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CHEMICAL CONTROL OF ADULT SOURGRASS IN COFFEE CROPS, THROUGH VARIOUS ASSOCIATIONS

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ABSTRACT - Weed management in coffee plants is carried out largely through the adoption of chemical control, with the use of herbicides. In this context, one of the species that most affects the development of coffee plants, and due to its difficulty in control, is sourgrass. Above all, most sourgrass biotypes are not efficiently controlled with the herbicide glyphosate, which is the most used in coffee growing. Thus, the search for strategies that can minimize the damage caused by this weed, appears with increasing demand, due to the great damage to coffee plants. Therefore, the objective of this study was to evaluate the chemical control of adult sourgrass in coffee plants, through several associations. Treatment control efficiency was visually evaluated, where a scale ranging from 0 to 100 was used, with 0 corresponding to the absence of symptoms and 100 corresponding to the total control of weed plants by the action of herbicides, respectively. This evaluation method was used at 7, 14, 21, 28, 35 and 42 days after application. The mixture of the herbicides Fluazifop-p-butyl and Clethodim is more efficient in controlling sourgrass over time. The association of the herbicide ammonium glufosinate with systemic herbicides implies a reduction in the control capacity of sourgrass plants over time.
Keywords: chemical control, herbicides, management.

CONTROLE QUÍMICO DO CAPIM AMARGOSO ADULTO EM CAFEEIROS, POR MEIO DE DIVERSAS ASSOCIAÇÕES

RESUMO - O manejo de plantas daninhas em cafeeiros é realizado em grande parte por meio da adoção do controle químico, com a utilização de herbicidas. Nesse sentido, uma das espécies que mais afetam o desenvolvimento dos cafeeiros, e muito também devido à sua dificuldade de controle, é o capim amargoso. Sobretudo, grande parte dos biótipos de capim amargoso não são controlados eficientemente com o herbicida glyphosate, que é o mais utilizado na cafeicultura. Assim, a busca por estratégias que possam minimizar os danos causados por esta planta daninha, surge com demanda crescente, devido aos grandes prejuízos às plantas cafeeiras. Diante disso, objetivou-se avaliar o controle químico do capim amargoso adulto em cafeeiros, por meio de diversas associações. A avaliação da eficiência de controle dos tratamentos foi realizada por meio de uma análise visual, onde se utilizou uma escala variando de 0 a 100, onde 0 corresponde à ausência de sintomas e 100 corresponde ao controle total das plantas infestantes pela ação dos herbicidas, respectivamente. Este método de avaliação foi utilizado aos 7, 14, 21, 28, 35 e 42 dias após a aplicação. A associação dos herbicidas Fluazifop-p-butyl e Clethodim, implica em maior eficiência de controle do capim amargoso no decorrer do tempo. A associação do herbicida Glufosinato de amônio com herbicidas sistêmicos implica em redução da capacidade de controle de plantas de capim amargoso no decorrer do tempo.
Palavras-chave: controle químico, herbicidas, manejo.

INTRODUCTION

News about cases of weed resistance has been routinely linked to herbicides, and the consequent losses in food production. In this context, it is known that the food demand is increasing, due to the exponential growth of the world population (FOLEY et al., 2011). Thus, several studies report losses in yield as a function of the competition of weeds with the crop of interest, mainly due to natural resources such as water, light, nutrients and space, directly interfering in crop growth and yield. Above all, in crops such as maize, coffee, soy and cotton, losses are up to 83%, 77%, 80% and 94%, respectively (BLANCO et al., 1982).

In coffee crops, there has been a great infestation of the plants *Digitaria insularis* (Sourgrass), *Coniza* sp. ("buva") and *Eleusine indica* (crowfootgrass), and these are no longer efficiently controlled with the commonly used herbicide and glyphosate (MELO et al., 2012).

Alternatively, other control strategies are carried out, such as mechanical management, through mowing, or also the use of other herbicides, such as ACCase inhibitors (BARROSO et al., 2014, ZOBIOLE et al., 2016; CANEDO et al., 2019). This mechanism of action is characterized by being selective, with specific control to grasses, that is, Poaceae, and consequent inactivity to Eudicotyledons (RODRIGUES; ALMEIDA, 2019). However, it is observed

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that, even under conditions of satisfactory control, sourgrass plants are able to sprout and reestablish themselves in the cultivation environment (GILO et al., 2016). In the case of sprouting, it occurs mainly from rhizomes of developed plants (GAZOLA et al., 2016), which completed the first vegetative cycle, making the management of this weed extremely difficult (MACHADO et al., 2006; LÓPEZ OVEJERO et al., 2017).

Thus, the search for strategies that can minimize the damage caused by this weed, when present in coffee plantations, arises with increasing demand, since infestations are increasing, and with the timing of application, frequently with adult plants, that are more difficult to control. Therefore, the objective of this study was to evaluate the chemical control of adult sourgrass in coffee plants, through several associations.

MATERIAL AND METHODS

The experiment was conducted in the municipality of Muzambinho (Minas Gerais State), between February and March/2019. The average annual temperature is 21.4 °C, while the average annual rainfall is 1606 mm, showing *Cwb* climate (humid temperate climate with dry winter and moderately hot summer), according to the climatic classification (SÁ JÚNIOR, 2012). A commercial coffee crop was used, aged 17 years, under pruning management, with zero harvest system, using coffee plants of cultivar Catuaí Vermelho IAC 144, with a 3.8 m spacing between rows and a x 1.1 m spacing between plants.

The experimental design used was in randomized blocks, in a factorial scheme, with 3 replications, and $5m^2$ plots containing 5 coffee rows infested with sourgrass at the flowering stage; the first factor was the tested herbicides and the second factor was period evaluation (Tables 1 and 2).

In experiment setting, information about climatic conditions was obtained, such as: air temperature, wind speed and relative humidity. The applications were made using a hand-held backpack sprayer with a flow rate of 300 L ha^{-1}. Treatment control efficiency was visually evaluated, where a scale ranging from 0 to 100 was used, with 0 corresponding to the absence of symptoms and 100 corresponding to the total control of weed plants by the action of herbicides, respectively. This evaluation method was used at 7, 14, 21, 28, 35 and 42 days after application, using the scale proposed by Garcia et al. (1994). The data obtained were subjected to analysis of variance using the Sisvar statistical software (FERREIRA, 2011); the significant difference between treatments was determined by the F test.

TABLE 1 - Herbicides isolated or in mixture, used for the control of adult sourgrass plants.

Nº	Herbicides
1	Control - without herbicide
2	Ammonium glufosinate 2.0 L ha^{-1}
3	Glyphosate 4.0 L ha^{-1}
4	Ammonium glufosinate 2.0 L ha^{-1} + Glyphosate 4.0 L ha^{-1}
5	Clethodim 0.5 L ha^{-1}
6	Clethodim 0.5 L ha^{-1} + Glyphosate 4.0 L ha^{-1}
7	Fluazifop 1.0 L ha^{-1}
8	Fluazifop 1.0 L ha^{-1} + Glyphosate 4 L ha^{-1}
9	Ammonium glufosinate 2.0 L ha^{-1} + Clethodim 0.5 L ha^{-1}
10	Ammonium glufosinate 2.0 L ha^{-1} + Fluazifop 1.0 L ha^{-1}
11	Clethodim 0.5 L ha^{-1} + Fluazifop 1.0 L ha^{-1}
12	Ammonium glufosinate 2.0 L ha^{-1} + Clethodim 0.5 L ha^{-1} + Fluazifop 1.0 L ha^{-1}
13	Ammonium glufosinate 2.0 L ha^{-1} + Clethodim 0.5 L ha^{-1} + Fluazifop 1.0 L ha^{-1} + Glyphosate 4.0 L ha^{-1}

TABLE 2 - Evaluation periods of herbicides isolated or in mixture, used for the control of adult sourgrass plants.

Nº	Periods
1	7 days after herbicide application
2	14 days after herbicide application
3	21 days after herbicide application
4	28 days after herbicide application
5	35 days after herbicide application
6	42 days after herbicide application

RESULTS AND DISCUSSION

Significance was observed for both factors, and for the interaction between them, so that it was necessary to break down the levels of each factor (Tables 3 and 4). For the factor herbicide application periods, there were significant differences for all studied periods (Table 4). When evaluating the percentage of weed control through the application of herbicides in each study period, it was found that the behavior in the different periods was different (Table 5).

For the first evaluation period, that is, 7 days after herbicide application, the formation of 3 distinct groups was

observed, according to the grouping method proposed in the Scott-Knott test, for the control percentage characteristic of weeds. Thus, treatments 10 and 13 were superior, with greater control efficiency.

TABLE 3 - Analysis of variance for the control percentage of adult sourgrass plants, according to the use of herbicides alone or in mixture, and the period of their evaluation.

Source of variation (SV)	MS
Herbicides	11344.97*
Period	1175.83*
Herbicides x Period	868.91*
Block	1088.63*
Residue	95.55
Variation coeficient (%)	22.16

*Significant by the F test, at 5% probability of error. MS = medium square.

TABLE 4 - Analysis of variance with the breakdown of herbicides within each period.

Source of Variation (SV)	MS
Period 1	2871.37*
Period 2	2743.91*
Period 3	2393.8*
Period 4	2290.28*
Period 5	2694.95*
Period 6	2695.19*
Residue	95.55

*Significant by the F test, at 5% probability of error. MS = medium square.

TABLE 5 - Average control percentage of sourgrass plants using herbicides alone or in mixture, in each study period.

Treatments	Days after herbicide application					
	7	14	21	28	35	42
	Percentage of control (%)					
1	0.00c*	0.00c	0.00d	0.00d	0.00d	0.00d
3	5.00c	5.00c	5.00d	5.00d	5.00d	5.00d
11	6.67c	11.67c	53.33b	78.33a	86.67a	83.33a
5	8.33c	11.67c	15.00d	25.00c	26.67c	13.33d
8	10.00c	21.67b	43.33c	61.67b	68.33a	60.00b
6	15.00c	28.33b	40.00c	50.00b	56.67b	61.67b
7	16.67c	28.33b	36.67c	65.00b	70.00a	66.67b
2	53.33b	61.67a	53.33b	30.00c	21.00c	10.00d
4	60.00b	66.67a	60.00b	33.33c	31.67c	23.33c
9	65.00b	68.33a	58.33b	50.00b	51.67b	26.67c
12	66.67b	75.00a	78.33a	78.33a	76.67a	70.00b
10	75.00a	66.67a	81.67a	70.00a	71.67a	60.00b
13	80.00a	85.00a	90.00	81.67a	85.00a	75.00a

*Averages followed by the same letter in the column, belong to the same group, according to the Scott-Knott grouping criterion at 5% probability of error.

There was an alternation of the best treatments over time, as well as the percentage of weed control, possibly due to the sprouting capacity of sourgrass plants and also due to the mode of action of each herbicide and/or their association (MACHADO et al., 2006). In the last study period, at the end of the experiment, that is, 42 days after application (DAA), it was found that the best were 13 and 11, which are an association of the herbicide's ammonium glufosinate 2 L ha^{-1} + Clethodim 0.5 L ha^{-1} + Fluazifop 1 L ha^{-1} + Glyphosate 4 L ha^{-1} and Clethodim 0.5 L ha^{-1} + Fluazifop 1 L ha^{-1}, respectively.

In this context, it is emphasized that, in the case of sourgrass plants that are already adult, with a rhizome formed (CHRISTOFFOLETI et al., 1994), control becomes very difficult, since this weed has defense mechanisms that hinder the action of herbicides in their metabolism when controlled late (MONDO et al., 2010). Still, according to Lorenzi (2014), a satisfactory control in weed management is that above 80% and, according to this study, 42 days after the application of the herbicides; treatments 11 and 13 obtained this index. Thus, the results mentioned above are important, since several studies report great difficulty in controlling this weed, even at early development stages,

before the intense tillering characteristic of it (ANDRADE JUNIOR et al., 2018).

From a strategic point of view, it is known that producers frequently alternate chemical control with other control methods, such as mechanical control, using a brush or brush cutter, alternating them with chemical control, which sometimes leads to not expecting 100% control of any herbicide. In view of this fact, it can be understood that an herbicidal effect must reach its maximum satisfactory control in at least about 20 DAA in order to become viable to interpose some other type of control strategy (LORENZI, 2014).

Marochi et al. (2018) found greater efficiency in the control of plants with resistance to glyphosate, including sourgrass, with the integration of control techniques such as mulching, crop rotation and herbicide rotation. It is important to point out that the integrated management of these techniques is better than an isolated technique.

Therefore, when observing the herbicidal effects at 21 DAA, treatments 10, 12 and 13 obtained controls above 78% and were significantly equal to each other, showing that, for a faster but less lasting effect, Fluazifop mixed with ammonium glufosinate, with or without the presence of Clethodim, is efficient for the control of sourgrass. Allied to this, when using integrated techniques to manage weeds, the option for these treatments is interesting when the coffee grower can use mowing or brushing, additional to this management, after 21 days. Still, Raimondi et al. (2020) observed that mowing can replace the chemical control of sourgrass and/or anticipate a chemical control to increase its efficiency.

Carvalho et al. (2011), Melo et al. (2012), Reinert et al. (2013), Gomes et al. (2017) and Bauer et al. (2021) highlight the great ability of this weed for resistance the application of the herbicide glyphosate, which is the most used in weed control in coffee growing. According to Heap (2019), the first case of resistant sourgrass biotypes to the herbicide glyphosate was in 2008. However, shortly afterwards, the dissemination of these biotypes was wide, so that, currently, it is rare to obtain sourgrass biotypes susceptible to the herbicide glyphosate.

According to the results of the percentage of sourgrass control using these herbicides, the superiority of treatments 13 and 11 was verified, as mentioned above. However, when analyzing the economic aspect, it appears that treatment 13 is identical to treatment 11, but with the addition of the herbicides, glyphosate and ammonium glufosinate. Thus, in addition to the greater financial contribution when compared to treatment 11, the environmental issue is also highlighted, where it is possible to use a smaller number of molecules for an efficient control of this weed. Probably, the addition of these two herbicides did not increase the efficiency of sourgrass control, since this weed is resistant to the herbicide glyphosate, and due to the fact that the association of contact herbicides, such as ammonium glufosinate (RODRIGUES; ALMEIDA, 2018), with graminicides, tend to lose control efficiency (CARVALHO, 2013).

Finally, the question of the resistance of sourgrass to the herbicide glyphosate is reinforced since, in both periods of evaluation, that is, varying from 7 to 42 days after the application of the herbicides, the treatment with glyphosate alone did not obtain control percentage above 5% at any period. Therefore, the data in this study provide alternatives for a satisfactory control of sourgrass, even in the condition of adult plants of this poaceae, as in frequent cases occurring in the field, where the coffee grower loses the timing for controlling these weeds. For the breakdown of the herbicides, it was found that only a few of them had differences (Table 6). Through the study of the averages and unfolding of this factor, it was found that 7 treatments interacted with the evaluation period (Figure 1).

TABLE 6 - Summary of the analysis of variance with the unfolding of the evaluation periods within each herbicide isolated or in mixture.

Source of variation (SV)	MS
Treatment 1	0.00
Treatment 2	1300.22*
Treatment 3	0.00
Treatment 4	1019.17*
Treatment 5	166.67
Treatment 6	951.29*
Treatment 7	1568.89*
Treatment 8	1689.17*
Treatment 9	666.67*
Treatment 10	162.50
Treatment 11	3930*
Treatment 12	69.17
Treatment 13	78.89
Residue	95.55

*Significant by the F test, at 5% probability of error. MS = medium square.

For treatment 2 (Figure 1A), that is, with the use of the herbicide ammonium glufosinate, there was a decrease in the control percentage as time progressed, so that, at the end of the experiment, the control of sourgrass plants were close to 10%, well below the ideal, aiming at the non-occurrence of competition with coffee plants (LORENZI, 2014). Thus, these results are associated with the mode of action of this herbicide which, when in contact with the plants, do not have translocation (RODRIGUES; ALMEIDA, 2018) and, as sourgrass plants were already in the adult development stage, with more lignified tissues (GAMELLI et al., 2012), the herbicide impacted damage just after application and, as the days passed, it was able to sprout (GILO et al., 2016) and thus, at the end of the study, it already contained a large number of new tillers.

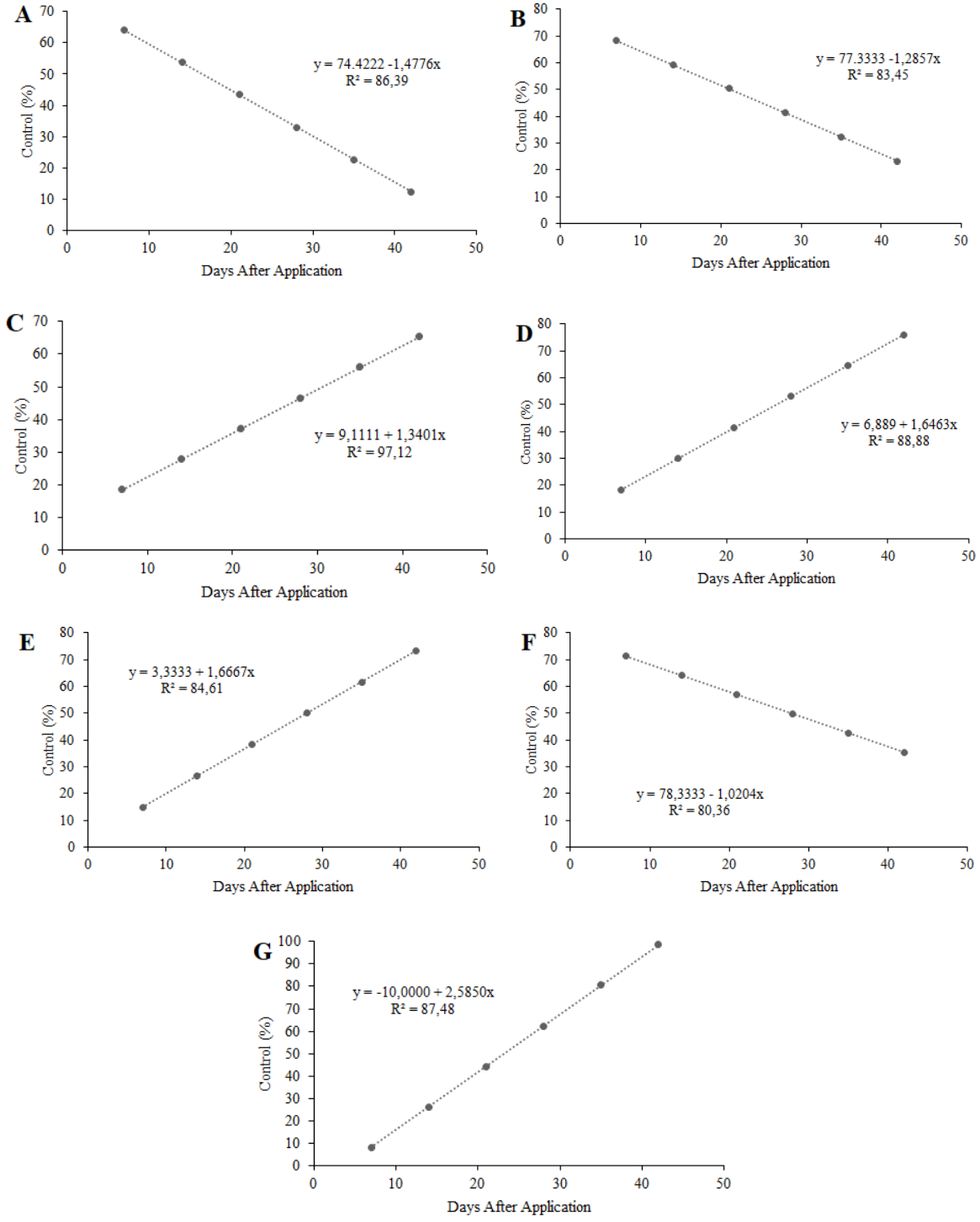

FIGURE 1 - Control percentage of adult sourgrass plants, according to the unfolding of the evaluation periods within the herbicides alone or in mixture: treatments 2 (A), 4 (B), 6 (C), 7 (D), 8 (E), 9 (F) and 11 (G).

Melo et al. (2012) observed a similar behavior of the same herbicide in sourgrass plants and, after 35 days of application, it had the worst control percentage, being statistically equal to the herbicide glyphosate, which does not have satisfactory efficiency in the control of *Digitaria insularis*, due to the occurrence of resistant biotypes of this species. The key point in the management of *D. insularis* is that, once established, the plant becomes very rustic due to the formation of numerous rhizomes and, with their set, the formation of large clumps. Once the perennialization process has occurred, this plant can bloom and spread seeds with low levels of dormancy throughout the year (GAMELLI et al., 2012). It should also be observed that the option for sequential applications can be used as more efficient control strategies for this weed (MENDES et al., 2020).

For treatment 4 (Figure 1B), that is, with the use of the herbicide ammonium glufosinate, associated with the herbicide Glyphosate, there was also a linear decrease in the percentage of control over time where, at 42 days, the control was not satisfactory, close to 30%. The association of contact herbicides with systemic herbicides tends to be negatively influenced due to the form of action of each, as previously mentioned. In this study, it is suggested that the decrease in the efficiency of weed control using this association is due to the partial loss of systemicity of the herbicide Glyphosate, as a function of the effect of the herbicide ammonium glufosinate, which implies immediate action in the plant cells, and reduces the possibility of movement of the herbicide (CARVALHO, 2013). However, Moreira et al. (2007) pointed to ammonium glufosinate as a management alternative in a mixture with glyphosate. It is noteworthy that this possibly occurred due to the use by these authors of sourgrass plants at the initial development stage, with few tillers emitted.

For treatment 6 (Figure 1C), that is, with the use of the herbicide Clethodim, associated with the herbicide Glyphosate, a linear increase in the percentage of weed control was observed for sourgrass. At the end of the experiment, it was found that the control percentage was close to 70% which, according to Lorenzi (2014), is not very satisfactory when it comes to chemical control of weeds through the use of herbicides. Melo et al. (2012) found an efficiency of 95% when using the same combination of herbicides at an early stage of development for sourgrass plants. However, in this study, efficiency may have been lower due to the stage of adult sourgrass plants which, due to perennialization, makes the action of herbicides difficult, as well as their consequent control.

For treatment 7 (Figure 1D), that is, with the use of the herbicide Fluazifop-p-butyl, there was an increasing linear effect for the control percentage of *Digitaria insularis* plants where, at 42 DAA, the control was approximately 80%. This herbicide is a graminicide, from the chemical group of aryloxyphenoxypropionates, with specific action to control this type of weed (LORENZI, 2014). Thus, the results found in this study are justified where, despite the fact that sourgrass plants are already adults, which makes the translocation of the herbicide difficult, the control through the use of Fluazifop-p-butyl was greater than 80% at the end of the experiment. In this context, some studies report the use of this herbicide and others with the same mechanism of action, in plants of the same species with up to two tillers, and observed control levels above 90% (BARROSO et al., 2014; CORREIA et al., 2015). However, according to Andrade Junior et al. (2018), when the plant grows and sprouts, this control drops to approximately 50%, which demonstrates the difficulty in controlling perennial plants.

For treatment 8 (Figure 1E), that is, with the use of the herbicide Fluazifop-p-butyl, associated with the herbicide Glyphosate, there was an increasing linear effect for the control percentage of *Digitaria insularis* plants where, at 42 DAA , the control was approximately 80%. That is, the same result when applied in isolation from the herbicide Fluazifop-p-butyl, which makes this association economically unfeasible for the control of adult sourgrass plants.

For treatment 9 (Figure 1F), that is, with the use of the herbicide Clethodim, associated with the herbicide ammonium glufosinate, there was a decreasing linear effect for the control percentage of *Digitaria insularis* plants where, at 42 DAA, the control was approximately 40%. Again, it is noteworthy that, when the combination of graminicides, which are systemic, occurs with contact products, such as Glufosinate, there is a great loss of efficiency for weed control (CARVALHO, 2013).

Finally, for treatment 11 (Figure 1G), that is, with the use of herbicide Fluazifop-p-butyl, associated with the herbicide Clethodim, there was an increasing linear effect for the control percentage of *Digitaria insularis* plants where, at 42 DAA, the control was greater than 95% according to the regression adjustment model, being very satisfactory for the control of this weed. It should be observed that, due to the particularity of this weed, which has a great capacity for sprouting after herbicide application, the association of these herbicides prevented weeds from sprouting, ensuring an efficient control over the evaluation period, at 42 DAA. In this context, both herbicides used are ACCase inhibitors, that is, they are specific herbicides for the control of grasses, such as sourgrass. Gamelli et al. (2012) report the possible removal of the panicle stem from sourgrass plants after application of the herbicide Clethodim, a fact that proves the translocation of the herbicide, even in adult plants, thus justifying its control efficiency.

Therefore, when analyzing all herbicides, alone or in mixture, during the evaluation period, treatment 11, with the association of herbicides Fluazifop-p-butyl and Clethodim, was the one that best controlled adult sourgrass plants. Finally, because this weed is very harmful to coffee plants and difficult to control, results such as those found here generate alternatives for coffee growers so that they do not have damage to the crop's productivity. Still, it emphasizes the need for future work seeking to understand new molecules in the control of this weed, and their interaction with the cultivation environment and the

conditions of climatic variations when applying the herbicides.

CONCLUSIONS

The mixture of the herbicides Fluazifop-p-butyl and Clethodim is more efficient in controlling sourgrass over time.

The association of the herbicide ammonium glufosinate with systemic herbicides implies a reduction in the control capacity of sourgrass plants over time.

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