



Integrated Pest Management In Coffee

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Author's contribution

The main author JRDO, carried out the initial survey of the data and made the introduction. The other authors in groups completed and formatted the remainder of the work. In addition to reviewing the tables. All authors read and approved the final manuscript.

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ABSTRACT

Coffee (*Coffea* sp.) is a crop of great economic relevance, it stands out as one of the most important agricultural commodities for the country. As with any other high value-added crop, coffee crops suffer from the attack of many pests, and proper management of these pests is critical to successful production. Integrated Pest Management (IPM) is a pest management system that associates the environment and population dynamics of the pest, considers the use of all available plant protection methods and the integration of appropriate measures to maintain the population level of the pest below the level of damage in an economically, environmentally and ecologically viable way. The purpose of this literature review was to gather information on research involving the integrated management of pests in the coffee crop.

Keywords: Management; pests; damage; control; coffee culture.

1. INTRODUCTION

Coffee pests present behaviors regulated by intrinsic factors of the environment, such as climate, microclimate, availability of food and presence of natural enemies. Changing these regulatory factors leads to balance instability and causes sudden changes in populations present in the ecosystem [1]. Brazil is the largest producer and exporter of this commodity, and is found to be the second largest consumer. Coffee growing stopped due to its relevant role in the country's trade balance, in the year 2017 it moved US \$ 5.2 billion [2]. In addition, it is one of the agricultural activities that most employs labor in the field.

Agricultural environments replace natural diversity with a reduced number of plants grown in extensive areas, which characterizes monocultures. These seek scale production and productivity through intensive use of technology and external inputs, such as pesticides, inorganic fertilizers, irrigation and high-yielding genetic material [3]. The imbalance in the system induces changes in the relationship between living beings and their natural enemies and this can lead to the appearance of high populations of bacteria, fungi, insects and spontaneous plants. These organisms compete for water, space, light and nutrients with plants of economic interest or attack their plant parts in search of the food necessary for their survival. This can reduce productivity and cause economic damage, thus, these organisms are now called pests [3].

The damage caused by insect pests is one of the main factors that lead to decreased production of the main crops. The most recent data indicate that insect pests cause an average annual loss of 7.7% in agricultural production in Brazil, which corresponds to a reduction of approximately 25 million tons of food, fibers and biofuels [4]. The changes that occurred in the conduction of the crop require, from the coffee grower, advanced technology for maintaining the crop free of these agents. Integrated pest management (IPM) is little exercised in Brazilian coffee farming, only a few measures are adopted that minimize the impact of agrochemicals on the environment. The main pests in coffee growing are, currently, the miner bug, the coffee borer and the cicadas [5]. The main control methods used in (IPM) are chemical, biological and culture. That said, the objective of this literature review was to look at how integrated pest management has been used in coffee cultivation in Brazil.

2. CONTROL METHODS AND THEIR USE IN BRAZILIAN CAFEICULTURE

2.1 Control

Like any agricultural crop produced, coffee plantations can be attacked by several diseases, which are abiotic and / or biotic. In the group of biotics, pest insects can be highlighted, which are intrinsically related to the conditions of the plant and the environment, such as climate, microclimate, availability of food, presence of natural enemies [6]. Among the pests of economic importance for coffee and that occur in most producing regions throughout the plant cycle, we can highlight the Coffee Bean borer *Hypothenemus hampei* (Coleoptera: Curculionidae), the Bicho-miner *Leucoptera coffeella* (Lepidoptera: Lyonetiidae) and the Red Mite *Oligonychus ilicis* (Acari: Tetranychidae).

The proper management of these pests can guarantee the success of the crop. For that, the Integrated Pest Management (IPM) must be used in order to live in a sustainable way with the plague, the environment and man [7].

I - Chemical Control: correct identification of pests and the complex of their natural enemies; monitoring of pests and use of pesticides from different chemical groups and modes of action, in a rational and localized manner; use of pesticides registered for the crop / pest in federal agencies and registered with the competent state agencies; recommendation through agronomic prescription; use of personal protective equipment; correct use of pesticide application technologies; restriction to preventive applications of insecticides and acaricides and their use with a broad spectrum of action [8].

II - Cultural Control: production of seedlings in protected nurseries; planting selected and healthy seedlings; use of living barriers; use of traps with food attractions and / or pheromones for monitoring and control; rational management of spontaneous plants; elimination of infested cultural remains; use of mulches; suitable production environments, times and places; use of fertilizer formulations with less solubility; management of the remaining organic matter, use of organic waste composting and use of green manure; fallow areas for the implementation of new coffee crops; use of crop rotation principles, etc. This aspect also includes genetic control, through the use of resistant

genetic materials and the direct and / or indirect induction of resistance [9].

III- Biological Control: preservation and use of the potential of natural control agents, such as bacteria, fungi, parasitoids and predators through cultural management and the correct use of selective pesticides (conservative) and / or their creation; mass release of these agents in the cultivation environment [10].

2.2 Chemical Control

In Brazil, coffee planting started in the state of Pará in 1727, brought in by the military Francisco de Melo Palheta. It expanded in the Northeast region, reaching, in 1825, the Paraíba Valley. Due to the climate and the fertility of the land, it was concentrated in the states of Minas Gerais and São Paulo [11]. Pesticides arrived in the south of Brazil together with the monoculture of soy, wheat and rice, associated with the mandatory use of these products for those who want and use rural credit. Nowadays, pesticides are widespread in conventional agriculture, as a short-term solution for the infestation of pests and diseases [12]. There are several experiments that explore the use of pesticides in the literature. Souza et al., 2013 in their work compared the efficiency of the insecticide cyantraniliprole 100, in the oil-dispersible formulation, with the endosulfan 350 EC, control standard in the experiment, in two sprays, with an interval of 30 days, for the control of the drill. According to (13) considering the percentage of fruits bored at 90 DAA (2nd) after the second spray (Table 1), it was observed that there was a negative and highly significant interaction between the dose of the cyantraniliprole product 100 OD and the percentages of boring fruits ($y = 6E-06x^2 - 0.242x + 32.804$; $r^2 = 0.97^{**}$), that is, with the increase of the dose there is a reduction in the percentage of boring fruits. Considering the percentage of fruits bored at 90 DAA (2nd) after the second spray (Table 1), it was observed that there was a negative and highly significant interaction between the dose of the cyantraniliprole product 100 OD and the percentage of bored fruits ($y = 6E-06x^2 - 0.242x + 32.804$; $r^2 = 0.97^{**}$), that is, with the increase in the dose, there is a reduction in the percentage of boring fruits. Promising results for cyantraniliprole OD were also found in the control of stem borer adults, from plants of the genus *Pinus*, *Dendroctonus ponderosae hopkins*, 1902 (Coleoptera: Curculionidae, scolytinae) under laboratory conditions [13].

Averages followed by the same lowercase letter in the column and uppercase in the row does not differ from each other by the Scott-Knott test, at 5% significance. 2 Percentages of efficiencies calculated according to Abbott (1925).

Promising results for cyantraniliprole OD have also been found in the control of adult stem borers, plants of the genus *Pinus*, *Dendroctonus ponderosae hopkins*, 1902 (Coleoptera: Curculionidae, scolytinae) under laboratory conditions [14]. The miner bug, *Leucoptera coffeella* (Guérin Mèneville, 1842) (Lepidoptera: Lyonetiidae), is the main pest of coffee trees (*Coffea arabica* L.) in Brazil, mainly in coffee growing in the Cerrado of Minas Gerais, and its losses to production can exceed 70%, depending on the intensity of its infestation [15].

When studying the efficiency of thiamethoxam in the control of the miner bug, [16] concludes based on the results obtained that thiamethoxam 250 WG applied in drip irrigation water and in a splash (drench) in the region of the coffee tree is very efficient in controlling the miner bug Table 2.

Another advantage presented by thiamethoxam is that it is compatible with entomopathogenic microorganisms [17], which have the potential to be used in pest control in the coffee crop.

2.3 Cultural Control

The diversification of plants to the population reduction of pests can include the arrangement of species in space and time, a composition and abundance of vegetation within and around cultivation areas, the type and intensity of management of the species employed [18]. The incidence of vegetation can occur from the planting area, over the entire extension of the property or, also, in the agricultural landscape. In a practical way, the management of vegetation can be structured by polycultures, by the preservation of natural vegetation in adjacent areas, by the use of fertilizers and green cover, by agroforestry systems, among others (see more examples in [19-21]).

Green manures, widely used in organic agriculture to improve the physical and biological characteristics of the soil, can also contribute to reducing the increase in pests. The pigeon pea (*Cajanus cajan*) and the crotalaria (*Crotalaria* sp.), Legumes used as green manure, requiring pollen that is nutritionally suitable for the generalist predator *Chrysoperla externa* (Neuroptera: Chrysopidae), which in several

Table 1. Percentages of boring fruits (PFB) and percentage of efficiency (% Eff.) Of the treatments

Treatments	Dose (L.p.c./ha)	30 DAA (1°)		30 DAA (2°)		90 DAA (2°)	
		26/01/2010		08/03/2010		26/04/2010	
		PBV ¹	%Efic. ²	PBV ¹	%Efic. ²	PBV ¹	%Efic. ²
1. Cyantraniliprole 100 OD	0,75	9,78b A	67,2	6,00a A	83,2	23,00a B	57,7
2. Cyantraniliprole 100 OD	1,00	11,75b B	60,5	2,50a A	93,0	22,50a C	58,6
3. Cyantraniliprole 100 OD	1,25	6,55b A	78,0	7,50a A	79,0	21,50a B	60,3
4. Cyantraniliprole 100 OD	1,50	6,63b A	77,8	5,45a A	84,7	11,00b A	79,7
5. Cyantraniliprole 100 OD	1,75	13,10b B	56,0	3,50a A	90,2	20,25a B	63,0
6. Cyantraniliprole 100 OD	2,00	2,58 a A	91,3	4,00 a A	88,8	13,50b C	75,1
7. Endosulfan 350 EC	1,50	8,30 b B	72,1	1,00 a A	97,2	42,75c C	21,5
8. Endosulfan 350 EC	2,00	7,08 b B	76,2	0,75 a A	97,9	28,00a C	48,5
9. Testemunha	-	29,78c A	-	35,68b A	-	54,25c B	-
C.V. (%)Treatment/Season= 43,30;Season/Treatment= 34,67							

Table 2. Evolution of the mining bug infestation in percentage of mined leaves (% FM) and percentage of efficiency (% E) of the treatments. Monte Carmelo, MG, 2002

Treatments	Percentage of mined leaves and efficacy in each sample made					
	02/05/2010		05/06/2010		09/07/2010	
	%FM	%E	%FM	%E	%FM	%E
1. Thiamethoxam 250 WG	3,0 d	87,6	8,2 d	88,5	17,9 d	79
2. Thiamethoxam 250 WG	0,4 e	98,4	5,2 d	92,7	20,5 d	70,1
3. Thiamethoxam 250 WG	15,0 b	38,3	50,7 bc	28,7	58,2 c	32,3
4. Imidacloprid 700 WG	21,5 a	11,5	67,4 ab	5,2	83,6 ab	2,8
5. Imidacloprid 700 WG	9,0 c	63,0	46,1 c	35,2	66,5 bc	22,6
6. Thiamethoxan 10 GR	18,6 ab	23,4	53,3 abc	25,0	74,9 abc	12,8
7. Aldicarb 150 GR	20,1 ab	17,3	70,3 a	1,2	84,0 ab	2,2
8. Control	24,3 a	-	71,1 a	-	85,9 a	-
C.V. (%)	15,3		17,5		13,7	

Trat. 1 = thiamethoxam 500 g a.i./ha, dripping; Trat. 2 = thiamethoxam 500 g a.i./ha, squirt in the neck of the plants; Trat. 3 = thiamethoxam 500 g a.i./ha, fillet in two grooves in the canopy projection; Trat. 4 = Imidacloprid 1120 g a.i./ha, dripping; Trat. 5 = Imidacloprid 1120 g a.i./ha, squirt in the neck of the plants; Trat. 6 = thiamethoxam 500 g a.i./ha, two grooves in the canopy projection; Trat. 7 = aldicarb 3750 g a.i./ha, two grooves in the canopy projection and Trat. 8 = control without application of insecticides

agroecosystems [22]. In addition, in organic coffee production systems, the use of green fertilizers planted between the lines increased the attack rate of predatory wasps in mines of the coffee tree miner (*Leucoptera coffeella*) [23].

Areas with natural vegetation, adjacent to the fields of cultivation, or where possible within the fields, must be preserved due to their importance in maintaining populations of natural enemies. These areas can function as places for hibernation or refuge from natural enemies, as sources of pollen and nectar, and of alternative hosts when there is low population density of pests in cultivated fields. In order to optimize the spacing between these areas and the main crop, it is important to consider the distance traveled by natural enemies to penetrate the cultivation areas. In the coffee tree, for example, wasps that effectively contribute to the population reduction of tree miner (*Leucoptera coffeella*) depend on the natural vegetation adjacent to the coffee plantation for nesting, which is more important than the presence of nests in the coffee plant itself, due to the foraging activity of the wasps [24]. The areas of natural vegetation can be arranged in the form of corridors, linking different crops, thus favoring the dispersion of natural enemies. Amaral et al., 2003 through the manipulation of legumes in the cultivation of coffee (*Coffea arabica* L.), the effect of increasing the diversity of plant species and increasing the complexity of plant architecture on the insect population (*Leucoptera*) was evaluated. *coffeella* (Guér-Mènev.), Lepidoptera: Lyonetiidae) and red mite (*Oligonychus ilicis*, Acari: Tetranychida), in addition to effects on the population and action of natural enemies. An experiment was conducted with variation of vegetation diversity, to verify its effect on *L. coffeella*, *O. ilicis* and their natural enemies, in two organic systems: (i) partially shaded system with banana in the coffee line and legumes between the lines and (ii) system not shaded with pigeon pea (*Cajanus cajan*) [25].

Each plot, in both systems, was composed of a total area of 75.6 m² comprising 4 rows of coffee plants with 18 plants each. The spacing between

plants was 0.5 m and between the lines was 2.8 m. In the center of each plot, six plants were chosen for sampling [25].

According to [25] the management of plant diversity can be considered as an important strategy in the ecological management of pests, mainly because it influences the predation of *L. coffeella*. Further studies are needed to determine: (i) mechanisms involved in increasing predation and maintaining natural enemies in the system, (ii) plants that selectively provide alternative resources and an enabling environment for the development of natural enemies. Finally, plants that provide efficient functional diversity for the organic management of coffee and maintenance of control must be identified.

2.4 Biological Control

Biological control is a natural phenomenon, the regulation of the number of plants and animals by natural enemies, the biotic agents of mortality. It involves the reciprocal density mechanism, which acts in such a way that a population is always regulated by another population, that is, a living being is always exploited by another living being and with reflexes in obtaining population growth, thus maintaining the balance of nature [26].

Biological control is becoming increasingly important in integrated pest management (IPM) programs, especially at a time when there is a lot of discussion about integrated production for sustainable agriculture. In this case, biological control constitutes, alongside taxonomy, the level of control and sampling, one of the supporting pillars of any IPM program. In addition, it is important as a control measure to keep pests below the level of economic damage, along with other methods, such as cultural, physical, plant resistance to insects and behavioral (pheromones), which can even be harmoniously integrated with chemical methods (selective products) or even with transgenic plants [27].

Table 3. Structure of the vegetation diversity experiment

System	Diversity	Plants Association
Partially shaded	0	Coffee
	1	Coffee + banana
	2	Coffee + banana + perennial peanut
	3	Coffee + banana + peanut + crotalaria

System	Diversity	Plants Association
Non-Shaded	4	Coffee + banana + peanut + crotalaria + estilosantes + spontaneous vegetation
	0	Coffee
	1	Coffee + pigeon pea
	2	Coffee + pigeon pea + perennial peanut
	3	Coffee + pigeon pea + peanut + crotalaria
	4	Coffee + pigeon pea + peanut + crotalaria + estilosantes + spontaneous vegetation

Table 4. Average number of live insects and percentage of control efficiency of coffee root cochineal under greenhouse conditions using two isolates (*Heterorhabditis* sp. CCA and *Heterorhabditis* sp. JPM3) using two application methods

Isolated	Method of application			
	Water suspension		Infected corpse	
	Average of insects/plant	Efficiency (%)	Average of insects/plant	Efficiency (%)
CCA	11 ± 4,72 Aa1	28	13 ± 5,52 Aa	18
JPM ₃	3 ± 2,72 Ba	68	8 ± 3,44 Aa	46
Control	17 ± 4,72 Aa	-	17 ± 4,72 Aa	-

Means followed by uppercase letters in the columns and lowercase letters in the lines differ from each other by the Scott-Knott test ($P < 0.05$)

When evaluating the performance of two heterorhabditids, previously tested in laboratory conditions for the control of *Dysmiococcus texensis* (Tinsley) and two ways of application in greenhouse and field, [28] addressed the use of entomopathogenic nematodes, as agents microbial control. According to [28] an offer obtained as efficient in the control of insects in laboratory conditions, when taken to field conditions, may not present the same results (Table 4). Factors of the environment, the host (sessile or mobile behavior, life habits, susceptibility) and the isolate, such as search capability, specificity or not to the host and resistance to unfavorable environmental conditions [29].

The JPM₃ isolate, applied in aqueous suspension, had an efficiency similar to that of the insecticide Actara, indicating it as a promising agent in the control of coffee root cochineal [30].

3. FINAL CONSIDERATIONS

Coffee plantations host few pest species, with the vast majority of arthropods (insects, mites, spiders, for example) found in coffee plantations being considered beneficial, and only a few species can be considered pests. Among these few pest species, a part of them - such as some mites, the miner bug and the coffee borer - can eventually cause economic losses to the producer and also to the quality of the drink. As a result of the use of pesticides to control them,

there are also socio-environmental and health damage to the population and increased production costs.

The presence of pests in coffee plantations drastically reduces productivity in addition to affecting the quality of the drink.

Therefore, it compromises the producer's final profit. For this, it is important to know the main pests present in the area, its population dynamics and the production environment in which it is inserted.

The most effective methods of controlling these pests, in the real sense of the term, are those that use the principles of Integrated Pest Management (IPM), that is, they combine chemical and biological management, among others, in favor of preservation in the agro-ecosystem, using pesticides as a last resort, only at the right time for each pest and in a controlled manner, selective to non-target arthropods, preserving the natural enemies of the pests and favoring their control.

4. CONCLUSION

In summary, the IPM consists of a set of practices to reduce the incidence of pests in a given crop. It is the set of several measures that aims to keep pests below a level that causes

economic damage to the crop. The IPM is based on social, ecological and economic criteria. For this, a cost / benefit analysis is performed. This aims at sustainable production, seeking to make the most of the beneficial action of natural enemies.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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