QUIZALOFOP-P-ETHYL CONTROLLING SOURGRASS (*Digitaria insularis*) AND GOOSEGRASS (*Eleusine indica*) IN INFESTED COFFEE AREAS

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(Received: October 18, 2019; accepted: October 29, 2019)

ABSTRACT: Chemical control is the main weed management system in coffee crop. Herbicides alternatives controlling grass weeds in infested coffee areas are limited, mainly due to the few options of registered herbicides. Thus, it is important to evaluate selective post-emergence herbicide to control these important weeds in coffee crop. The objective in this work was to evaluate the selectivity, efficiency and agronomic viability of the herbicide quizalofop-P-ethyl compared to GLI OVER SL (glyphosate) on grass control in coffee crop. Two experiments were carried out in randomized blocks with four replicates in the municipality of Lavras and Santana da Vargem (MG - Brazil) in a commercial coffee crop cultivar "Mundo Novo" and "Catuai" to evaluate the herbicide effectiveness in the crop rows. The experimental design was a randomized block design with seven treatments and four replicates. Treatments consisted of the herbicide doses (25, 50, 75 and 100 g a.i. ha^{-1}) compared to the standard glyphosate at the dose of 1,680 g a.i. ha^{-1} + Iharol at 0.5% v/v. Application occurred when sourgrass and goosegrass were at the beginning of development with up to 4 tillers (early vegetative stage) and in a second trial, at advanced stages of development (highly branched and /or flowering). Control assessments in percentage were performed at 7, 14, 21 and 28 days after application (DAA) of the treatments. A note of phytotoxicity was given following the European Weed Research Council (EWRC) patterns. The control of weeds was evaluated in each experimental plot using the visual notes scale, where: 0% represents no control, and 100% total control of the species in question, compared to the population present in the non-weed control. In general, the dose of 1,500 and 2,000 mL per hectare of quizalofop-p-ethyl (75 and 100 g a.i. ha^{-1}) for the weeds at early vegetative stage presented the highest levels of controls (above 90%). The dose of 2,000 mL per hectare (100 g a.i. ha^{-1}) was efficient at 28 DAA to control more developed plants. No symptoms of phytotoxicity caused by the herbicide quizalofop-P-ethyl were detected at any dose tested. Quizalofop-P-ethyl can be recommended for integrated weed management in coffee for sourgrass and goosegrass.

Index terms: Weeds, Quizalofop-P-ethyl, efficiency, agronomic viability, selectivity.

1 INTRODUCTION

Coffee (*Coffea arabica*) production in Brazil occupies a total area of 1.73 million hectares, with estimated production of 34.4 million bags (60 kg) and average yield of 23.78 bags per hectare in 2019 (CONAB, 2019). Due to weed interference, coffee productivity and quality can be severely compromised and therefore weed management is one of the main practices that overload the production cost (SILVA; SILVA, 2007).

There is scarce information on the effect of weed density on coffee crop described in the literature; however, the period of highest competition between coffee and weeds extends from October to April, coinciding with the flowering and ripening period of the coffee tree. Considering the productivity of the crop, ideally during this period the coffee plantation must be kept clean, without weed interference (FIGUEIREDO NETO et al., 2008).

In Brazil, sourgrass has become dominant in coffee farms (LEMES et al., 2010). This fact can cause many problems to Brazilian coffee growers due to the lack of information about the interference of this plant in coffee and the possible control strategies to be used (CARVALHO, 2013). The ideal weed management in coffee crop must economically eliminate the damage caused by weeds without causing damage to the coffee tree. It should be noted that chemical control operations do not dispense, but facilitate integrated weed management (FIALHO, 2011).

In areas occupied by perennial crops such as coffee, the main weed management strategy is glyphosate, at first in full area management applications and then in jet driven (GALLI; MONTEZUMA, 2005; FERREIRA et al., 2010). Glyphosate use is widespread and has been misused in coffee crops all over the country, this fact that may be leading to the emergence of biotypes of sourgrass and goosegrass resistant to this herbicide also in coffee growing areas (CARVALHO, 2013).

Due to the management strategy adopted, the selection pressure of glyphosate herbicide resistant biotypes is very high in coffee crops. When resistance biotype is selected in an area or region, as noted by several authors (ADEGAS et al., 2010a; CARVALHO et al., 2013), the study of control alternatives becomes vital to ensure weed management success.

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There are few herbicides recommended for coffee plants with selective action (LORENZI, 2014) and, in many cases, the adoption of nonselective herbicides implies damaging the plants due to their phytotoxicity.

According to Ronchi, Silva and Ferreira (2001), the use of herbicides applied in post-emergence results in positive factors for the crop, especially those planted in craggy topography soils subject to erosion. Among the post-emergence herbicides that may be selective to the crop, the herbicide quizalofop-p-ethyl, which is widely used for the control of Poaceae family in agriculture, can be highlighted, and its use has been intensified as an alternative to the control of weeds resistant to the herbicide Glyphosate (RODRIGUES; ALMEIDA, 2011). This herbicide has as its mechanism of action the inhibition of the enzyme Acetyl CoA carboxylase (ACCase), within the chemical group of aryloxyphenoxy propionate herbicides. The inhibition of ACCase explains the reduction in growth, the increase in membrane permeability and the ultrastructural effects observed in cells. This enzyme, found in the plastid stroma, converts Acetyl Coenzyme A (AcetylCoA) into Malonyl Coenzyme A (Malonyl-CoA) by the addition of a CO_2 molecule to AcetylCoA. It is a key reaction at the beginning of lipid biosynthesis that measures the rhythm of this biosynthesis (BURKE et al., 2006).

Based on this context the objective of this work was to evaluate the efficiency and agronomic viability of the herbicide quizalofop-P-ethyl (50 g a.i. L^{-1}) compared with Glyphosate in the control of grasses weeds in coffee.

2 MATERIAL AND METHODS

Experiment I was carried out at "Chácara Vitor Lucas", located in Santana da Vargem, State of Minas Gerais, at 832 m altitude, 45°30'79" W and 21°14'71"S. The coffee variety used was Mundo Novo, planted with a spacing of 1 m between plants and 3 m between rows, density of 3,333 plants per hectare.

Experiment II was carried out at "Pé de Serra Farm", located in Lavras / MG, at 984 m altitude, Latitude 21º19'01 '' S Longitude 045º01'25''O. The experiment was set up in an area consisting of clayey Red Latosol. The coffee cultivar used was Catuaí with 3 m row spacing and 0.6 m row spacing, density of 5555 plants per hectare.

The product used to conduct the experiment was in compliance with the Special Temporary Registration - RET Number: 194813 - valid until 09/05/2016 - phase III.

Planting fertilization for both experiments was performed based on soil analysis and according to recommendations in the 5th Approach - Recommendations for the use of correctives and fertilizers in Minas Gerais (GUIMARÃES et al., 1999).

The experimental design used in both experiments was randomized blocks with seven treatments and four replicates. The plots were established in 30 m^2 being 3 m wide and 10 m long, the useful area was 24 m^2.

The period of the experiment was from January to February 2015. To prove the efficacy and agronomic feasibility of the herbicide quizalofop-P-ethyl in post-emergence weed control, a product based on glyphosate (Gli over) was used as a control standard. The treatments used in the experiment are described in Table 1, as well as the commercial product, doses, active ingredient concentrations and formulations of the evaluated products. Integrated management measures recommended for coffee crop such as: monitoring of rust, cercosporiosis, ascoquita/ phoma complex, leaf miner and drill were adopted.

Product application was carried out as post-emergence using a CO_2 pressurized costal spray (3 kgf / cm^2) with a flat nozzle (Fan) 110.03 and an average flow rate of 150 L/ha.

Four evaluations of control percentage were performed in the useful area of the four plots, from controls (check and check + hand weeding) and treatments. The evaluations were spaced every 7 days, performing the last evaluation at 28 days after applying the treatments.

Sourgrass and goosegrass was evaluated in two stages: 1) initial development with up to 4 tillers and 2) advanced stage of development, highly profiled and / or flowering. A phytotoxicity score was given by the EWRC scale (1964), where one means no symptoms and nine total plant death for the coffee trees. Weed control was evaluated in each experimental plot using the visual score scale of Frans et al. (1986), where: 0% represents lack of control, and 100% total control of the species evaluated, comparing with the population present in the non-weeded control. In the check of each block a square of 1m^2 was launched in the area and the assessment of the population of sourgrass and goosegrass was made.

TABLE 1 - Treatments with respective dosages, used in the control of *Digitaria insulares* and *Eleusine indica* in coffee crop (*Coffea arabica*). Agricultural Year 2015.

Treatment	Active ingrediente	Formulation	Dose	
			g a.i/ha	(mL c.p./ha)
1. Untreated check	-	-	-	-
2. Handweeded check	-	-	-	-
3. IHH 0513	Quizalofop-P-ethyl	EC	25	500
4. IHH 0513	Quizalofop-P-ethyl	EC	50	1,000
5. IHH 0513	Quizalofop-P-ethyl	EC	75	1,500
6. IHH 0513	Quizalofop-P-ethyl	EC	100	2,000
7. GLI OVER +	Glyphosate +	SL	1680	3,500
IHAROL	Adjuvant		0.5% V/V	0.5% V/V

g a.i./ha = grams of active ingredient per hectare; mL c.p./ha = mililiters of commercial product per hectare; EC = emulsifiable concentrate; SL = soluble concentrate.

For data analysis, the SISVAR Statistical Software was used (FERREIRA, 2011). The F test was performed, and when in the occurrence of significance Tukey test at 5% significance was performed.

3 RESULTS AND DISCUSSION

Results revealed that weed density was affected significantly due to different weed control treatments.

For sourgrass at the development stage of up to four tillers, for all evaluations, there is a statistical difference between the treatments (P> 0.05). At 28 days after application (DAA) quizalofop-p-ethyl treatments at the dose of 1,500 and 2,000 mL c.p. ha^{-1} and the glyphosate standard dose were the most effective treatment, differing from the control and the other treatments. It is also verified that the Quizalofop-P-ethyl – 20,00 mL/ha, demonstrated a highly satisfactory performance in younger plants (greater than 95% control in assessments at 21 and 28DAA) (Table 2), confirming security for its recommendation in post emergence when this weed presents itself at a very early stage, even favoring a lower weed competition in coffee crop which is always observed in studies that defend the post emergence applications of herbicides in high precocity situations (ALCÂNTRA; SILVA, 2010).

These results corroborate those found by Takano et al. (2013), who concluded that the control is superior with an application in the early stages of weed development, being more effective along the sequence of 2 – 4 > 4 - 6 and > 10 leaves. In the case of sourgrass, efficient control at an advanced stage of development becomes more difficult, especially due to the formation of starch-rich rhizomes, which hinders the translocation of herbicides by the plant, as well as allows intense shoot regrowth, even after treated with the herbicide (MACHADO et al., 2006; MACHADO et al., 2008).

Melo et al. (2012), Barroso et al. (2010) and Cassol et al. (2019) found similar results, with control over 90% after glyphosate + clethodim application in sourgrass plants of 3 to 5 tillers. Thus, the active ingredient quizalofop-P-ethyl at the correct dose becomes an important tool controlling younger sourgrass plants as the control is similar or superior to applications involving more than one product as in case of the above studies.

Regarding the control of "Sourgrass" (*Digitaria insularis*), at advanced stage (Table 2), it was observed at 07 DAA that the standard glyphosate herbicide (Gli Over SL – 3,500 mL c.p./ha) differed statistically from the control and all the others treatments providing 72.5% efficacy compared to the weed check. At 21 DAA all treatments differed from the control and provided efficiencies of 70 to 100%, with emphasis on the dose of 2,000 mL c.p./ha of quizalofop-p-ethyl and the Gli Over SL standard. At 28 DAA, quizalofop-p-ethyl treatments at dose of 2,000 mL c.p. ha^{-1} and the Gli Over SL standard raised out, differing from the control and other treatments, yielding efficiencies from 95% to 100% and were statistically similar.

TABLE 2 - Sourgrass (*Digitaria insularis*) control with quizalofop-P-ethyl in 2015 crop season.

Treatment		Assessments			
	Dose*	7DAA	14DAA	21DAA	28DAA
		Up to 4 tillers			
1. Untreated check	-	0 d	0 e	0 d	0 c
2. Handweeded check	-	100 a	100 a	100 a	100 a
3. quizalofop-P-ethyl	500	11.3 c	32.5 d	80 c	83.8 b
4. quizalofop-P-ethyl	1,000	17.5 c	45 c	91.3 b	85 c
5. quizalofop-P-ethyl	1,500	30 b	61.3 b	91.3 b	86.3 bc
6. quizalofop-P-ethyl	2,000	35 b	62.5 b	96.3 ab	95 ab
7. glyphosate **	3,500	95 a	100 a	100 a	100 a
CV (%)	---	7.28	6.88	4.57	5.15
		Advanced stage of development (more than 4 tillers)			
1. Untreated check	-	0 d	0 d	0 d	0 c
2. Handweeded check	-	100 a	100 a	100 a	100 a
3. quizalofop-P-ethyl	500	0 d	27.5 c	70 c	65 b
4. quizalofop-P-ethyl	1,000	0 d	28.8 c	85 b	78.8 b
5. quizalofop-P-ethyl	1,500	0 d	47.5 b	73.8 c	73.8 b
6. quizalofop-P-ethyl	2,000	11.3 c	52.5 b	86.3 b	95 a
7. glyphosate **	3,500	72.5 b	95 a	100 a	100 a
CV (%)	---	8.23	14.52	6.53	8.29

Means followed by the same letter do not differ from each other by the Tukey test at 5% significance; *mL c.p. ha^{-1}: milliliters of commercial product per hectare; **plus mineral oil (Iharol) added at 0.5% v/v C.V. = coefficient of variation.

The sourgrass control at advanced stage of development using quizalofop-P-ethyl herbicide at the 21 DAA and 28 DAA evaluations were close to those observed by Gemelli et al. (2013) and Zobiole et al. (2016), in which the application of glyphosate + clethodim and glyphosate + haloxifop on sourgrass plants at full bloom stage provided control close to 80%.

Adegas et al. (2010b) demonstrated that applying clethodim, fluazifop-P-buthyl, fenoxaprop-pethyl, tepraloxydim, [clethodim + fenoxaprop-pethyl], paraquat, haloxyzafop-methyl and imazapyr in sourgrass plants at up to two tillers stage its possible to reach control efficiency greater than 90%. Correia, Accra and Balieiro (2015) found that at 48 DAA, quizalofop more glyphosate treatments were more effective in controlling all the amaranth populations than glyphosate alone.

In Correia, Accra and Balieiro (2015) study, *D. insularis* plants were cut before the first herbicide application, without sequential application, glyphosate + quizalofop treatments at 31 DAA and 55 DAA resulted in higher percentage of control.

According to Barroso et al. (2014), at more advanced stages of sourgrass, the use of mixtures increased the control achieved by the isolated use of glyphosate. The use of quizalofop was superior to the use of other graminicides in mixture, being better with the use of glyphosate ammonium salt or potassium salt. Interference in the electron transfer process is faster with glyphosate application than with an ACCase inhibitor. According to Gemelli et al. (2012), ACCase inhibitor herbicides effectively control sourgrass plants, producing the characteristic symptom of growth area necrosis due to blockade of lipid synthesis.

Regarding the plants that were evaluated at the stage of "Up to four tillers", all evaluations for the test product quizalofop-p-ethyl showed an efficiency level between 73.7 to 100% for treatment 5 (quizalofop-p-ethyl - 1500 mL/ha) and 6 (quizalofop-p-ethyl - 2000 mL/ha) consecutively

(Table 3), indicating a better performance of the test product in younger *E. indica* plants, reinforcing the statements of Alcântra and Silva (2010). Evaluation of plants at advanced stage of development shows that a high level of efficacy was obtained only for treatment 6 (QUIZALOFOP-P-ETHYL - 2000 mL/ha) in the third (21 DAA) and fourth (28 DAA) evaluations. It is noteworthy that even late was a good level of efficiency for the test product, despite the statistical difference with Treatment 7 (standard) - Gli Over SL – 3,500 mL/ha, especially if we consider weed resistance management.

Vidal et al. (2006) found efficient control of an *E. indica* biotype originating in the state of Mato Grosso with the application of the herbicides clethodim, quizalofop-P-ethyl, haloxyfop-methyl and fluazifop-P-butyl, but observed inefficient control when the fenoxaprop-P-ethyl and sethoxydim herbicides.

According to data obtained by Takano et al. (2018), the herbicides clethodim, haloxifop, quizalofop-tefuril, quizalofop-methyl and fluazifop provided 100% control at 14 DAA for *E. indica* with one tiller. At 28 DAA, the herbicides clethodim, haloxifop, quizalofop-tefuril, quizalofop-methyl and fluazifop applied solo or in combination with glyphosate, provided control above 96%.

Treatments with clethodim (108 g ha^{-1}), haloxifop (60 g ha^{-1}), quizalofop-tefuril (both doses), quizalofop-methyl (100 g ha^{-1}), glyphosate + haloxifop (960 + 120 g ha^{-1}), glyphosate + quizalofop-tefuril (960 + 120 g ha^{-1}) and glyphosate + fluazifop (both doses) provided control between 80% and 90% and were in the second level of efficacy. The other treatments were not effective in controlling four-tiller grass plants (TAKANO et al., 2018). Therefore, the results of the treatments found in this experiment corroborate the results mentioned above, since the treatments with quizalofop-P-ethyl obtained a control percentage between 80% and 90%.

TABLE 3 - Goosegrass (*Eleusine indica*) control with quizalofop-P-ethyl in 2015 crop season.

Treatment	Assessments				
	Dose*	7DAA	14DAA	21DAA	28DAA
Up to 4 tillers					
1. Untreated check	-	0.0 a	0.0 a	0.0 a	0.0 a
2. Handweeded check	-	100 d	100 c	100 d	100 d
3. quizalofop-P-ethyl	500	21.25 b	25.0 b	25.0 b	20.0 b
4. quizalofop-P-ethyl	1,000	27.50 b	32.50 b	42.5 c	40.0 c
5. quizalofop-P-ethyl	1,500	73.75 c	95.0 c	97.5 d	97.50 d
6. quizalofop-P-ethyl	2,000	87.50 d	100 c	100 d	100 d
7. glyphosate **	3,500	100 d	100 c	100 d	100 d
CV (%)	---	18.01	11.65	21.68	20.43
Advanced stage of development (more than 4 tillers)					
1. Untreated check	-	0.0 a	0.0 a	0.0 a	0.0 a
2. Handweeded check	-	100 d	100 d	100 d	100 c
3. quizalofop-P-ethyl	500	2.75 a	6.25 a	6.25 a	5.0 a
4. quizalofop-P-ethyl	1,000	6.25 a	10.0 a	15.0 a	13.75 a
5. quizalofop-P-ethyl	1,500	27.50 b	43.75 b	57.5 b	62.50 b
6. quizalofop-P-ethyl	2,000	50.0 c	62.50 c	80.0 c	87.50 c
7. glyphosate **	3,500	97.5 d	100 d	100 d	100 c
CV (%)	---	13.15	20.9	21.05	21.39

Means followed by the same letter do not differ from each other by the Tukey test at 5% significance; * mL p.c. ha^{-1}: milliliters of commercial product per hectare; **plus mineral oil (Iharol) added at 0.5% v/v; C.V. = coefficient of variation.

The hypothesis to the lower efficacy of herbicides in the advanced stage of *E. indica* is that the cuticle of individuals with more than three tillers presents higher wax accumulation, which may limit the herbicide absorption by the plant. These waxes act as a herbicide accumulation compartment and therefore partially prevent the entry of the active ingredient into the epidermal cells and, consequently, the phloem (CHAMEL; VITTON, 1996; MALPASSI, 2006). In this sense, for effective control of goosegrass in advanced stages, complementary or sequential applications may be necessary (WIECKO, 2000).

Regarding phytotoxicity, the herbicide GLI OVER + IHAROL caused slight symptoms of phytotoxicity, characterized by chlorosis in the lower part of the coffee tree, normalizing after 28 DAA. The herbicide quizalofop-p-ethyl did not cause any phytotoxicity symptoms that could be visually detected in coffee plants.

4 CONCLUSIONS

The herbicide quizalofop-p-ethyl does not cause phytotoxicity in coffee plants.

The herbicide quizalofop-p-ethyl is an option to control Sourgrass (*Digitaria insularis*) goosegrass (*Eleusine indica*) from 1,500 mL/ha for younger plants (up to 4 tillers) and at 2,000 mL/ha for more developed plants.

The above specified doses of quizalofop-p-ethyl herbicide for sourgrass and goosegrass at different stages of development should be recommended for integrated weed management in coffee and it´s selectively to coffee plants.

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