these pollinators

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Abstract

The Neotropical region to which Brazil belongs, has a great and rich diversity of natives bees, up to a total of 3.000 species including the allochtone genus *Apis* that by natural crossing among European and African races produced a hybrid called Africanized honeybee. In this way, beekeeping enjoys a spectacular moment with good production mainly of honey and propolis from *Apis mellifera*, causing Brazil to be recognized around the world as a country with great potential. Brazilian bee losses nevertheless remain a question, compared with countries of the northern hemisphere where several reports show that the vanishing of honeybees is associated with diseases caused by *Varroa*, *Nosema*, virus or pesticides. We can suggest different issues in the Brazilian situation that are directly influencing the honeybee population. Given the extension of the territory and rich flora, all possible food resources and nest sites for the good development of bees may be considered present.

However, we verified that annual bee losses in the Southeast can reach 20-30%, mainly due the genetic mechanisms of swarming (nest abandon). Many times the major factor leading to nest abandon is lack of food, often taken mistakenly by the untrained beekeeper as death of the hive caused by diseases or pesticides. Although in Brazil diseases do not represent an important problem for Africanized honeybees, some cases of presence of *Nosema ceranae* and *Varroa destructor* led the specialists to precaution and monitoring the colonies. In spite of this, the Brazilian beekeeping is managed without use of any acaricide or antibiotic, producing contaminant-free products.

As to pesticides, Brazil has a particular climatic and soil condition that might differently affect the risk of exposure of bees to xenobiotics. For example, comparing the dynamics of carbamate pesticides in soil between Brazil and Europe, it was found that in our condition ten-fold more time is needed to obtain the metabolites sulfone and sulfoxide, both more soluble and toxic than it precursor. Comparing the pesticides consumption, currently Brazil has become the world leader followed by USA, with a total spending of 44.9% herbicide, 28.5% insecticide and 22.1% fungicide. Even with this consumption Brazil still belongs to the group that uses a relatively small amount of active ingredient per hectare, less than Japan and France. However cultures like tomato, potato, citrus, cotton and coffee that are often visited by bees during bloom, are also those where the use of pesticides is needed for the pest control. Thus, little is known yet about pesticide losses of the Brazilian bees! What are real effects of pesticides, toxic plants, diseases, genetic improvement, beekeeping management, starvation or interactions among these? Therefore, our local group on ecotoxicological assessment is trying to increase the knowledge on the pesticides hazard to bees (*Apis* and non-*Apis*) in order to protect these.

Keywords: Brazilian bees, overview, pesticide, diseases, environment, protection.

1. Introduction

The commercial beekeeping for obtaining products such as honey and wax is one of the most ancient activities developed by man, as reported since the beginning of the pre-history till the contemporaneous time[1]. When it comes to the origin of bees and particularly about *Apis mellifera* L.,

1758 (Hymenoptera: Apidae), several studies suggest the African continent as the center of origin, with at least two great natural dispersions by migration (from Europe and Asia) and other artificial introductions provided by man during the process of colonization of the new world[2].

In Brazil, the first reported introduction of the subspecies *A. mellifera mellifera* was in Rio de Janeiro city in 1839. Between 1870 and 1900, the Italian bee *A. mellifera ligustica* Spinola, 1806 was introduced in the Southern region of the country[1]. Little more than 100 years after the introduction of these subspecies indigenous to Europe, non-adapted to the Neotropical region, some queens of the African subspecies *Apis mellifera scutellata* Lepeletier 1836 were imported through a genetic improvement program established in 1956, and introduced in colonies in the town of Rio Claro, São Paulo. In 1957, some colonies of this African subspecies swarmed and crossed under natural conditions with the resident European subspecies, giving rise to a fertile intraspecific hybrid called Africanized honeybee (AHB) in which the behavioral characteristics of the African bees and not of European bees[3] predominate.

In addition to the bees of the genus *Apis*, there is in Brazil a great and rich range of native bees, either eusocial or solitary, responsible for a great part of pollination and reproduction of a number of plant species. Through the surveys already accomplished, estimates lead to believe that in Brazil over 3000 species of native bees exist, that is, up to now over 1500 of them have described[4,5]. Within this group, it are the bees belonging to the tribe Meliponini and the genera *Melipona* Illiger 1806, *Tetragonisca* Moure 1946, *Scaptotrigona* Moure 1942, *Nannotrigona* Cockerell 1922, characterized by the absence of a sting and that can be handled in a rational way for honey production and pollination, mainly of greenhouse crops (protected environments)[6]. Owing to the importance and preservation of the native bees, a federal law was created and approved which has as a basic principle the protection of the keeping of these pollinators[7].

Thanks to the large terrestrial biomass formed by the Amazonia, Cerrado (tropical savanna), Atlantic Forest (Mata Atlântica), Araucaria moist Forests (Mata de Araucárias), Caatinga (xeric shrubland), Pampas (lowlands) and Pantanal (tropical wetland), the favorable climatic conditions (annual average of 20-25°C), the learning of management of the AHB, the investment in research etcetera, Brazil has stood out and obtained recognition of the international market for its products, mainly honey and propolis. In the latest three years Brazil has exported on average over 21,000 tons of honey from a total amount of product estimated as more than 50,000 ton/year. Of the propolis marketed in Japan 90% is of Brazilian origin:

(ABEMEL, 2012 (http://abemel.com.br/portal/) and

(SEBRAE, 2012 (http://www.sebrae.com.br/setor/apicultura).

In comparison with countries in the Northern hemisphere where losses can reach up to 30 to 50% of the colonies of *A. mellifera*[8] (colony collapse disorder and other phenomena), there is little information in Brazil about hive decline and similar phenomena and on the possible consequences of bee losses. Different from North America and Europe where beekeeping is intensely managed, it is given high government investments, among other for genetic improvement. In Brazil, the beekeeping of *A. mellifera* is done mostly by small farmers with little technical and scientific knowledge, making the exploitation of the potential of the AHB and the existing vegetation unviable.

Therefore, the particular conditions for the Brazilian bee such as plants of bee importance, genetics, behavior, diseases, pesticides and management should be studied thoroughly in order to obtain reliable information about the AHB and to exploit the full potential of these bees in Brazil.

2. Genetics/behavior

Differently from the European honey bee subspecies (EHB) of *A. mellifera*, AHB possesses particular characteristics resulting from the hybridization process as well as from the environment (Ruttner, 1988). The adaptation strategies of the AHBs as compared with the EHBs can be summarized in three regards: (i) climate, (ii) defense of predators and (iii) interaction between available resources and hive behavior[9]. Without doubt, the factor climate is one of the most important to be evaluated, affecting directly the hive's development by the availability of resources in the environment and its direct

reflections on production. A comparative survey between EHB and AHB found that the subspecies originating from temperate regions (Northern hemisphere) co-evolved by surviving and adapting themselves to the conditions of cold. The subspecies from the African continent have evolved by creating mechanisms necessary for colony defense against predators and parasites, which accounts for the success of the colonization by the AHB in the tropical region of the Americas and the non-adaptation to environments of temperate climate such as, for example, central regions of the Argentina and USA[2, 3,10].

In the tropical region of the Americas, the AHB has presented in general two dispersal mechanisms, one reproductive and another of abandon. In the former case, it is found that in times of food abundance, the colonies show a fast population growth and production of several reproductive swarms in a short time period. In the other case, the absence of suitable food resources causes the hive to start swarming[11]. In this way many cases of hive losses by either inadequate management or food absence are confounded as losses caused by diseases or pesticides. For instance, during winter in the Southeast region (e.g. South of Minas Gerais), colony losses can reach 20-30%, mainly due the incorrect management of hives (starvation) (Carvalho SM, 2011, pers. comm.). Similar examples are also found in other regions in Brazil. In the state of Rio Grande do Sul, the loss of 40% of the colonies between the winter and spring in 2006 was ascribed to extreme climate factors such as low temperatures and excessive rain[12].

3. Diseases, parasites and predators

Similar to the other countries where *A. mellifera* is present, it is possible to find several bee diseases in Brazil, except for example the American foulbrood (AFB) caused by *Bacillus larvae* ssp. *larvae*. Up to the present, only two cases of AFB spores were reported in Brazil, that is, one in 2001 in Rio Grande do Sul state and other in 2006 in Paraná state. In both cases, the AFB spores were found in bee products (honey/pollen) from illegal imports. Afterwards, all measures for the control and monitoring of the diseases were taken, in addition to notifying the World Organization for Animal Health/OIE[12]. In this manner, Brazil remains one of the few areas in the world free of AFB, even bordering to countries such as Argentina and Uruguay, where this disease is present since 1989[13]. One important fact is that the use of chemicals (e.g. acaricide, antibiotic, etc) is prohibited by the Brazilian law, producing contaminant-free products and so achieving world recognition.

On the other hand and not causing great problems, it is possible to find in several parts in the country (spring/summer) characteristic symptoms of European foulbrood (EFB), which is caused by a complex of disease agents (*Melissococus pluton, Bacillus pluton, Bacillus orpheus, Bacillus eurydice, Bacillus laterosporus* and *Streptococus apis*)[14]. Also in states of the South/Southeast the occurrence of chalkbrood disease was reported, which was introduced a little more than 10 years ago through the import of pollen contaminated with spores of a fungus (*Ascosphaera apis*)[13]. In most of the cases reported, this disease does not present a severe risk as has been found in countries of Europe and the USA, likely due to the warm climate and more intense hygienic behavior of the AHB.

Out of the several bee viruses, only few are reported in Brazil. Likely the low incidence is not linked to the absence of the virus, but rather to the difficulty of diagnosis from the part of the beekeepers. Following a metagenomic analysis in bee samples of the Southeast region[15], four viruses were found in Brazilian bees, namely *Acute Bee Paralysis Virus*, *Black Queen Cell Virus*, *Deformed Wing Virus* and *Israeli Acute Paralysis Virus*. Also the microsporidians *Nosema apis* and *Nosema ceranae* were still found, which are believed to be closely related to the CCD in the USA. In the particular case of *N. apis*, recent monitoring lead to believe that its presence is linked to colder regions of Brazil, as it was found only in samples obtained in the states of Paraná and Santa Catarina (Teixeira EW, unpublished).

For a long time, it was believed that the larval death of *A. mellifera* occurring in the Cerrado region during late winter and early spring was caused by *Sac Brood Virus* (SBV). However, studies found that the symptom was not a disease but rather the toxic effect of the pollen of *Stryphnodendron polyphyllum* (Fabaceae, Mimosoideae)[16] (Figure 1), named *Brazilian Sacbrood-like Disease* (BSBD). It is important to remember that the pollen of S. *polyphyllum* is not only toxic to the AHB, but also to the

native bees *Scaptotrigona depilis* (Moure 1942) and *Tetragonisca angustula* (Latreille 1811)[17] and also that the pollen and nectar of several other species are regarded as toxic to all bees in Brazil[6,18,19].

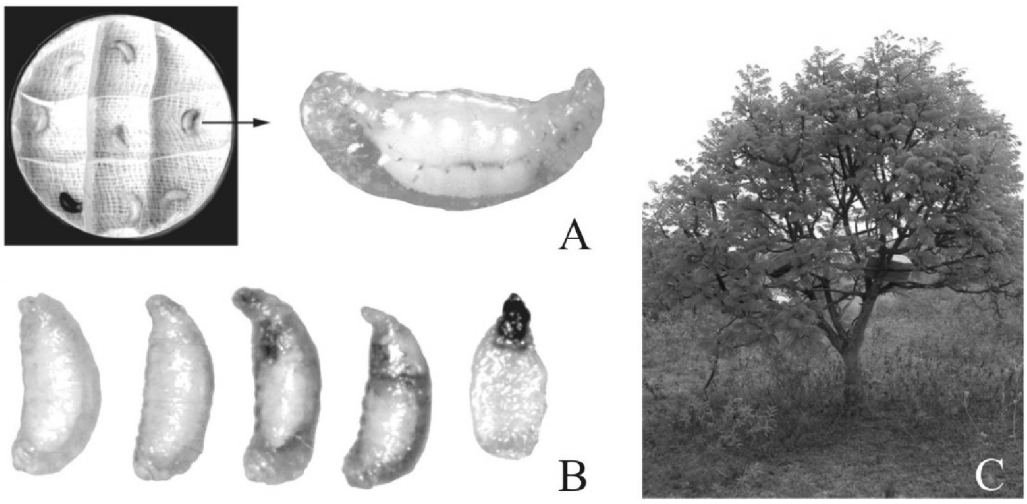

Fig. 1 Symptoms of Brazilian Sacbrood-like Disease in *A. mellifera* larvae fed *in vitro* (A) with pollen of *Stryphnodendron polyphyllum* and samples collected in hives during bloom (B) (from Carvalho et al., 2004); (C) a tree of *Stryphnodendron polyphyllum* on the Cerrado near Lavras, Minas Gerais, Brazil (Photo: Stephan Carvalho).

Among several parasites of bees, we found the mites *Acarapis woodi* (Rennie 1921) and *Varroa destructor* Anderson & Trueman 2000. The first case of occurrence of *A. woodi* in Brazil took place in the state of Rio Grande do Sul in 1970, likely from material coming from Uruguay where this mite had already been reported since 1953[20]. Nowadays, little is spoken about the presence and damages caused by this mite, and it is deemed an unimportant parasite of AHB under Brazilian conditions. Confirming this hypothesis, studies found that an important mechanism of resistance of bees against *A. woodi* is autogrooming, for which the AHB is more resistant than the EHB as it breaks the migratory cycle but not the reproductive stage of the parasite [21,22].

In relation to the ectoparasite *Varroa destructor*, the early reports in Brazil date back to 1978[1], while at present found in every region. An important characteristic of the AHB against this parasite compared with other subspecies of *A. mellifera*, is the more intense hygienic behavior, conferring increased tolerance[23]. In addition, factors as high tropical temperatures affect directly the reproductive rate of this mite, besides a little rigorous and relatively short winter[24]. Also the short development time of AHB (egg-larva-pupae-adult) can affect the life cycle of *V. destructor*[25]. In this sense, pioneering works showed that even with an average infestation of 5.0% in AHB hives in Brazil, the mite *V. destructor* does not cause significant damages to bees[26]. However, after the occurrence of CCD in the USA where it is believed that one of the main factors of the hive loss is the presence of *V. destructor*[27], the question about the real situation of the mite in Brazil was again risen. Recently, a study showed that even with low population levels of *V. destructor* on AHB, rates up to 23.0% of mortality of larvae and pupas are found[28].

Not less important than the questions cited above, for Brazil in the Neotropical region with a rich diversity of insects it is found that lots of these insects are important predators which may become enemies of bees. Indisputably, the ants (Hymenoptera: Formicidae) are the main causes of damages both to *A. mellifera* and the native bees, with emphasis on species of the genus *Camponotus* Mayr, 1861 [14]. There are also reports about attacks by ants of the genus *Solenopsis* Westwood, 1840[6]. In addition, other animal also can attack the hives such as wasps, armadillos and birds. Fortunately, in

Brazil there are no reports about the occurrence of new pests and predators as *Vespa velutina* Lepeletier 1836 (Hymenoptera: Vespidae) in France[29] and *Aethina tumida* Murray 1867 (Coleoptera: Nitidulidae) in the USA and Europe[30].

4. Pesticides

Brazil possesses a great and competitive farming sector, which for its climatic and soil characteristics is considered a food barn to the world. In that context, we can mention crops of soybean, sugar cane, fruits, vegetables etc. Factors contributing to the Brazilian agricultural success are the increase of yield per area and the increase of the planted area, brought about mainly by investments in research and technology, in particular the genetic improvement and control of pests, diseases and weeds[31]. Official data show that in the agricultural year 2010/11 a total area of 61.89 million of hectares was grown, while only grains (rice, bean, corn, soybean and wheat) occupied 46.27 million of hectares, with a yield of 142.9 million of tons. Estimates for the agricultural year 2020/21 point to a growth of 9.5% in the planted area (reaching 50.66 million de hectares) with an increase of 23.0% of the total product, reaching 175.7 million of tons[32,33].

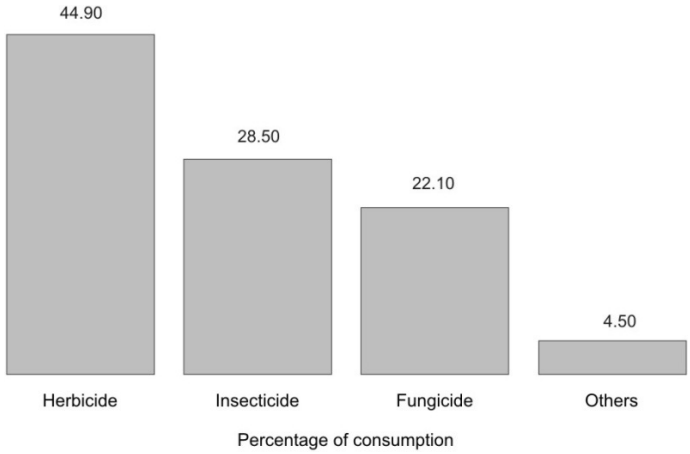

Fig. 2. Pesticide consumption in Brazilian crops[32].

Because of the expanding agribusiness, Brazil has become the greatest world market of pesticides, passing other countries as for example, the USA. In the year of 2007, 673.9 thousand tons of formulated products were consumed, with a total billing of US$7,125 billion against 646.0 thousand tons of products and US$ 6.000 billion in the USA. Out of the total consumed in Brazilian market, 44.9% were herbicides, 28.5% insecticides, 22.1% fungicides and 4.5% others (Figure 2)[34]. Considering that Brazil lies into a tropical region and has natural resources available across the year as adequate sunshine, water and temperature, it is possible to have two crops per year, causing Brazil to be the largest market in total sales and not in consumption of pesticide per area[33]. Another important characteristic is the amount of food produced on the basis of the investment in pesticides. In the ranking, Brazil takes the sixth place with expenditure of 7.39 US$ per ton of food produced, preceded by the USA < Argentine < EU (without France) < France < Japan (Figure 3) (Sindag, 2011*).

* Data from FAOSTAT and AMIS Global, available on the Sindicato Nacional da Indústria de Produtos para Defesa Agrícola/SINDAG at http://www.sindag.com.br/index.php - access in october/2011.

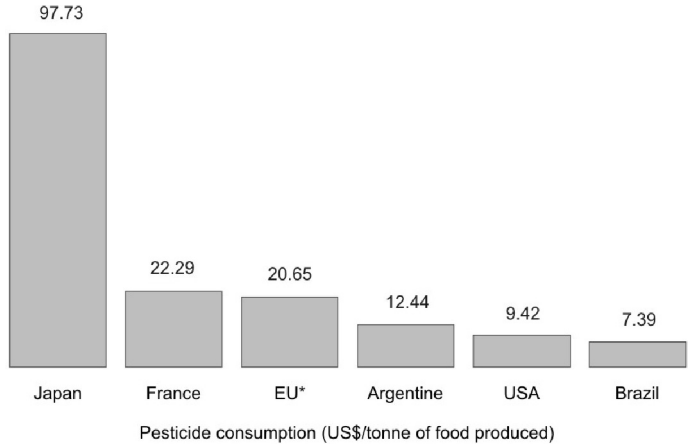

Fig. 3 Pesticide spent (in US dollar) per ton of food produced in different countries. *European Union without France (SINDAG, 2011[*]).

Several characteristics of the Brazilian agriculture are important and needed discussion, mainly climate and soil. For example the amount of organic matter and soil microbiology, are of extreme importance to the mobility, stability and metabolism of pesticides. In comparison with countries of non-tropical climate (e.g. Europe and North America), the organic matter content in Brazilian soils is inferior, which increases the mobility of molecules with low octanol-water partition coefficients[35]. So not only the mobility but also insecticide metabolism (e.g. carbamates) in Brazilian soils is different. Studies show that in Brazil both oxidation and production of toxic metabolites (e.g. sulfone and sulfoxide) need ten-fold more time than in soils of Europe and the USA, suggesting that such characteristics are directly linked to the low organic matter content of the Brazilian soils, consequently a short microbiological activity[36,3738].

Considering the accidents with bees brought about by the application of pesticides, little is known about the real Brazilian situation, for which it is difficult to predict whether bees are safe or not in relation to the effect of pesticides. Several reports about the possible contamination or death of bees by pesticides are mentioned in the states of Minas Gerais, Piauí and Rio Grande do Sul[39]. One particular accident occurred in the state of São Paulo as a result of application of thiamethoxam over a citrus crop. After aerial application, one hundred hives near to the treated area were found dead. Samples of bees collected *in loco* had residues of this neonicotinoid in the order of 0.04 mg/kg[40]. Early results suggest that the AHB can be more tolerant to some organophosphate and pyrethroid insecticides than the European subspecies[41].

Relative to the risks of exposure of bees to pesticides, factors like type of formulation (powder, liquid, fumigation etc), mixtures of compounds (insecticide + fungicide), environmental and application systems cannot be neglected. Differently from what occurs in Europe and the USA, where there is a periodical inspection of equipment for pesticide application, there is no such regulation in Brazil and no law or educational campaign aiming at the responsible use of machines and equipment. In a country with such a great farming area, increased consumption of pesticides and use of new technologies of application (e.g. aerial spraying) studies on the deleterious effects on bees are necessary[42].

5. Concluding remarks and future works

Like any other country with a booming agriculture, the particular characteristics in Brazil can affect native and exotic bee populations under natural conditions. Reports about decline of bee populations are notified in several parts of the country. There are however no technical and scientific confirmations and only a very small percentage of these cases is elucidated. The actual monitoring of

diseases in colonies of *A. mellifera* show that there is not any predominant disease which may account for a systematic bee decline[43]. One can further question the effect of nectar or pollen from plants which are admittedly toxic to bees, as is the case with *S. polyphyllum*, *Spatodea campanulata* (Bignoniaceae) etcetera. In relation to pesticides, the increase of consumption of these compounds in Brazil begins to generate discussions of the risks on the populations of beneficial insects and pollinators.

In conclusion, the situation of the bee populations in Brazil remains unknown, as it is not possible to state with certainty whether these are at risk or not. Therefore research for genetic improvement, improvement of beekeeping practices, food supplements, synergism among pesticides, disease monitoring, influence of the surrounding area (e.g. toxic plants) etcetera, need to be developed to contribute to the preservation of this important insect group.

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