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Efficacy of tank mixtures of post-emergence herbicides in common bean

Júlia Carvalho Costa[1]

Silvino Guimarães Moreira[2]

Antonio Henrique Fonseca de Carvalho[3]

Guilherme Vieira Pimentel[4]

Diego Rafael Quispe Torres[5]

Junior Cézar Resende Silva[6]

Abstract

In common bean, the occurrence of weeds can cause significant reductions in the final grain yield. This study aimed to evaluate the efficiency of different herbicide trials, applied individually or in a mixture, in the management of common bean weeds. A randomized complete block was used, arranged in subdivided plots. The main plots consisted of three types of beans (Carioca Pérola cultivar, Black cultivar IPR Tuiuiu and one Red Bean strain VR20) and the subplots of different control modes, in four replications: hand weeding, fomesafen (250 g per hectare of ingredient active (g ha^{-1} of a.i.)), fomesafen (375 g ha^{-1} of a.i.), imazamox + bentazon (0,23 + 0,6g ha^{-1} of a.i.), imazamox + bentazon + fomesafen (0.23 + 0.6 + 125 g ha^{-1} of a.i.) and imazamox + bentazon + fomesafen (0.23 + 0.6 + 83 g ha^{-1} of a.i.). The following traits were evaluated during three seasons: weeds present in the area, phytotoxicity symptoms, and common bean grain yield. The data were analyzed using a variance analysis (F test), the means obtained were grouped by the Scott Knott test at 5 % probability. Differences in grain yield performance were observed between cultivars and crops season due to herbicide application. The most efficacy treatment for weeds was imazamox + bentazon + fomesafen (230 + 600 + 125 g ha^{-1} of a.i.), resulting in improved control and greater efficiency in avoiding grain yield losses.

Keywords: Chemical control. *Phaseolus vulgaris*. Grain Yield. Phytotoxicity. Weed.

Introduction

The common bean (*Phaseolus vulgaris* L.) adapts to the diverse soil and climatic conditions of Brazil. Currently, weed interference is considered one of the most influential factors in reducing common bean yields in all growing seasons (BORCHARDTT *et al*., 2011; LAMEGO *et al*., 2011).

One of the major problems in controlling weeds in common bean (*Phaseolus vulgaris* L.) is the lacking availability of products the effective control of broadleaf weeds (dicotyledons) have been

1 Universidade Federal de Lavras- UFLA. Mestranda em Fitotecnia. juliacarvalhocos@gmail.com. *Campus* Universitário, Caixa Postal: 3037, Lavras/MG, Brasil, 37200-000.

2 UFLA. Professor. silvino.moreiraufla@gmail.com.

3 UFLA. Mestrando em Fitotecnia. antonio.carvalho@dag.ufla.br.

4 UFLA. Professor. guilherme.pimentel@ufla.br.

5 UFLA. Mestrando em Fitotecnia. rafo.qtorres@gmail.com.

6 UFLA. Mestrando em fitotecnia. resendejunior62@gmail.com.

released in recent years (MANCUSO *et al*., 2016). Herbicide Amplo® (bentazon + imazamox), one of the most used in the crop for broadleaf weed control, was released more than 10 years ago.

Due to the absence of new products, combinations of herbicides with pre and post-emergence action with different modes of action have been used to improve the levels of weed control (BRESSANIN *et al*., 2015). The combination of these products contributes to reduce selection pressure and diminish new cases of resistant plants (GALON *et al*., 2016).

Currently, 27 active ingredients are registered for weed control in beans in Brazil, three of which are applied before sowing or emergence, and 24 for post-emergence application. Nevertheless, only 7 of the active ingredients for a post-emergence application can control broadleaf weeds (dicotyledons), and 11 can control grass weeds (monocotyledons) (AGROFIT, 2018).

Although 11 active ingredients can control grass weeds in common bean, they all have the same mode of action. It is therefore difficult to rotate the mechanisms of action, as recommended in the literature. According to Weed Science (2018), these herbicides are ACCase (acetyl-CoA carboxylase) inhibitors and can be divided into two chemical groups oxime cyclohexanedione (DIMs) and aryloxyphenoxypropionic acid (FOPs).

Broadleaf weeds can be controlled by three products (imazamox, imazapyr, and imazethapyr) whose mechanism of action is the inhibition of ALS (acetolactate synthase), of the Imidazolinone group. Three other products inhibit PROTOX (protoporphyrinogen oxidase), i.e., fomesafen, acifluorfen-sodium, and acifluorfen, of which fomesafen is also recommended for pre-emergence weed management. Lastly, bentazon, whose mechanism of action is the inhibition of photosystem II (PSII) (MANCUSO *et al*., 2016).

While some studies described efficient weed control by some products such as fomesafen (BARCELLOS JÚNIOR *et al*., 2016), imazamox + bentazon (SILVA *et al*., 2013), other studies reported undesirable injury in common bean. The latter products can compromise grain yield (FREITAS *et al*., 2009; MANABE *et al*., 2015; OLIVEIRA *et al*., 2013). Also, most studies were performed with old cultivars no longer used in the current production systems. It is believed that there may be differences in sensitivity of the current cultivars to isolated molecules, as well as in the mixtures of the same, calling for further studies.

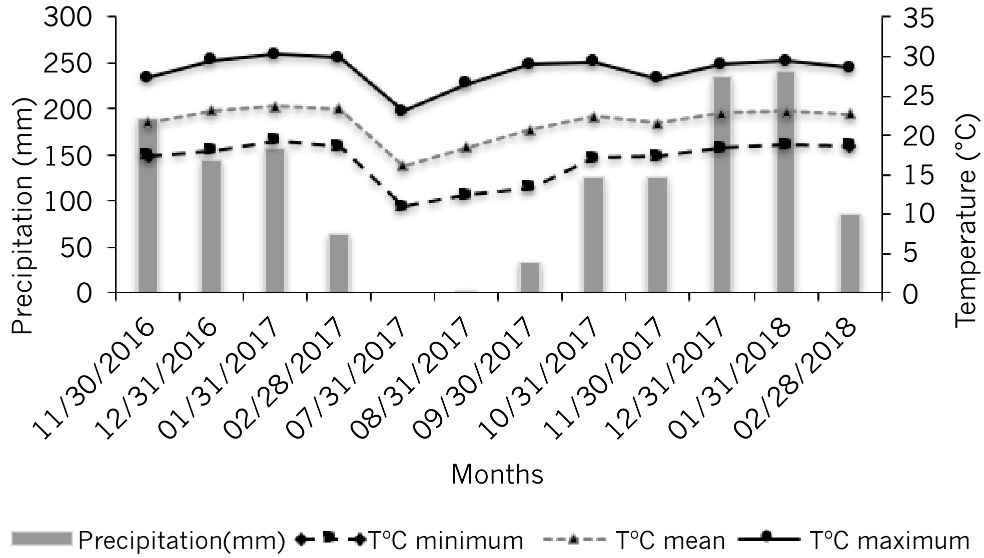
Another important factor was the permission to mix products in tanks in Brazil in 2019. Consequently, studies are required to test the efficacy of weed control as well as the potential phytotoxicity to the current cultivars of these blends. This study assessed the weed control efficacy and phytotoxicity of separate or combined herbicides for common bean cultivars, as well as the effect on yield-related traits of the grain classes carioca, black, and red.

Material and methods

The experiment was installed at the Muquem Farm of the Federal University of Lavras (UFLA), in Lavras, MG, during the growing seasons 2016 and 2017. The geographical coordinates of the farm are latitude 21°14' S, longitude 45°00' W, and altitude 918 m.

The climate in the county of Lavras has well-defined seasons, with a dry season from April to September and a rainy one from October to March, and is classified as Cwa, according to Köppen climate classification. The average annual temperature is around 20.4 °C, with means of 22.8 °C and 17.1 °C, respectively, in the hottest and coldest month. The annual precipitation is 1,460.0 mm, the total annual evaporation 1,034.3 mm and the mean annual relative humidity 76 %. The mean maximum and minimum temperatures and average monthly rainfall (FIGURE 1) and other data were provided by the Meteorological Station of Lavras.

Figure 1 – Diagram of the mean rainfall and maximum and minimum monthly temperatures in Lavras in 2016, 2017, and 2018.



Source: Instituto Nacional de Meteorologia (2018).

The soil of the experimental area is the Oxysol, and the soil chemical properties of the area before the experiments are shown in Table 1.

Table 1 – Summary of the soil chemical analysis of the experimental areas in Lavras/MG, at a soil depth of 0-20 cm, in the growing seasons 2016/2017 and 2017/2018.

Growing season	pH	P[(1)]	K	Ca	Mg	Al	H+Al	SB	T	V
	H_2O	mg dm^{-3}		-------------------$cmol_c$		dm^{-3}-----------------				%
16/17 rainy	5,8	10,1	81	2,5	0,5	0,5	3,3	3,1	6,4	49
16/17 winter	5,9	23,1	142	3,8	0,8	0,1	3,4	3,9	8,3	59
17/18 rainy	5,7	8,70	153	2,9	0,8	0	4,1	4,1	8,2	50

SB= Sum of bases; T = CEC at pH 7; V= base saturation; [(1)]P Mehlich 1.

Source: Elaborated by the authors (2018).

The experiment was arranged in a randomized complete block design, in subdivided plots. The main plots consisted of three types of common bean (Carioca bean: Pérola, Black bean: IPR Tuiuiu, and Red bean: VR20) and the subplots of the different herbicides and mixtures, with four replications, in three growing seasons. The subplots consisted of a hand weeding treatment without herbicide and the others of the application of different herbicide mixtures (Table 2).

Table 2 – Common bean cultivars evaluated in the field in response to different treatments.

Commercial product	Active ingredient	Rates	
		p.c ($L.ha^{-1}$)	ai (g L)
Hand weeding	-	-	-
Flex®	fomesafem	1	250
Flex®	fomesafem	1,5	375

(continuae...)

Table 2 – Continuation.

Commercial product	Active ingredient	Rates	
		p.c ($L.ha^{-1}$)	ai (g L)
Amplo®	bentazon + imazamox	1	600 + 28
Amplo® + Flex®	bentazon + imazamox +fomesafem	1 + 0,5	600+ 28 + 125
Amplo® + Flex®	bentazon + imazamox + fomesafem	1 + 0,35	600 + 28 + 83

Source: Elaborated by the authors (2018).

Common bean was sown mechanically on November 10, 2016; July 21, 2017 and November 15, 2017, corresponding to the growing seasons 1, 2, and 3, respectively. Thirteen seeds per meter were planted in rows, spaced 0.6 m apart, for a plant density of 220,000 ha^{-1}. In the 2016/2017 rainy crop season, the subplots consisted of six 10 m long rows, making a total area of 36 m^2, and the plots composed of 648 m^2. On the other hand, in the fall/winter 2017 and 2017/2018 rainy crop season, each subplot consisted of six 6 m long rows, making a total area of 21,6 m^2, and the plots were composed of 388,8 m^2.

The seeds were treated with the fungicides carboxanilide + dimethyldithiocarbamate (Vitavax-Thiram® 200 + 200 g ha^{-1} of a.i.), at a rate of 250 mL per 100 kg seeds and with fungicides/insecticide pyraclostrobin + thiophanate-methyl + fipronil (Standak Top®, 25+ 225 + 250 g ha^{-1} of a.i.), at a rate of 200 mL per 100 kg seeds.

The fertilization recommended for common bean was applied as proposed by Souza and Lobato (2004). Fertilization at sowing consisted of 320 kg ha^{-1} of the fertilizer NPK 8-28-16, resulting in 26; 90; 51 kg ha^{-1} of N, P_2O_5, and K_2O, respectively. When the crop reached the phenological stage V3 (first trifoliolate leaf), cobalt and molybdenum were applied by mechanical spraying. Subsequently, side dressing was applied, with 100 kg N ha^{-1}, with urea as the source.

The herbicides were applied at 26, 25, and 29 days after crop emergence in growing season 1, 2, and 3 respectively. At that time, cultivar Pérola and IPR Tuiuiu plants were in stage V4.4 (fourth trifoliate leaf) and cultivar VR20 in V4.3 (three trifoliate leaves). For the application of the treatments, a CO_2 pressurized backpack sprayer with a syrup volume of 200 L ha^{-1} was equipped with a bar with four spray nozzles type DG 110 02 that produced medium droplets at an average pressure of 200 kpa.

Hand weeding was performed only once with a hoe, on the same date as the herbicide application. To control the grass weeds in the area, fluazifop-p-butyl (Fusilade® 250 g ha^{-1} of a.i.) at 1 L ha^{-1} was applied across the experimental area, four days after treatment application (broadleaf herbicides) in all growing seasons.

At 7 and 14 days after herbicide application, the weed infestation level in each treatment was evaluated, by determining the number of weeds per species. To this end, the weeds contained within a square of 0.5 m x 0.5 m were counted. The plant density per species (plant m^{-2}) was determined and the relative density was calculated as the number of plants per species in relation to the total (in %).

The phytotoxicity was evaluated according to the intoxication of the plants by a visual assessment of the damages in common bean, at 7 and 14 days after herbicide application. The scores were based on the mean of four replicates, attributed based on the grade scale, of the European Weed Research Council (EWRC), according to Melhorança (1984): 1: no damage; 2: small changes (discoloration, deformation) visible on some plants; 3: small changes (discoloration, deformation) on many plants; 4: strong discoloration (yellowing) or significant deformation, but no necrosis (tissue death); 5: necrosis (blackening) of some leaves, particularly on the edges, accompanied by leaf and shoot deformation;

6: necrosis (deformation) on more than 50% of the leaves and shoots; 7: more than 80% destroyed leaves and shoots; 8: extremely serious damage, leaving only minor green patches on the plants; 9: plant death.

In all experiments, grain yield was evaluated, based on the moisture content corrected to 13 %, in kg ha^{-1}. The data were subjected to individual analysis of variance for each experiment, to test the homogeneity of variance and, later, the combined analysis for the locations. The means were compared by the Scott-Knott test at 5 % probability, using the statistical software SISVAR (FERREIRA, 2011).

Results and discussion

In the evaluations of weed control, the coefficient of variation was high (CV > 20%) in all growing seasons (Table 3), as reported elsewhere (SILVA *et al*., 2014). The analysis of variance for weed control in the experimental area indicated significant differences ($p < 0.05$) among the herbicides applied and the cultivation environments at 7 and 14 days after application (DAA), in response to the control modes.

In growing season 1 (rainy season 2016/2017), all herbicides resulted in a control level similar to that of hand weeding (Table 3), except for herbicide bentazon+imazamox at the prescribed rate (1 L ha^{-1}), as observed at 7 and 14 DAA. However, Machado *et al*. (2008) reported high efficacy in the control of *Euphorbia heterophylla*, *Ipomea sp*., *Commelina benghalensis,* and *Bidens pilosa* after bentazon+imazamox application at the full rate (1 L ha^{-1}).

Table 3 – Percentage of weed control (%), as affected by weed control modes.

Control forms			7 DAA[1]		
bentazon	imazamox	fomesafem	Rainy season (16/17) imazamox	Autumn/ winter (2017) fomesafem	Rainy season (17/18)
------------g.ha^{-1} a.i------------			--------------------Control (%) --------------------		
No herbicides (weeding)			100 aA	100 aA	100 aA
_	_	250	92 aA	58 bB	57 bB
_	_	375	94 aA	75 aA	67 bA
600	28	_	43 bA	58 bA	42 bA
600	28	125	87 aA	75 aA	82 aA
600	28	83	81 aA	83 aA	60 bA
C.V.1 (%)			37,56		
C.V.2 (%)			38,96		
			14 DAA		
------------g.ha^{-1} a.i------------			--------------------Control (%) --------------------		
No herbicides (weeding)			100 aA	100 aA	100 aA
_	_	250	84 aA	42 bB	14 bB
_	_	375	92 aA	60 bB	30 bB
600	28	_	53 bA	49 bA	23 bA
600	28	125	92 aA	53 bB	49 bB
600	28	83	85 aA	50 bB	16 bC
C.V.1 (%)			69,1		
C.V.2 (%)			50,4		

Means followed by the same lowercase letter in a column and upper case in a row do not differ from each other statistically by the Scott-Knott test at 5 % probability.
Note. [1]DAA: days after application.

Source: Elaborated by the authors (2018).

The low control efficacy of bentazon+imazamox in the first growing season may be related to the irregular weed occurrence in the experimental plots and to the presence of *Bidens pilosa* (hairy beggartick) and *Alternanthera tenella* (joyweed) and in a larger population in the total area (Table 4).

Table 4 – Percentage of weeds in the total area on day 0 before the application of weed control, in growing seasons 1 and 2 (2016/17) and growing season 3 (2017/18).

Rainy season 2016/17	
Bidens pilosa	56 %
Alternanthera tenella	28 %
Galinsoga parviflora	8 %
Others	5 %
Commelina benghalensis	3 %
Autumn/winter 2017	
Commelina benghalensis	36 %
Ipomoea triloba	31 %
Richardia brasiliensis	14 %
Amaranthus retroflexus	10 %
Others	9 %
Rainy season 2017/18	
Commelina benghalensis	29 %
Alternanthera tenella	21 %
Blainvillea dichotoma	18 %
Ipomoea triloba	17 %
Others	15 %

Source: Elaborated by the authors (2018).

Although bentazon+imazamox is recommended for the control of *Bidens pilosa* (hairy beggartick), in this case, the control was inadequate due to the high infestation with this weed in the area. The data of the weed control level observed here differed from those presented by Marchioretto and Magro (2017). These authors stated an efficient control of *Bidens pilosa* with imazamox (30 g ha^{-1}), blended or sequentially applied with bentazon (480 g ha^{-1}), or by applying fomesafen (125 g ha^{-1}), although an antagonistic effect of the mixture or the sequential application was observed. On the other hand, Nicolai *et al*. (2006) do not recommend the use of ALS-inhibiting herbicides for the control of resistant biotypes of *Bidens pilosa* and *Bidens subalternans*. However, the characteristic of ALS resistance in *Bidens pilosa* was not evaluated or proven in this study anyway.

In the case of *Alternanthera tenella*, although germination is more intense in the presence of light, it can also germinate in the dark, causing the species to emerge later in the cycle of summer crops, hampering an effective control (CANOSSA *et al*., 2008).

On the other hand, in growing season 2 (autumn/winter 2016/17), bentazon+imazamox and fomesafem, demonstrating the low efficacy of herbicides when applied separately, 7 DAA. However, when applied together (1 L ha^{-1} bentazon+imazamox + 0.5 L ha^{-1} fomesafem) the control efficacy was adequate. After 14 days, herbicide proved less efficient than hand weeding. This was due to the high infestation with traboeraba (*Commelina benghalensis*) (TABLE 4), for which the herbicides, although recommended for this species, could not efficiently control it; apart from the fact that other weed species germinated, after the last evaluation.

In growing season 3 (rainy season 2017/2018), the control of the herbicide mixture of bentazon+imazamox (1 L ha^{-1} ha^{-1}) + fomesafem (0.5 L ha^{-1}) was significant, similar to that of hand weeding (100 % weed-free). However, after 14 days, the control of this treatment tended to be better than the others, with a 28.1 % higher efficacy than when using 1 L ha^{-1} fomesafem. However, at 14 days, no significant difference compared to the control (hand weeding) was observed. This fact can be explained by the emergence of new weed species in the experimental area.

According to Silva *et al*. (2013), the blend of fomesafen + bentazon + imazamox allows a reduction in fomesafen rates by up to ¼, resulting in excellent weed control and easy conditions of bean harvesting, as well as reducing the residual risk for sorghum and corn. Regarding the evaluation of phytotoxicity, no symptoms were observed after the products were applied, proving the control efficacy of the herbicides regarding the three bean cultivars.

Linhares *et al*. (2014) concluded that the mixture bentazon + imazamox does not alter the growth characteristics of common bean plants, for being selective. Also, concerning phytotoxicity, Galon *et al*. (2017) reported that the herbicides fomesafen, bentazon, or the commercial blend bentazon + imazamox caused some lesions on the black bean cultivar BRS Campeiro. However, the plants recovered quickly from the injuries and the subsequent development was not affected.

According to the analysis of variance for grain yield data, the experimental precision was good (CV 15.6 %). The yields differed according to the cultivars, control modes, and growing seasons. By partitioning the triple interaction, the effect of the herbicides on each bean cultivar could be studied, and their behavior within each cultivation environment (growing season) assessed (TABLE 5). Therefore, the same treatment results in different responses in control efficiency when applied in different environments, since the efficacy of a herbicide or herbicide mixture for weed control can vary according to the weed community and environmental factors.

Table 5 – Average triplex of the outspread of application control modes (herbicides trials) within the crop and cultivars for common bean grain yield in kg.ha^{-1}.

	Herbicides (H)					
C-A	**Weeding**	**fomesafem (250 g i.a)**	**fomesafem (375 g i.a)**	**bentazon+ imazamox (600+28 g i.a)**	**bentazon+ imazamox+ fomesafem (600+28 + 125 g i.a)**	**bentazon+ imazamox+ fomesafem (600+28 + 83 g i.a)**
Pérola- 1	2280 a	2220 a	2220 a	2040 a	2460 a	2460 a
Pérola- 2	1020 a	1140 a	1320 a	1080 a	1320 a	1020 a
Pérola- 3	1740 a	1260 b	1020 b	1080 b	1680 a	1260 b
IPR Tuiuiu-1	2160 c	3000 a	3240 a	2640 b	2940 a	3360 a
IPR Tuiuiu-2	1380 b	1680 a	1320 b	1440 b	1860 a	1860 a
IPR Tuiuiu-3	1500 a	1560 a	1560 a	1320 a	1320 a	1200 a
VR 20-1	2160 b	2280 b	2940 a	2940 a	2580 a	2760 a
VR 20-2	1260 a	1440 a	1500 a	1260 a	1020 a	1260 a
VR 20-3	2340 a	2220 a	2460 a	2220 a	2280 a	2220 a
Média - H	1760	1867	1953	1780	1940	1933
C.V.1 (%)			15,7			
C.V.2 (%)			15,6			

Means followed by the same letter on the lines, do not differ statistically from each other by the Scott-Knott test at 5 % probability.
Note. 1: rainy season 2016/2017. 2: autumn/winter (2016/17). 3: rainy season (2017/18).

Source: Elaborated by the authors (2018).

In the first growing season (rainy season 2016/2017), there was no effect of the control modes on common bean yield of cultivar Pérola (TABLE 5). However, the yield of cultivar IPR Tuiuiu was reduced when bentazon+imazamox (1 L ha^{-1}) was applied and by hand weeding. This result differs from that reported by Galon *et al*. (2017), who observed similar yields to the control for black beans.

The low yield in this treatment (TABLE 5) can be attributed to the lower efficacy of bentazon+imazamox, observed in this study, in controlling weeds in the first growing season (2016/2017). Although hand weeding controlled the weeds by 100 %, the yield reduction can be explained by the germination of weed species, after the last evaluation at 14 days, which did not occur in the study of Galon *et al*. (2017).

The yields of cultivar VR20 were lowest in the plots where hand weed control (weeding) and control with 1 L ha^{-1} fomesafem were performed. This fact can be attributed to the germination of new weed species in the area, after the evaluation 14 days after chemical weeding, as well as at the location of fomesafem application, since these control modes leave no residues in the soil.

In growing season 2 (autumn/winter 2016/2017) however, no effect of the control modes on cultivars Pérola and bean lineage VR20 was observed. Nevertheless, for cultivar IPR Tuiuiu, the mean yields were lowest when treated with hand weeding and application of 1 L ha^{-1} bentazon+imazamox and 1.5 L ha^{-1} fomesafem. Although the efficacy of hand weeding was effective up to 14 DAA (TABLE 3), the efficiency of this practice was not evaluated after 14 DAA. As this method leaves no residues, weeds that possibly occurred after 14 DAA may have affected the common bean yield negatively. In the case of cultivar IPR Tuiuiu, grown in the plots treated with 1 L ha^{-1} bentazon+imazamox, it is believed that the lower efficacy in weed control may have affected common bean yields.

Regarding fomesafem at 1.5 L ha^{-1}, although it controlled weeds efficiently (TABLE 3) and no phytotoxicity symptoms on the bean plants were visually detectable, there may have been some hidden phytotoxicity in the plants of cultivar IPR Tuiuiu, resulting in the lowest yields. According to Cieslik, Vidal and Trezzi (2014), a possible explanation for the recovery of common bean plants from herbicide symptoms is that the herbicide does not move from the sprayed tissue to the new shoots as well as the action of the enzymes glutathione S-transferase (GST), which detoxify the herbicides.

Although in this study only the yield of cultivar IPR Tuiuiu was affected by the different herbicides, yield losses due to weeds are common. In studies with carioca bean, the common bean yield was reduced by 67 %, in a comparison of the yield produced in a total absence of weeds (completely weed-free - 2516 kg ha^{-1}) with that produced in the presence of some weeds during the entire cycle (partially weed-free environment - 1095 kg ha^{-1}) (SALGADO *et al*., 2007). As a result of weed interference, Vogt *et al*. (2013) reported yield losses in black bean cultivars from 30.8 % to 54.9 %. For cultivar IPR Tuiuiú, Galon *et al*. (2016) observed a productivity decrease of approximately 30 % at 41 days after emergence, when up to 10 % of weed cover was maintained.

Interestingly, the common bean yield was lower in the winter than in the other seasons. This was unexpected because the crop was planted in a central pivot area, in which common bean yields tend to be very high. However, in this area, the seasonally low temperatures possibly affected crop productivity negatively.

In growing season 3, Pérola produced a higher yield when treated with hand weeding and the mixture of bentazon + imazamox (1 L ha^{-1}) + fomesafem (0.5 L ha^{-1}) (rainy season 2017/2018). In a study by Marchioretto and Magro (2017), the highest yields were also achieved when fomesafen herbicides were combined with the commercial mixture bentazon with imazamox. This can be explained by the higher level of weed control in the area of these two treatments than in the others, which reduced weed competition and improved productivity. The cultivars IPR Tuiuiu and bean lineage VR20 did not respond to the different weed control modes.

It is worth mentioning that the prescribed rate of fomesafem (Flex®) for weed control in common bean (1 L ha^{-1}), independently of the cultivar, causes some delay in crop growth, as described by Linhares *et al*. (2014). The only mixture officially recommended for chemical weed control in common bean was bentazon + imazamox (Amplo®), which is a commercial product for broadleaf weed control. The other blends were tested because they are commonly used by the producers. Currently, after the approval of law 6299/02 that allows herbicide mixtures in tanks, all blends tested here may be used.

Conclusions

Separate applications of Flex® 1 L ha^{-1} (fomesafen) and the mixture of Amplo® + Flex® blends (imazamox + bentazon + fomesafen) control weeds efficiently.

The separate and mixed applications of the herbicides have no phytotoxicity effects on any of the studied common bean cultivars.

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Eficácia da mistura em tanque de herbicidas pós-emergentes em diferentes cultivares de feijão-comum

Resumo

Na cultura do feijoeiro, a ocorrência de plantas daninhas pode causar grandes reduções no rendimento final dos grãos. Este trabalho teve como objetivo avaliar a eficácia de diferentes herbicidas, aplicados de forma isolada ou em mistura, no manejo de plantas daninhas na cultura do feijoeiro-comum. O delineamento estatístico adotado foi blocos casualizados, no esquema de parcelas subdivididas. As parcelas principais foram constituídas por três cultivares de feijão (cultivar Carioca Pérola, cultivar do grupo preto IPR Tuiuiu e cultivar do grupo vermelho Ouro VermelhoVR20) e as subparcelas pelos diferentes modos de controle, com quatro repetições: capina manual, fomesafem (250 g ha^{-1} de ingrediente ativo (i.a.)), fomesafem (375 g ha^{-1} de i.a.), imazamox + bentazon (0,23 + 0,6 g ha^{-1} de i.a.), imazamox + bentazon + fomesafem (0,23 + 0,6 + 125 g ha^{-1} de i.a.) e imazamox + bentazon + fomesafem (0,23 + 0,6 + 83 g ha^{-1} de i.a.). Avaliaram-se durante três safras plantas daninhas presentes na área, sintomas de fitotoxicidade e produtividade do feijoeiro. Os dados foram submetidos à análise de variância (Teste F) e as médias obtidas foram agrupadas pelo teste Scott-Knott a 5 % de probabilidade. Verificaram-se diferenças na produtividade de grãos, sendo observadas entre cultivares e safras devido à aplicação dos herbicidas. O tratamento mais eficaz foi imazamox + bentazon + fomesafem (230 + 600 + 125 g ha^{-1} de i.a.), resultando no melhor controle de plantas daninhas e maior eficiência na produtividade final dos grãos.

Palavras-chave: Controle químico. *Phaseolus vulgaris*. Produtividade. Fitotoxicidade. Plantas daninhas.

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