Chapter

Integrated Weed Management in Coffee for Sustainable Agriculture—A Practical Brazilian Approach

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Abstract

Brazil is the largest coffee exporter in the world market and ranks second among coffee-consuming countries. The use of technology has been largely responsible for the great development of Brazilian agriculture in recent years. Then, the efficiency of integrated weed management has made the country more competitive in coffee farming. Therefore, integrated weed management (IWM) practices are the foundation for sustainable weed management in coffee fields. Weed competition cause losses in crop production. In weed control, besides chemical control, there are other methods that are efficient, economical, and beneficial to the coffee plant and to the environment that can be used on any property, such as preventive and cultural managements; and mechanical, biological, and physical controls. The combination of weed control methods has proven to be a sustainable practice in coffee production. In integrated management, the inherent advantages of each control method must be combined. Lastly, IWM provides an efficient control action with lower costs, better environmental conservation, and higher crop productivity. Thus, this chapter discusses the main practices of sustainable weed management in coffee, addressing issues such as competition, benefits, main weeds, and IWM systems.

Keywords: integrated weed management, weed control, herbicide, cover crop

1. Introduction

Brazil is the largest coffee exporter in the world market and ranks second among coffee-consuming countries. This quantity of coffee corresponds to one-third of the world's production, which places it as the largest producer for more than 150 years. The country has approximately 264,000 coffee-producing farms, of which 78% are considered family coffee farming [1]. Brazilian coffee-producing farms are present in 5 geographic regions, in 16 states of the Federation, in which there are 1448 cities that produce coffee, which corresponds to approximately 26% of Brazilian cities [1]. The Brazilian coffee planted area in 2020 corresponded to 2.162 million hectares, an area that includes the *Coffea arabica* and *Coffea canephora* [2]. Of this total, 276,000 hectares (13%) are in training and 1.885 million hectares (87%) in production [2]. In the case of Brazil, besides the development of technology, the availability of land and labor makes the country internationally competitive. As a technology-intensive crop, coffee is an activity that generates employment and income, especially when considering the other activities throughout the product chain, as well as the trade balance surplus, a factor that favors economic development. Although the area occupied by coffee plantations is not significant in relation to the area explored with other agricultural activities, coffee contributes significantly to Brazilian agribusiness, both economically and socially. Furthermore, it is possible to verify that the area occupied by Brazilian coffee farming had a reduction of approximately 17% in the last 2 decades [2].

Even so, in the last 20 years (2001–2020), the volume of coffee produced increased by approximately 200% as a result of the increase in crop productivity [2]. The use of technology has been largely responsible for the great development of Brazilian agriculture in recent years. In coffee growing, it is no different! Then, the efficiency of the integrated management of pests, diseases, and weeds; the nutrition of coffee trees; pruning and conduction of crops; irrigation, and the development of new varieties have made the country more competitive in coffee farming.

Coffee plants have a very low initial growth rate [3], which also impairs soil cover [4, 5]. Thus, especially during the juvenile phase (up to 2 years in the field), the coffee crop is highly sensitive to competition from weed species [5, 6]. This results in a noticeable reduction in coffee growth and yield, and weed control is one of the major field management practices, which can entail high costs [4, 7, 8]. In Brazil, there are different coffee-producing regions, each using specific cultural practices for crop management [9]. Therefore, the integrated weed management (IWM) practices adopted will vary between farms, depending on local characteristics. In fact, the adoption of site-specific IWM practices is the foundation for sustainable weed management in any cropping system [10]. However, this is not always a usual practice of the grower, often opting for chemical control only using glyphosate-based products.

The objectives of this chapter on IWM of coffee in Brazil are: (a) state the main practices of sustainable weed management and (b) address the major issues of weed competition, benefits, main weed species involved, and discuss the leading IWM systems.

2. Weed competition

Several studies have related the losses in coffee growth when in competition with weeds. In this sense, Oliveira et al. [11] found that without adequate control of weeds, observing the critical periods of control in coffee, there were losses in crop production where the weeds were not controlled throughout the year, reaching reductions of 43%.

It is well known that weeds affect the coffee crop in various ways during its life cycle [5]. For example, it has been shown that young coffee trees suffer competition with different weed species under both controlled conditions [12–16] and in field studies [6, 17, 18]. Reduced plant growth has correlated with decreased photosynthetic efficiency [19] and nutrient accumulation by the branch [16, 20] and root systems of coffee plants [13] These studies also showed that the effect of weed competition on coffee was strongly dependent on both the weed species and density, and the age of the coffee plant after transplanting.

In another study, Ronchi et al. [20] verified severe competition in the relative content of macro (N, P, K, Ca, Mg, and S) and micronutrients (Zn, Cu, B, Fe, and Mn) in the aerial part of coffee plants when in competition with beggarticks (*Bidens pilosa*), dayflower (*Commelina diffusa*), motherwort (*Leonurus sibiricus*), apple-of-Peru (*Nicandra physalodes*), pusley (*Richardia brasiliensis*), and arrowleaf (*Sida rhombifolia*).

Therefore, IWM in coffee should consider the characteristics of individual weed species as well as their high nutrient recycling potential. Impaired crop growth due to weed competition soon after field transplanting will certainly cause irreversible losses in crop productivity [17].

3. Positive aspects of weeds

According to Souza et al. [21], weeds present in coffee plantations should be controlled to avoid loss of production and to facilitate farming and harvesting operations. On the other hand, if well managed, they can be beneficial to the crop, by contributing to shading the soil, avoiding direct sunlight (shading soil); mitigating the effects of erosion during the period of greater rainfall; and increasing the organic matter content of the soil through the decomposition of roots and aerial parts. However, it is important to avoid the production of weed seeds.

4. Common weeds in coffee plantations

The practice of surveying the predominant weed population in the cultivation area is considered of great importance, identifying its species and knowing its main characteristics, in order to support decision-making for the most appropriate control. The composition of the floristic community is always subject to the occurrence of variations, influenced by regional conditions, soil characteristics, type of exploration, and management system, which contribute to a greater or lesser presence of certain species in a given place and period. In coffee growing, we can group the main predominant weed species, highlighting the classifications as to the period of occurrence (dry and rainy), life cycle (annual and perennial), and type of leaf (narrow and

Monocotyledons					
Common name	**Latin name**	**Family**	**Infestation period**	**Cycle**	**Leaf**
Dayflower	*Commelina benghalensis*	Commelinaceae	Dry and rainy	Perennial	Broad
Nutsedge	*Cyperus rotundus*	Cyperaceae	Dry and rainy	Perennial	Narrow
Brazilian satintail	*Imperata brasiliensis*	Poaceae	Dry and rainy	Perennial	Narrow
Bermudagrass	*Cynodon dactylon*	Poaceae	Dry and rainy	Perennial	Narrow
Bahiagrass	*Paspalum notatum*	Poaceae	Dry and rainy	Perennial	Narrow

Monocotyledons					
Common name	**Latin name**	**Family**	**Infestation period**	**Cycle**	**Leaf**
Kikuyu grass	*Penisetum clandestinum*	Poaceae	Dry and rainy	Perennial	Narrow
Jamaican crabgrass	*Digitaria horizontalis*	Poaceae	Rainy	Annual	Narrow
Alexandergrass	*Urochloa plantaginea*	Poaceae	Rainy	Annual	Narrow
Sandbur	*Cenchrus echinatus*	Poaceae	Rainy	Annual	Narrow
Jaraguagrass	*Hyparrhenia rufa*	Poaceae	Dry and rainy	Perennial	Narrow
Guineagrass	*Panicum maximum*	Poaceae	Dry and rainy	Perennial	Narrow
Goosegrass	*Eleusine indica*	Poaceae	Rainy	Annual	Narrow
Sourgrass	*Digitaria insularis*	Poaceae	Dry and rainy	Perennial	Narrow
Dicotyledons					
Morningglory	*Ipomoea acuminata*	Convolvulaceae	Dry and rainy	Annual	Broad
Purslane	*Portulaca oleracea*	Portulacaceae	Dry and rainy	Annual	Broad
Radish	*Raphanus raphanistrum*	Cruciferae	Dry	Annual	Broad
Indigo	*Indigofera hirsuta*	Leguminosae	Dry and rainy	Perennial	Broad
Arrowleaf	*Sida rhombifolia*	Malvaceae	Dry and rainy	Perennial	Broad
Sanguinaria	*Alternanthera tenella*	Amaranthaceae	Dry and rainy	Perennial	Broad
Pigweed	*Amaranthus* spp.	Amaranthaceae	Dry and rainy	Annual	Broad
Buttonweed	*Borreria alata*	Rubiaceae	Dry and rainy	Annual	Broad
Pusley	*Richardia brasiliensis*	Rubiaceae	Dry and rainy	Annual	Broad
Poinsettia	*Euphorbia heterophylla*	Euphorbiaceae	Dry and rainy	Annual	Broad
Beggarticks	*Bidens pilosa*	Asteraceae	Dry	Annual	Broad
Sowthistle	*Sonchus oleraceus*	Asteraceae	Dry	Annual	Broad
Ageratum	*Ageratum conyzoides*	Asteraceae	Dry and rainy	Annual	Broad
Tasselflower	*Emilia sonchifolia*	Asteraceae	Dry	Annual	Broad
Marigold	*Tagetes minuta*	Asteraceae	Dry and rainy	Annual	Narrow

Dicotyledons					
Common name	**Latin name**	**Family**	**Infestation period**	**Cycle**	**Leaf**
Smallflower	*Galinsoga parviflora*	Asteraceae	Dry and rainy	Annual	Broad
Starbur	*Acanthospermum hispidum*	Asteraceae	Dry and rainy	Annual	Broad
Fleabane	*Conyza bonariensis*	Asteraceae	Dry and rainy	Annual	Broad

Source: Santos [22].

Table 1.
Main weed species prevalent in coffee plantations.

broad), consolidated in **Table 1**, according to Moraes et al. [23], Souza et al. [24], IBC [25], Silveira et al. [26], Matiello [27], and Matiello et al. [28].

5. Weed control methods

In weed control, besides chemical control, there are other methods that are efficient, economical, and beneficial to the coffee plant and to the environment that can be used on any farm. The management of weeds for sustainable agriculture is partitioned into (a) preventive management, (b) cultural management, (c) biological control, (d) physical control, (e) mechanical control, and (f) chemical control (herbicide).

5.1 Preventive management

Similar to cultural methods, preventive management for weed suppression are low-cost and advantageous for the coffee crop. According to Ronchi and Silva [5], there are very few but relatively important preventive methods that should be applied in coffee production systems, either to curb the entry or to decrease the dispersion of weed seeds in coffee plantations, they follow below:

- Care for seeds in soil correctives (straw and manure).
- Keeping farm roads free of weeds by clearing them or applying herbicides.
- Cleaning machinery during or after any mechanized operation on the farm.
- Remove any new weed infestations before they become more dense.
- Controlling weed species until the flowering stage to prevent seeds from spreading through the area by mechanical operations and animals, or to avoid increasing the weed seed bank in the soil [29].
- In areas of Mechanized Harvesting, the cleaning of the harvester should be performed. According to Matiello et al. [9], mechanized coffee harvesting has contributed to the dispersion of morningglory (*Ipomoea* spp.) seeds in crops, and

this species should be controlled in its initial stage of development or by cleaning harvesters frequently to prevent infestation.

5.2 Cultural management

In coffee plantations in formation, a strip of 40–50 cm on each side of the planting line is kept free of weeds. In this case, the soil is exposed to solar radiation, the impact of rain, and the action of winds, all of which are harmful to the coffee plant, due to water evaporation and excessive heating of the first 10 cm of the soil surface. Currently, many producers work with intercropping between coffee trees and Congo grass (*Urochloa ruziziensis*) and signal grass (*Urochloa decumbens*). In this intercropping, the forage is cultivated between the rows (**Figure 1**), while the coffee planting row is kept covered by the residue thrown by the mower, during the mowing between the rows.

In soil exposed to the sun, plant growth is impaired by soil temperature and also by the evaporation of up to 15,000 liters of water per hectare per day [30]. The deposition of 5 t ha^{-1} of mown palisade grass (*Urochloa brizantha*) biomass, on the street of the coffee plantation, provides the equivalent of 70 kg ha^{-1} of nitrogen (N) and 8 kg ha^{-1} of potassium (K_2O). In a palisade grass pasture cultivated for 10 years without fertilizers, 45% more available phosphorus was found in soil samples taken under the clumps, compared to samples between the clumps [31].

Figure 1.
Consortium of Congo grass (Urochloa ruziziensis) with coffee, Larga farm, Ibiá, MG, Brazil. Photo: Daniel Resende Fontes.

Cutting green manures, such as pinto peanut, slender leaf rattlebox, jack bean, velvet bean, and millet, forms over time a layer of mulch that protects the soil and prevents or hinders the germination of the seeds of photoblastic positive weeds [32], which need light for their germination, Some examples of these weeds are: *Sida cordifolia*, *Sida rhombifolia*, and *Sida spinosa* [33] *Amaranthus* spp. and *Conyza* spp.

Millet is an annual grass (Poaceae) of tropical climate that has good resistance to drought, wide adaptation, and good mass production, in addition to fast growth, vigorous roots, and good capacity for nutrient cycling [34], considered a classic example of a cover crop, because it has a C/N ratio of 30 or higher in the budbreak and flowering phases [35], and can be an interesting option for cultural management and green manure.

Partinelli et al. [36], studying the effects of control treatments (no planting of cover crops), millet and the legumes pigeon pea, velvet bean, and cowpea, found that the biological fixation of nitrogen contributed about 80% of N accumulated by legumes, and depending on the production of dry biomass the contribution ranged from 27 to 35 kg N ha^{-1}. The pigeon pea (29.1 g kg^{-1}) and velvet bean (32.6 g kg^{-1}) showed the highest concentration of N.

On the other hand, regarding coffee plantations in formation, in organic and conventional systems, it was found that the bean straw mulch formed a physical barrier against weeds, providing soil coverage in the control of coffee weeds, obtaining satisfactory control and retaining more moisture in the soil, besides enabling the process of mineralization of this straw, which benefits the coffee in the organic system [37].

There are studies that have shown that residues of coffee husk and leaves caused inhibition of the germination of several wild species such as *Amaranthus retroflexus*, *Bidens pilosa*, *Cenchrus echinatus*, and *Amaranthus spinosus*, because of the release of allelopathic substances [38].

Martins et al. [39] found that plots subjected to *Mucuna deeringiana* mulch between the rows showed more than 90% reduction in weed density that was attributed to the allelopathic effects of this mulch.

In fact, different types of organic materials, including coffee waste such as coffee pulp, husk [40], and beans [41], have the potential to be used to control weeds through cover crop applications. For example, Yamane et al. [41] recently demonstrated that cover application of coffee grounds at 16 kg m^{-2} resulted in significant weed control for half a year. This inhibition was a result of an allelopathic effect due to the presence of caffeine, tannins, and polyphenols in coffee grounds [42].

Knowledge of the specificity of the allelopathic potential of plant residues will allow the efficient use of this resource in coffee growing as a practice in conventional coffee production, and especially in the production of certified coffee, whose products have a niche market with great prospects for expanding international demand.

Based on this information, we conclude that keeping the coffee trees permanently clean in the skirt area (chemical control) and with the weeds between the rows controlled by a rotary weeder (mechanical control) has stood out as a method that has maintained the principles of sustainability [43], besides producing organic matter for the coffee trees.

5.3 Biological control

The biological control method basically consists of using an agent that keeps the weed population at a lower level than would occur naturally, causing no economic damage to the crop.

The use of animals for weed control is hardly practiced anymore in modern coffee farming. This method consists of using ruminant animals (sheep) or birds (chickens) that will feed on the weed, thus reducing their population. The use of this method is little known in Brazilian coffee growing, and more investment in research is needed for it to become an alternative in the future.

5.4 Physical control

As emphasized in the sections above, if the weed vegetation is kept at a sufficient distance from the coffee row (to avoid resource competition), there is no need to eliminate the vegetation from the entire area (except during the harvest period in some countries) [5]. In addition, cover crops (mulching) or green manure can be successfully intercropped with coffee, as reported in the crop control.

Vegetable residues from other crops (if available on the farm at no additional cost), from the coffee tree (leaves and stems), or from tree branches, especially after pruning, can be used as mulching [5]. And the use of polyethylene plastic on the coffee row is also considered mulching.

5.5 Mechanical control

Manual weeding is one of the most important control methods on coffee farms, although they are slow and laborious [5]. During the formation stages, if preventive measures fail or if selective herbicides are not used, weeds that eventually germinate should be removed during the seedling formation and growth period [4]. Two years after field transplanting, several manual weeding operations are recommended to establish and maintain an adequate weed control range along the coffee rows, although herbicides can also be applied judiciously. On coffee farms where selective pre-emergence herbicide is applied as the primary method of weed control in the coffee rows, at least one manual weeding operation is performed 2–3 weeks after coffee planting, prior to herbicide application to regulate the soil surface and remove weeds.

The mechanical control of weeds is widely accepted by producers as a replacement or complement to other methods, especially manual ones, due to the fact that these methods have a higher yield, faster, and more economical. The difficulty of hiring labor, its high cost, and low yield, make the option for mechanical methods essential for large farms, being executed with the application of appropriate management techniques. These methods have great application in coffee farming, but they depend on the availability of equipment, spacing between rows, size of the plantation, slope index, and complementary methods of weed control. The most used implements coupled to tractors are the following:

- Grazer: normally with 2 knives, activated by the tractor's power takeoff, it is the most used implement in coffee farming, because it reduces the dissemination of weed seeds, being used at any time before flowering and fruiting, avoiding the formation of soil erosion processes. It must be used in the rainy and hot seasons of the year in coffee plantations with wider spacing. With adequate management, it is possible to keep weeds growing with controlled growth and to have the deposition of plant residues after cutting, forming mulch on the soil surface. In this operation some weed roots may die, which contributes to the formation of channels in the soil, favoring its aeration and water infiltration. Excessive use of the brush cutter can cause soil compaction, dominance of creeping weeds, and sprouting of some species, especially perennials.

- Brush: Contains a set of blades with a movement similar to that of a hammer mill, which grinds the weeds and plant residues such as branches and leaves. Several brands on the market with various types of blades and hammer, which presents greater efficiency over larger weeds and small tangled bushes, producing a thick layer of mulch over the soil.

5.6 Chemical control

The chemical method, or the use of herbicides, is a practice widely used in coffee farming, but for a better yield and effectiveness, the farmer must be careful in the correct choice of herbicide to be used in the field, according to several factors such as community, weed infestation level and stage of development, crop phase, soil type, time of application, toxicology of the herbicide, cost, equipment, and skilled labor in the application, in order to maximize efficiency while minimizing the effect on the environment [44].

Advantages:

- Speed and good operational yield
- Better applicability during rainy periods
- Keep the soil intact (without disturbance)
- Gradual weed disinfestation (perennial and vegetative propagated)
- Low cost and good efficiency in weed control

Disadvantages:

- Can cause injury, due to the drift effect
- When used in excess, can expose a lot of soil
- Requirement of adequate equipment with permanent maintenance
- Need for more training of producers or specialized labor
- May select resistant or tolerant weeds

Mixing herbicides is an important common practice to increase the spectrum of weed control in coffee plantations [5], compared to other crops, there are few herbicide formulations available for coffee. Herbicides are characterized by observing three main aspects [28]:

1. Selectivity: selective for the crop or non-selective (full action)
2. Season of use: used in PRE- or POST-emergence

3. Translocation in weeds: contact or systemic

These herbicides should be applied in a directed spray to the soil (PRE) or to weeds, respectively, to avoid injury to the coffee plant, for example, oxyfluorfen, is not completely selective on Arabica coffee [18] and to overcome the umbrella effects of higher coffee plants, the application doses of these herbicides should be determined based primarily on the physicochemical characteristics of the soil for herbicides applied PRE, and on herbicides in POST, the weed species and the stage of their development. On adult coffee plants, herbicides are mainly used between the rows, but applications in the coffee plant row may be necessary (e.g., to control *Ipomoea* spp.) [5]. In between the rows, herbicides have often been used during the rainy season for weed control in a narrow band beyond the projected skirt of the coffee plant. Total or partial desiccation in the strip, the weed residues are retained in the soil, contributing to soil and water conservation, nutrient cycling, and organic matter accumulation.

When recommending herbicides for the coffee crop, see **Table 2**, which consolidates the identification of the most commonly used herbicides, with their application times, dosages per hectare, and spectrums of action [28, 29, 46–50].

Chemical weed control in coffee farming became public through the replacement of the total-action, post-emergence, non-systemic, and highly toxic herbicide paraquat (banned in Brazil) by glyphosate, a systemic herbicide, also non-selective to coffee trees and applied post-emergence with low toxicity [51]. Due to its low cost, high

Application time	Commercial product	Active ingredient	Doses/ha	Narrowleaves	Action form
PRE	Goal and Galigan	Oxyfluorfen	2.0–6.0 L	Broad and narrow leaves	Contact
PRE	Sencor	Metribuzin	1.0–2.0 L	Broadleaves	Systemic
PRE	Alion	Indaziflam	0.15–0.20 L	Broad and narrow leaves	Systemic
PRE	Falcon	Pyroxasulfone + flumioxazin	0.45–1.0 L	Broad and narrow leaves	Contact and systemic
PRE	Boral and Stone	Sulfentrazone	1.4–2.0 L	Broad and narrow leaves	Systemic
PRE and POST	Flumyzin 500	Flumioxazin	0.05–0.240 L	Broadleaves	Contact
POST	Round up Original	Glyphosate	3.0–5.0 L	Broad and narrow leaves	Systemic
POST	Finale	Glufosinate-ammonium	2.0–3.0 L	Broad and narrow leaves	Contact
POST	Heat	Saflufenacil	35–100 g	Broadleaves	Contact
POST	Ally	Metsulfuron-methyl	6–10 g	Broadleaves	Systemic
POST	Aurora	Carfentrazone-ethyl	75–125 g	Broadleaves	Contact
POST	Clorimurom	Chlorimuron-ethyl	50–80 g	Broadleaves	Systemic
POST	Verdict Max	Haloxyfop-P-methyl	0.185–0.290 L	Narrowleaves	Systemic

Source: ADAPAR [45].

Table 2.
Main herbicides recommended for coffee plantations.

availability in the market, excellent toxicological profile and large number of controlled species, both grasses and broadleaves, the main herbicide used in coffee culture is glyphosate [52]. Repeated application during a season using the same active ingredient can select tolerant plants or resistant biotypes.

In order to control weeds of resistant biotypes, and avoid selection of new biotypes, herbicide associations are recommended for the control of a greater amount of weeds [53, 54]. The search for alternatives for the control of these resistant species, through IWM, find strategies to reduce the selection pressure of these biotypes such as reducing weed infestation, adopting an efficient green manure system, integrating and alternating control methods, such as preventive and cultural methods associated with chemical methods, alternating or associating herbicides with different mechanisms of action and using herbicides with different metabolism routes.

6. Integrated weed management (IWM)

IWM in coffee is based on the rational combination of different weed control practices (e.g., preventive, cultural, mechanical, biological, physical, and chemical) [5]. Every weed control system in coffee plantations should always be reviewed and analyzed with criteria every year, observing its effect on the soil and culture, as well as its technical and economic feasibility, respecting the conditions of each plantation [55]. Thus, no weed control practice is used in isolation [10].

Figure 2.
Integrated weed management (IWM) at Alquino farm, Pratinha, MG, Brazil. PRE-emergence herbicide application (A), mowing of Urochloa ruziziensis (B), mulching in the coffee row (C), and mulching in the coffee row (D). Photo: Daniel Resende Fontes.

Season	Time Brazilian	Crop	Weed control	
			In the intercrop rows	In the crop rows
Beginning of rains	September to November	Current	Planting of *Urochloa ruziziensis* (cultural control)	PRE and POST herbicide application
		Next	Mechanical grazer (throwing green matter on the coffee line) (mechanical control)	Green cover (cultural and biological control)
		Later	Mechanical grazer (throwing green matter on the coffee line) (mechanical control)	Green cover (cultural and biological control)
During the rains	December to February	Current Next Later	Mechanical grazer (throwing green matter on the coffee line) (mechanical control)	Green cover (cultural and biological control)
End of rains (tilling)	March to May	Current	POST herbicide application (chemical control)	No need (cultural control)
		Next	Blade carving (mechanical control)	
During the dry season (spraying)	June to August	Current	Push the mulch from the rows to the inter-row (furrower) (mechanical control)	Mulching (cultural control)
		Next		Straw application (biological and cultural control)

Source: Adapted from Santos [56].

Table 3.
Suggestion for integrated weed management (IWM) in coffee plantations.

Every weed control system in coffee plantations should always be reviewed and analyzed with criteria every year, observing its effect on soil and crop, as well as its technical and economic feasibility, respecting the conditions of each plantation [55]. The IWM of coffee consists of the union of all types of control (**Figure 2**), applied in a combined, successive, and rotational manner at a given time and space, considering the conditions of the plantation and the execution of other agricultural practices.

Priority should be given to carrying out different controls in order to take advantage of the available resources and achieve greater efficiency, reduce costs, and obtain maximum safety for humans and minimum damage to the environment (**Table 3**).

7. Conclusions

The combination of weed control methods has proven to be a sustainable practice in coffee production. In integrated weed management, the inherent advantages of each control method must be combined, considering requirements such as safe application, age, spacing, and size of the plantation, as well as full knowledge of the weeds, their growth stage, leaf type, frequency, and population density. By reinforcing the study of the biology and physiology of weeds, we can guarantee the formation of a consistent diagnosis, which will provide an efficient control action with lower costs, better environmental conservation, and higher crop productivity.

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Conflict of interest

The authors declare no conflict of interest.

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