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Article

Herbicide Mixtures to Control Dayflowers and Drift Effect on Coffee Cultures

Misturas de Herbicidas para o Controle da Trapoeraba e o Efeito da Deriva na Cultura do Café

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ABSTRACT - The dayflower species *Commelina benghalensis* and *C. diffusa* are among the main weeds in coffee crops. The purpose of this study was to evaluate the efficacy of herbicides/herbicide mixtures in controlling dayflower species and to evaluate the possible intoxication of coffee cultures, as well as the effect of mixture interactions. Two experiments were conducted, the first one in a 12 x 2 factorial arrangement with 12 herbicides/mixtures (glyphosate, glyphosate + metsulfuron-methyl, glyphosate + flumioxazin, glyphosate + 2.4-D, glyphosate + oxyfluorfen, glyphosate + carfentrazone-ethyl, metsulfuron-methyl, flumioxazin, 2.4-D, oxyfluorfen and carfentrazone-ethyl) and two dayflower species (*C. benghalensis* and *C. diffusa*) and the second one, in a 6 x 2 + 1 factorial arrangement, with six herbicides/mixtures (glyphosate, glyphosate + metsulfuron-methyl, glyphosate + flumioxazin, glyphosate + 2.4-D, glyphosate + oxyfluorfen and glyphosate + carfentrazone-ethyl) and two application forms on coffee plants (reaching 1/3 of the coffee canopy and with a protected canopy), plus a control treatment without herbicides. There was tolerance variation within the dayflower species to the tested herbicides. *Commelina benghalensis* was controlled by glyphosate, 2.4-D, glyphosate + 2.4-D and glyphosate + metsulfuron-methyl, while *C. diffusa* was controlled by 2.4-D and glyphosate mixtures by + metsulfuron-methyl, glyphosate + oxyfluorfen and glyphosate + flumioxazin. The mixture glyphosate + 2.4-D is effective in controlling dayflower, but it caused intoxication and growth reduction of the coffee. There was antagonism in the mixture glyphosate + carfentrazone-ethyl in controlling both species, as well as for glyphosate + oxyfluorfen and glyphosate + flumioxazin for *C. benghalensis*.

Keywords: antagonism, *Coffea arabica, Commelina benghalensis, Commelina diffusa*, synergism.

RESUMO - As espécies de trapoeraba ***Commelina benghalensis*** *e* ***C. diffusa*** *estão entre as principais plantas infestantes na cultura do café. Objetivou-se com este trabalho avaliar a eficácia de herbicidas/misturas de herbicidas no controle das espécies de trapoeraba e a possível intoxicação na cultura do café. Foram conduzidos dois experimentos, sendo o primeiro em esquema fatorial 12 x 2, com 12 herbicidas/misturas (glyphosate, glyphosate + metsulfuron-methyl, glyphosate + flumioxazin, glyphosate + 2,4-D, glyphosate + oxyfluorfen, glyphosate + carfentrazone-ethyl, metsulfuron-methyl, flumioxazin, 2,4-D, oxyfluorfen e carfentrazone-ethyl) e duas espécies de trapoeraba (*__C. benghalensis__ *e* __C. diffusa__*), e o segundo, em esquema fatorial 6 x 2 + 1, com seis herbicidas/misturas (glyphosate, glyphosate + metsulfuron-methyl, glyphosate + flumioxazin, glyphosate + 2,4-D, glyphosate + oxyfluorfen e glyphosate + carfentrazone-ethyl) e duas formas de aplicação nas plantas de café (atingindo 1/3 da copa do café e*

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com a copa protegida), mais uma testemunha sem herbicidas. Verificou-se variação na tolerância das espécies de trapoeraba para os herbicidas avaliados. ***C. benghalensis*** *foi controlada pelos tratamentos glyphosate, 2,4-D, glyphosate + 2,4-D e glyphosate + metsulfuron-methyl, enquanto* ***C. diffusa*** *foi controlada pelo 2,4-D e pelas misturas glyphosate + metsulfuron-methyl, glyphosate + oxyfluorfen e glyphosate + flumioxazin. A mistura glyphosate + 2,4-D, embora eficiente no controle das trapoerabas, causou intoxicação e paralisação no crescimento do café. Houve antagonismo na mistura glyphosate + carfentrazone-ethyl para o controle das duas espécies, bem como nas misturas glyphosate + oxyfluorfen e glyphosate + flumioxazin, para* ***C. benghalensis****.*

Palavras-chave: antagonismo, *Coffea arabica*, *Commelina benghalensis*, *Commelina diffusa*, sinergismo.

INTRODUCTION

Several factors influence the quantitative and qualitative aspects of coffee production, among which it is worth mentioning weed interference, which competes with the crop for water, light and nutrients, as well as hosting pests and diseases and hindering cultural treatment and harvesting operations.

The interference of weeds on coffee plants may be more damaging in the first two years after transplanting the seedlings into fields, due to the slow initial growth of the crop compared to the weed community (Fialho et al., 2010), making interventions necessary. To do so, control performing is necessary, and it is usually carried out through cutting and chemical control between the rows and through herbicides applied by directed spraying or manual weeding in the planting line (Melloni et al., 2012). However, the unavailability of enough workforce, together with low yield and high operating costs, has meant that manual weeding is only used as a complementary method to chemical control.

In chemical control, which is carried out after the establishment of coffee seedlings in the field, glyphosate is the most used herbicide (Green, 2007; França et al., 2010). However, the repeated use of this herbicide has resulted in the selection of tolerant weeds - in particular, the dayflower species *Commelina benghalensis* and *Commelina diffusa* (Santos et al., 2001).

Considering the difficulties in controlling *C. benghalensis* and *C. diffusa* in coffee plantations, it is common to mix other herbicides with glyphosate in the spraying tank for post-emergence applications (Silva et al., 2014). Moreover, the use of herbicide mixtures with different action mechanisms reduces the selection pressure of resistant weed biotypes (Maciel et al., 2011). Nonetheless, when tank-mixing herbicides, synergistic, antagonistic or additive effects may occur and the quantitative calculation of the toxicity of mixtures can be useful in order to determine the advantages and disadvantages of using them (Gazziero, 2015).

The targeted application of non-selective herbicides on young coffee plantations may result in a drift-induced intoxication for plants (França et al., 2010). Few studies report the toxicity level for coffee, as well as the efficacy of herbicide mixtures in weed control.

Based on the above considerations, this study had the purpose to evaluate the efficacy of glyphosate (applied individually), and of the mixtures glyphosate + metsulfuron-methyl, glyphosate + flumioxazin, glyphosate + 2.4-D, glyphosate + oxyfluorfen and glyphosate + carfentrazone-ethyl in controlling *C. diffusa* and *C. benghalensis*, as well as their effect on the intoxication and growth of coffee plants.

MATERIAL AND METHODS

Two experiments were conducted with plants cultivated in field pots in the municipality of Viçosa - Minas Gerais state, between January and August 2015, using three parts of Red-Yellow Latosol with clayey texture, one part of bovine manure, one part of sand and 5 kg m^{-3} of simple superphosphate as substrate.

Experiment I - Efficacy of herbicide mixtures in controlling dayflower species

The experiment was conducted using a randomized complete block design in a 12 x 2 factorial arrangement, with 12 herbicides/mixtures (Table 1) and two dayflower species (*C. benghalensis* and' *C. diffusa*), with three replications. Each experimental unit consisted of a pots with a 3.0 liter capacity, filled with the aforementioned substrate.

Three dayflower seedlings, obtained in the field through vegetative propagation and with a pair of leaves, were transplanted in each planter. Pots were irrigated daily, in order to maintain soil moisture around 70% of the field capacity. At 30 and 70 days after transplanting (DAT), top dressing was performed with 3.0 g pot^{-1} of N-P-K fertilizer (20-05-20).

At 60 DAT, plants were pruned and standardized at 10 cm in height, and 30 days after pruning, when stems reached approximately 25 cm in length, herbicides were sprayed using a backpack sprayer, at a constant pressure of 300 kPa maintained by CO_2, equipped with a TT 11002 two-tip bar, spaced 50 cm apart, at 50 cm from the target, calibrated to apply a spray volume of 150 L ha^{-1}. The environmental conditions at the time of application were: 80% relative humidity, 25 °C approximately, and cloudy weather.

Table 1 - Description of the treatments evaluated as for the control of the two dayflower species

Treatment	Dose
1. Control treatment	-
2. Glyphosate	720 g ha^{-1}
3. Glyphosate + metsulfuron-methyl	720 g ha^{-1} + 6 g ha^{-1}
4. Glyphosate + flumioxazin	720 g ha^{-1} + 45 g ha^{-1}
5. Glyphosate + 2.4-D	720 g ha^{-1} + 536 g ha^{-1}
6. Glyphosate + oxifluorfen	720 g ha^{-1} + 720 g ha^{-1}
7. Glyphosate + carfentrazone-ethyl	720 g ha^{-1} + 40 g ha^{-1}
8. Metsulfuron-methyl	6 g ha^{-1}
9. Flumioxazin	45 g ha^{-1}
10. 2.4-D	536 g ha^{-1}
11. Oxyfluorfen	720 g ha^{-1}
12. Carfentrazone-ethyl	40 g ha^{-1}

At 7, 14, 28 and 60 days after application (DAA), control efficacy visual evaluations were performed, assigning grades from 0 to 100, where 0 represents the absence of intoxication and 100 the plant death. Interactions between herbicides were determined from data obtained at 28 and 60 DAA, through equation 1 proposed by Colby (1967), where *E* represents the expected value with the association of herbicides, *X1* is the isolated effect of glyphosate and *X2* is the isolated effect of the herbicide used in a mixture with glyphosate. The means of the observed and estimated values were compared by t test at 5% probability.

$$E = X1 + \frac{X2(100 - X1)}{100} \qquad \text{(eq. 1)}$$

At 60 DAA, plants that survived the treatments were fragmented in stem, leaves and roots and were washed to eliminate soil. Leaves went through a Licor Equipamentos area meter, model LI-3100, to determine the leaf area. Afterwards, leaves, stems and roots were placed in paper bags and brought to a forced air circulation oven at 65 °C until constant weight, in order to determine the dry matter of stem, root and leaf.

The obtained data were submitted to analysis of variance by F test and, in case of significance, the means were compared by Tukey's test, at 5% probability. Data about leaf area, and dry matter of root, stem and leaf were transformed into $(x+1)^{0.5}$.

Experiment II – Coffee intoxication and growth under simulated herbicide drift

The experiment was conducted in a randomized complete block design, in a 6x2+1 factorial arrangement, with six herbicides/mixtures (Table 2), two application forms (with and without protecting coffee plants) plus one control treatment with no herbicide application, with four replications. Each experimental unit was consisted in a planter containing 10 liters of substrate, with a coffee plant (Yellow Catuaí).

Coffee seedlings whose height was approximately 15 cm were transplanted to pots and irrigated daily, so as to maintain their moisture at around 70% of the field capacity. At 60 and 100 days

Table 2 - Description of the applied herbicides and their respective doses

Treatment	Dose
2. Glyphosate	720 g ha^{-1}
3. Glyphosate + metsulfuron-methyl	720 g ha^{-1} + 6 g ha^{-1}
4. Glyphosate + flumioxazin	720 g ha^{-1} + 45 g ha^{-1}
5. Glyphosate + 2.4-D	720 g ha^{-1} + 536 g ha^{-1}
6. Glyphosate + oxyfluorfen	720 g ha^{-1} + 720 g ha^{-1}
7. Glyphosate + carfentrazone-ethyl	720 g ha^{-1} + 40 g ha^{-1}

after transplanting (DAT), the N-P-K (20-05-20) fertilizerwas applied in the proportion of 0.5 g L^{-1} of soil, and at 110 DAT, monopotassium phosphate was applied in the proportion of 0.25 g L^{-1} of soil (2.5 g per planter).

At 120 days after transplanting, when plants were approximately 35 cm tall, herbicides were applied. In unprotected treatments, herbicides reached the lower third of coffee plants and, in protected treatments, coffee plants were surrounded by polyethylene bags, so that the mixture reached only the soil, without touching with the leaves. Herbicide application was performed using a backpack sprayer, at the constant pressure of 300 kPa maintained by CO_2, with two TT 11002 tips spaced 50 cm apart, and spraying volume of 150 L ha^{-1}.

The characteristics evaluated in coffee cultures were: plants intoxication at 14, 28 and 49 days after application (DAA), through visual evaluations, with grades varying from 0 to 100, where 0 represents the absence of intoxication and 100 the death of plants.

On the day of herbicide application and at 90 DAA, the height of coffee plants was measured and, from the difference between the evaluations, their growth in height was determined. Also at 90 DAA, coffee plants had their parts separated into stem, leaves and roots, the latter being washed in order to eliminate soil. Leaves went through the Licor Equipamentos area meter, model LI-3100, to determine the leaf area. Afterwards, leaves, stems and roots were placed in paper bags and brought to a forced air circulation oven at 65 °C, until constant weight, in order to determine the dry matter weight of stem, root and leaf.

The obtained data were submitted to analysis of variance; in case of significance, the means were compared by Tukey's test at 5% probability. The means of treatments with herbicide application, with and without protection, were compared with the additional control treatment by t test at 5% probability.

RESULTS AND DISCUSSION

Efficacy of herbicide mixtures in controlling dayflower species

In the experiment involving the evaluation of dayflower control (experiment I), there was a significant interaction between the control of *C. benghalensis* and *C. diffusa* and the evaluated herbicides/mixtures, demonstrating that they have different behaviors as for their sensitivity to herbicides (Table 3).

As for *C. benghalensis*, the best control levels, 7 and 14 days after application (DAA), were verified with the use of carfentrazone-ethyl herbicide, individually or mixed with glyphosate. At 28 DAA, the glyphosate + flumioxazin mixture satisfactorily controlled this species, and so did isolated carfentrazone-ethyl and its mixture with glyphosate (Table 3). However, at 60 DAA, control levels when using carfentrazone-ethyl individually or in combination with glyphosate were very low, with the best results being verified for glyphosate and 2.4-D applied individually, and for glyphosate + metsulfuron-methyl and glyphosate + 2.4-D mixtures.

As for *C. diffusa*, the glyphosate + carfentrazone-ethyl, glyphosate + oxyfluorfen and glyphosate + flumioxazin mixtures provided excellent control at 14 DAA; however, as verified for *C. beghalensis*, the mixture with carfentrazone-ethyl allowed regrowth, reducing the control level from 28 DAA (Table 3). At 60 DAA, better control rates for *C. diffusa* were observed when applying 2.4-D individually or with the mixtures glyphosate + metsulfuron-methyl, glyphosate + oxyfluorfen, glyphosate + flumioxazin and glyphosate + 2.4-D.

The initial efficacy of carfetrazone-ethyl applied individually or in combination with glyphosate and the subsequent reduction in the control level for dayflower species is probably due to the fact that this herbicide translocates in a reduced form into the plant (Rodrigues and Almeida, 2011)

Table 3 - Control of *C. benghalensis* and *C. diffusa* plants on day 7, 14, 28 and 60 after the application (DAA) of herbicides

Treatment	7 DAA		14 DAA		28 DAA		60 DAA	
	COMBE	COMDI	COMBE	COMDI	COMBE	COMDI	COMBE	COMDI
Control treatment	0.00 Ah	0.00 Ag	0.00 Ag	0.00 Ag	0.00 Ag	0.00 Ag	0.00 Ab	0.00 Ac
Glyphosate	10.00 Bg	28.33 Ae	16.66 Bf	28.33 Af	65.00 Acd	16.66 Bf	95.00 Aa	81.00 Ba
Glyphosate + metsulfuron-methyl	13.33 Bfg	71.66 Ab	18.33 Bef	68.33 Ad	81.66 Bb	93.33 Aa	93.33 Aa	95.00 Aa
Glyphosate + flumioxazin	33.33 Bd	86.66 Aa	85.00 Bb	93.33 Aa	85.00 Bab	95.00 Aa	71.66 Bb	93.33 Aa
Glyphosate + 2.4-D	21.66 Be	48.33 Ac	40.00 Ad	36.66 Aef	76.66 Abc	53.33 Bd	93.36 Aa	98.00 Aa
Glyphosate + oxyfluorfen	46.66 Bc	73.33 Ab	61.66 Bc	93.33 Aa	80.34 Bb	93.33 Aa	71.66 Bb	95.33 Aa
Glyphosate + carfentrazone-ethyl	91.66 Aa	86.66 Ba	93.33 Ac	91.66 Aab	95.00 Aa	93.33 Aa	11.83 Ac	26.66 Ab
Metsulfuron-methyl	21.66 Ae	16.66 Bf	26.66 Ae	6.66 Bg	30.00 Ae	0.00 Bg	70.00 Ab	10.00 Bbc
Flumioxazin	30.00 Bd	70.00 Ab	63.33 Bb	83.33 Abc	26.66 Bef	66.66 Ac	16.66 Ac	26.66 Ab
2.4-D	18.33 Bef	38.33 Ad	40.00 Ad	40.00 Ae	60.00 Bd	80.00 Ab	95.00 Aa	98.00 Aa
Oxifluorfen	73.33 Ab	66.66 Bb	85.00 Ab	70.00 Bd	15.00 Bf	23.33 Aef	4.66 Bc	30.00 Ab
Carfentrazone-ethyl	93.33 Aa	85.00 Ba	95.00 Aa	76.66 Bcb	86.66 Aab	30.00 Be	5.00 Bc	16.66 Abc
VC	6.07		5.50		8.24		13.85	

In the columns, means followed by the same lowercase letters do not differ from each other by Tukey's test at 5% probability, and on the lines, for each evaluation period, means followed by the same capital letters do not differ by the Tukey's test at 5% of probability.

and acting superficially, without completely reaching the reserve tissues, thus allowing regrowth from 28 DAA.

From day 28 DAA, a significant intoxication increase was observed for treatments with glyphosate alone, 2.4-D alone and for the mixtures glyphosate + 2.4-D and glyphosate + metsulfuron-methyl. This is due to the slow effect of these herbicides on plants (Silva et al., 2007), especially when used at low doses.

When comparing the efficacy of herbicides/mixtures in controlling each dayflower species, at 60 DAA, there is a greater tolerance from *C. diffusa* to glyphosate applied individually. Santos et al. (2001) found that *C. diffusa* is less sensitive to glyphosate than *C. benghalensis*. According to these authors, a greater tolerance from *C. diffusa* to glyphosate is due to a higher starch concentration in the stem, which slows down the symplastic translocation of herbicides to growth points, allowing regrowth even after the total loss of leaves.

Despite the greater tolerance to glyphosate, *C. diffusa* was more sensitive than *C. benghalensis* to the mixtures glyphosate + flumioxazin and glyphosate + oxyfluorfen, with control indexes above 90%, indicating the possibility of other controlling mixtures in addition to glyphosate + 2.4-D, which is widely used by producers.

The interactions of the herbicide mixtures are shown in Table 4, where at 28 DAA it is possible to observe synergism in treatments with glyphosate + flumioxazin and glyphosate + oxyfluorfen, additive effect for glyphosate + metsulfuron-methyl and glyphosate + carfentrazone-ethyl blends and antagonistic effect for the mixture glyphosate + 2.4-D for *C. benghalensis*, whereas for *C. diffusa* there was additive effect for all the mixtures, except for glyphosate + 2.4-D.

At 60 DAA, antagonism was observed for treatments involving mixtures of glyphosate with the herbicides oxyfluorfen, flumioxazin and carfentrazone-ethyl, which are PROTOX inhibitors, with a reduction in the control level in relation to the previous evaluations; this is due to the rapid action of PROTOX-inhibiting herbicides, which act causing lesions on the leaves, when applied in post-emergence, a few hours after application (Silva et al., 2007). This, in turn, reduces the absorption and translocation of glyphosate to reserve tissues, namely stem and roots, since the absorption of glyphosate in the used formulation (isopropylamine salt) takes six hours and, moreover, translocation to the other organs of the plant is slow.

Thompson and Nissen (2000), while evaluating the absorption and translocation of ^{14}C-carfentrazone-ethyl in *Abutilon theophrasti* plants, observed the rapid absorption of the herbicide, with symptom onset on treated leaves two hours after the application, and total necrosis 24 hours after it. On the other hand, Carvalho et al. (2012), while evaluating the absorption and translocation of glyphosate in glyphosate-resistant and -susceptible *Digitaria insularis*, found that, 12 hours after the application, most of the herbicide was in the leaves and there was practically no

Table 4 - Interactions of herbicides mixed with glyphosate on the intoxication of *C. benghalensis* and *C. diffusa* plants, 28 and 60 days after application (DAA)

Herbicide	28 DAA		60 DAA	
	Observed	Expected	Observed	Expected
	C. benghalensis			
Glyphosate + metsulfuron-methyl	81.7 [ns]	75.5	93.3 [ns]	98.5
Glyphosate + flumioxazin	85.0 [+]	74.3	71.6 [-]	95.8
Glyphosate + 2.4-D	76.7 [-]	86.0	93.3 [ns]	99.7
Glyphosate + oxyfluorfen	80.3 [+]	70.2	71.7-	95.1
Glyphosate + carfentrazone-ethyl	95.0 [ns]	95.3	11.8-	95.2
	C. diffusa			
Glyphosate + metsulfuron-methyl	93.3 [+]	16.6	95.0 [ns]	83.7
Glyphosate + flumioxazin	95.0 [+]	72.0	93.3 [ns]	86.6
Glyphosate + 2.4-D	53.3 [-]	83.0	98.0 [ns]	99.6
Glyphosate + oxifluorfen	93.3 [+]	36.3	95.3 [ns]	89.8
Glyphosate + carfentrazone-ethyl	93.3 [+]	41.0	26.6 [-]	83.9

[(-)] antagonistic effect, [(+)] synergic effect and [ns] additive effect, by t test at 5% probability.

accumulation in the other organs of the plants. This may have resulted in the marked antagonistic effect of glyphosate + carfentrazone-ethyl for the two dayflower species in this work (Table 4).

Also at 60 DAA, there was an additive effect of glyphosate + 2.4-D and glyphosate + metsulfuron-methyl for *C. benghalensis*, whereas for *C. diffusa* it was observed in all mixtures except for glyphosate + carfentrazone-ethyl.

Due to the better control level (Table 3), *C. benghalensis* plants submitted to the application of glyphosate and 2.4-Dand the mixtures glyphosate + metsulfuron-methyl and glyphosate + 2.4-D accumulated less leaf, stems and root dry matter at 60 DAA (Table 5). Similar responses were observed for *C. diffusa* when the same herbicides were applied and, in addition, when the mixtures of glyphosate + oxyfluorfen and glyphosate + flumioxazin were applied.

Carfentrazone-ethyl alone and in combination with glyphosate, despite an efficient initial control (Table 3), allowed regrowth of the dayflower species, resulting in the same dry matter accumulation as that of the control treatment without herbicides.

Table 5 - Leaf area, dry matter weight of leaves (LDM), stem (SDM) and root (RDM) of *C. benghalensis* and *C. diffusa*, 60 days after the application of herbicides (DAA)

Treatment	Leaf area (cm^2 per planter)		RDM (g per planter)		SDMC (g per planter)		LDM g per planter	
	COMBE	COMDI	COMBE	COMDI	COMBE	COMDI	COMBE	COMDI
Control treatment	734.99 Aa	132.16 Bab	1.68 Ba	7.45 Aab	15.82 aA	10.80 abB	4.44 Aa	1.89 Bab
Glyphosate	0.00 Ae	18.16 Aa	0.82 Ae	0.70 Ac	15.82 Aa	10.80 Ba	0.00 Ae	0.29 Ac
Glyphosate +mMetsulfuron-methyl	0.00 Ae	3.04 Ac	0.22 Ae	0.43 Ac	3.12 eA	0.67 cA	0.00 Ae	0.06 Ac
Glyphosate + flumioxazin	256.17 Acd	10.59 Bc	1.10 Acd	0.38 Bc	11.14 Aab	3.74 Bb	1.14 Acd	0.13 Bc
Glyphosate + 2.4-D	0.00 Ae	0.99 Ac	0.95 Ae	0.32 Ac	3.12 Acde	0.67 Ab	0.00 Ae	0.01 Ac
Glyphosate + oxifluorfen	348.19 Abcd	10.84 Bc	1.38 Abcd	0.32 Bc	7.61 Abcd	0.35 Bb	1.85 Abcd	0.11 Bc
Glyphosate + carfentrazone-ethyl	477.17 Aabc	34.97 Bbc	0.92 Aabc	1.78 Bbc	0.76 Ae	0.33 Ab	2.30 Aab	0.44 Bbc
Metsulfuron-methyl	178.84 Ad	166.96 Aab	0.44 Ad	2.80 Aab	8.31 Abc	0.19 Bb	1.32 Ad	1.72 Aab
Flumioxazin	678.97 Aa	195.81 Ba	2.29 Aa	3.47 Ba	2.51 Ade	0.83 Ab	4.20 Aa	1.91 Ba
2.4-D	2.03 Ae	4.30 Ac	1.32 Ae	1.49 Ac	10.34 Aab	10.42 Aa	0.01 Ac	0.07 Ac
Oxifluorfen	763.45 Aa	146.13 Bab	2.82 Aa	2.45 Bab	11.48 Aab	3.53 Bb	4.14 Aa	1.89 Bab
Carfentrazone-ethyl	534.99 Aab	134.20 Bab	2.93 Aab	1.48 Bab	2.88 Acde	0.08 Ab	2.10 Aab	1.54 Bab

In the columns, means followed by the same lowercase letters do not differ from each other by Tukey's test at 5% probability, and on the lines, for each evaluation period, means followed by the same capital letters do not differ by the Tukey's test at 5% of probability.

When comparing growth rates of dayflower species without the application of herbicides, higher relative values in terms of leaf area and leaf dry matter for *C. benghalensis* are observed, whereas *C. diffusa* has a higher amount of dry matter accumulated in the stem and roots (Table 5), which are reserve organs of the plant and may influence the regrowth potential and/or hinder the translocation of herbicides. These results support the ones by Santos et al. (2001), who found greater difficulty in controlling *C. diffusa* in relation to *C. benghalensis*.

Coffee intoxication and growth under simulated herbicide drift

In experiment II, where the herbicide effects on the coffee crop were evaluated, there was an interaction between the applied herbicidal and protection factors of plants for intoxication at 14 and 28 DAA. There was a positive plant protection effect only for the mixture glyphosate + 2.4-D herbicide (Table 6).

Table 6 - Intoxication of protected and unprotected coffee plants, 14 and 28 days after application (AAD)

Herbicide	14 DAA		28 DAA	
	Protected	Unprotected	Protected	Unprotected
Glyphosate	2.50 aA	0.00 bA	7.50 aA	3.75 bA
Glyphosate + metsulfuron-methyl	5.00 aA	13.75 abA	5.00 aA	2.50 bA
Glyphosate + flumioxazin	8.75 aA	17.50 abA	6.25 aA	2.50 bA
Glyphosate + 2.4-D	7.50 aB	25.00 aA	10.00 aB	46.25 aA
Glyphosate + oxyfluorfen	7.50 aA	12.50 abA	3.75 aA	12.50 bA
Glyphosate + carfentrazone-ethyl	5.00 aA	12.50 abA	0.00 aA	7.50 bA
VC %	89.7		76.35	

In the columns, means followed by the same lowercase letters do not differ from each other by Tukey's test at 5% probability, and on the lines, for each evaluation period, means followed by the same capital letters do not differ by the Tukey's test at 5% of probability.

When comparing herbicides within each application system, there is no difference between herbicides/mixtures as for protected applications, in the evaluations performed at 14 and 28 DAA. However, when applications were unprotected, at 14 DAA, there were lower intoxication levels for glyphosate applied individually, followed by moderate intoxication levels (10-20%) for the herbicides metsulfuron-methyl, flumioxazin, oxyfluorfen and carfentrazone-ethyl in tank-mix with glyphosate, with plant recovery at 28 DAA. For the mixture glyphosate + 2.4-D applied without protection, intoxication symptoms were more severe, reaching 46% at 28 DAA.

The highest coffee sensitivity to 2.4-D and glyphosate in the first cultivation year is reported by Ronchi and Silva (2003). According to these authors, when these herbicides could reach only the lower leaves of the crop, there was a high injury rate on coffee plants (90%). However, the use of mixtures allowed the application of lower doses of each herbicide, reducing the intoxication level and allowing the recovery of plants; this explains the lower injury level in this study, where low doses were used because of the mixture.

At 49 DAA (Table 7), there was no difference among the applied herbicides, regardless of the protection, indicating plant recovery after that period, even when the mixture glyphosate + 2.4-D was applied.

Even without showing any intoxication symptom at 49 DAA (Table 7), plants submitted to the application of glyphosate + 2.4-Dshowed lower growth, with lower rates of leaf area, and dry matter of leaves, stem and roots, in relation to the other treatments and to the control treatment without herbicide application (Table 8). As for the other herbicides, no difference was observed in the respective variables, in relation to the control treatment without herbicides.

Considering the aforementioned, even though it was possible to observe a satisfactory control of the two dayflower species (Table 3) with the application of glyphosate + 2.4-D, it is not recommended to apply this mixture on crops with young coffee plants, due to the intoxication risk for plants and consequent damage to the crop growth. On the other hand, although mixtures

Table 7 - Intoxication of coffee plants at 49 DAA

Herbicide	49 DAA^{ns}
Glyphosate	1.87
Glyphosate +metsulfuron-methyl	0.62
Glyphosate + flumioxazin	8.75
Glyphosate + 2.4-D	10.62
Glyphosate + oxyfluorfen	7.57
Glyphosate + carfentrazone-ethyl	3.12
Protection	
Protected	4.37
Unprotected	6.45
VC %	148

^{ns} Not significant by F test at 5% probability.

with the herbicides flumioxazin, oxyfluorfen and carfentrazone-ethyl did not reduce coffee growth, they were not efficient in controlling dayflower species.

The glyphosate + metsulfuron-methyl mixture was the treatment that resulted in a better control efficiency for the two dayflower species and in a lower effect on coffee growth, whereas for areas infested by *C. diffusa*, mixtures of the herbicides oxyfluorfen or flumioxazin were also efficient; glyphosate, applied individually, is more efficient in controlling *C. benghalensis*.

Table 8 - Leaf area, dry matter weight of leaves (LDM), stem (SDM) and root (RDM), 90 days after herbicide application and plant growth in height during the experimental period

Herbicide	Leaf Area (cm² per plant)	LDM (g per plant)	SDM (g per plant)	RDM (g per plant)	Plant growth (cm)
Glyphosate	1979.87 a	21.87 ab	13.50 ab	9.50 ^{ns}	5.12*^{ns}
Glyphosate + metsulfuron-methyl	2360.50 a	27.50 a	16.87 a	10.62	6.87
Glyphosate + flumioxazin	2060.62 a	24.21 a	15.87* a	10.37	7.62
Glyphosate + 2.4-D	1355.62* b	14.25* b	10.25* b	7.37*	4.62
Glyphosate + oxyfluorfen	1920.25 ab	22.37 ab	13.12 ab	9.87	8.00
Glyphosate + carfentrazone-ethyl	2207.25 a	26.00 a	15.5 a	10.37	6.50
Protection					
Protected	1981.66 a	2.37 a	13.12 b	8.70 b	6.66 ^{ns}
Unprotected	1979.70 a	23.33 a	15.08 a	10.66 a	6.25
VC %	19.61	22	21.48	27.02	39.4
Control treatment without herbicide	2056.84	22.57	13.30	8.85	6.62

In the columns, averages followed by the same lowercase letters do not differ from each other by Tukey's test at 5% probability. * differ from the control treatment without herbicide by t test at 5% probability.

It is possible to conclude that there is variation in the tolerance of dayflower species to the evaluated herbicides. *C. benghalensis* was controlled by the treatments with glyphosate, 2.4-D, glyphosate + 2.4-D and glyphosate + metsulfuron-methyl, while *C. diffusa* was controlled by 2.4-D and glyphosate + metsulfuron-methyl, glyphosate + oxyfluorfen and glyphosate + flumioxazin. The mixture glyphosate + 2.4-D was efficient in controlling dayflowers, but it caused intoxication and reduced coffee growth. There was antagonism in the mixture glyphosate + carfentrazone-ethyl in controlling both species, and in the mixtures glyphosate + oxyfluorfen and glyphosate + flumioxazin for *C. benghalensis*.

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