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Phytosociology of weeds in bean crops with different herbicides control[1]

Fitossociologia de plantas daninhas em cultivos de feijão sobre diferentes manejos de herbicidas

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Abstract - Knowledge on changes in weeds communities caused by weeds management practices is important when effective strategies for the control of these species are set. A field experiment was conducted to assess the effects of herbicides applications with different sprayer boom heights on the weeds dynamics and beans yield. A 3x4+1 factorial arrangement was adopted, comprised of the combination of three herbicides (fomesafen. fluazifop-p-butyl and a mixture of both) and four different boom heights (0.20; 0.30; 0.40 and 0.50 m above target) and one control (non-weeded check). Thirty days after application (DAA), the following phytosociological indices were determined: relative frequency, relative density, relative dominance, and importance value. Sixty days DAA, yield rates were determined. Prior to the experiment installation, 22 species were identified in the entire experimental area. The species *Alternanthera tenella*, *Chelidonium majus*, *Digitaria horizontalis* and *Bidens pilosa* dominated the area where there was no weed control. Reduced boom heights for application of fomesafen diminished the importance of dicot species. In the plots with fomesafen + fluazifop-p-butyl applications, the number of dicot weeds was greater than the other species, with predominance of *A. tenella* e *B. pilosa*. In general, the similarity index between the different herbicides and different boom heights was low, which indicates that the treatments used result in different weeds populations. Bean crops reduces the weeds diversity, and the application of herbicides has a positive effect on weeds infestation, with consequent gains in productivity.
Keywords: fluazifop-p-butyl; fomesafen; herbicides mixture in tank; *Phaseolus vulgaris*; herbicides application technology

Resumo - O conhecimento das alterações na comunidade infestante provocado pelo manejo de plantas daninhas é importante para definição de estratégias eficientes para o controle destas. Realizou-se um experimento de campo para avaliar os efeitos do uso de herbicidas em diferentes

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alturas de barra na dinâmica de plantas daninhas e produtividade do feijoeiro. Adotou-se arranjo fatorial em esquema 3x4+1, constituído pela combinação de três herbicidas (fomesafen, fluazifop-p-butil e sua mistura) e quatro alturas de barras do pulverizador (0,20; 0,30; 0,40 e 0,50 m) e mais a testemunha sem capina. Aos 30 dias após aplicação (DAA) determinou-se os seguintes índices fitossociológicos: frequência relativa, densidade relativa, dominância relativa, índice de valor de importância e índice de similaridade. Aos 60 DAA foi determinada a produtividade. Antes da instalação do experimento foram identificadas 22 espécies em toda área experimental. As espécies *Alternanthera tenella*, *Chelidonium majus*, *Digitaria horizontalis* e *Bidens pilosa* predominaram na área cultivada em que não houve controle. A redução da altura de barras na aplicação do fomesafen reduziu a importância das espécies eudicotiledôneas. Nas parcelas com aplicação de fomesafen + fluazifop-p-butil o número de infestantes eudicotiledôneas foi superior às demais, com predominância de *A. tenella* e *B. pilosa*. No geral, o índice de similaridade entre os diferentes herbicidas e as diferentes alturas de barra foi baixo, o que indica que os tratamentos aplicados resultam em diferentes populações de plantas daninhas. O feijoeiro reduz a diversidade de plantas daninhas e a aplicação de herbicidas altera a infestação destas com consequência no ganho em produtividade.

Palavras-chaves: fluazifop-p-butil; fomesafen; mistura de herbicidas em tanque; *Phaseolus vulgaris*; tecnologia de aplicação de herbicidas

Introduction

Common bean (*Phaseolus vulgaris L.*) is one of the major staples of the Brazilian diet. Brazil is the world's largest beans producer, but crop yields are still low (955 kg ha^{-1}) (CONAB, 2016), which can be attributed to the limited use of cultivation technologies by farmers, especially family farmers, and an inadequate selection of management technologies by large producers to best suit each situation (Galbiatti et al., 2011).

The interference of weeds has been one of the key factors that have affected adversely the bean crop yields (Ferreira et al., 2006; Cury et al., 2013). When poorly managed, weeds can cause crop losses of up to 67% (Salgado et al., 2007; Borchardtt et al., 2011). Thus, it is necessary to employ weeds control techniques at the right time to avoid crop losses caused by the presence of invasive species.

Among the weeds control techniques, the use of chemicals has been the most usual solution adopted by farmers because it is less labor intensive, has a high control efficiency, and is more cost-effective when compared to the other methods (Arruda et al., 2005). In bean crops, weeds control can be achieved with post-emergence applications of the commercial mixture of fluazifop-p-butyl and fomesafen herbicides (Manabe et al., 2014). Fluazifop-p-butyl inhibits the Acetyl-CoA carboxylase enzyme, impeding the lipids synthesis in plants, and is effective in controlling grasses originated from seeds. Fomesafen inhibits the protoporphyrinogen oxidase and has a wide spectrum of action on dicot weeds at their early growth stage (Silva e Silva, 2007).

Herbicides effectiveness in weeds control is directly associated with an appropriate application of the product on target. In the case of herbicides, one of the most important aspects of the application technology is the proper height of the sprayer boom since minor changes in the boom height in relation to the target species can affect a uniform application of the herbicide and, consequently, the crops and weeds selectivity (Freitas et al., 2005; Pereira et al., 2015).

The use of herbicides in agricultural systems changes the weeds population dynamics for being a key factor in the species selection. Studies have been conducted using phytosociological indices, which allow an analysis of the impact that management systems and cultural practices have on growth dynamics and dominance of invasive weeds communities in agricultural systems (Oliveira and Freitas, 2008). Several studies have already demonstrated the impacts of herbicides on weeds dynamics (Malik et al., 2007; Reis et al., 2013; Mendes et al., 2014). However, there are little information on the effects of the application technology on the weed flora.

Given the above, this study aimed to assess the effects of application of fomesafen and fluazifop-p-butyl at different boom heights on the phytosociological indices of weeds in bean crops.

Material and Methods

The experiment was carried out in an experimental site in the municipality of Viçosa-MG from September 2013 to January 2014.

The soil in the area was classified as Red-Yellow Argisol having the following physicochemical characteristics: 43, 14 and 43 g kg^{-1} of clay, silt and sand, respectively; 5.6 pH value (water); 2.6 dag kg^{-1} of organic matter; 5.9 and 64 mg dm^{-3} of P and K respectively; Ca, Mg, Al, H+Al and $_{effective}$CEC of 2.0; 0.8; 0.3; 3.3 and 2.9 cmol dm^{-3}, respectively. The vegetation at the site was desiccated fifteen days before planting by using a tank mixture of glyphosate herbicide (1080 g ha^{-1}) + 2,4-D (540 g ha^{-1}).

The experimental design consisted of randomized blocks with four replications. The treatments were arranged in a 3x4+1 factorial design, the first factor corresponding to the herbicides (fomesafen, fluazifop-p-butyl and a combination of both) and the second factor to the sprayer boom heights (0.20; 0.30; 0.40 and 0.50 m), and one control without weeding (not cleared of weeds). The total foot area of each experimental plot was 36 m^2 (4 m x 9 m in width and length, respectively, and 9 m^2 of useful area.

Sowing of bean cv. *carioca* seeds was performed mechanically using no-till farming, and 100 seeds m^{-1} were planted at 0.5m spacing between rows. Basic fertilization was used, consisting of 4-14-8 (N-P_2O_5-K_2O) formulation at a dosage of 350 kg ha^{-1}, added to an application of 60 kg ha^{-1} of N to the crop rows 40 days after the culture emergence. During the experiment, supplementary irrigations were made at dates of drought periods, in September, October, and December 2013.

The herbicides applied were fomesafen (Flex®, 250 g ha^{-1} i.a., CS, Syngenta), fluazifop-p-butyl (Fusilade® 250 EW, 250 g ha^{-1} i.a., EW, Syngenta) and a tank mixture of both products, simulating what growers do in field. Applications of the herbicide solutions were performed 30 days after emergence (DAE) of the seedlings, using a precision knapsack sprayer driven by CO_2, equipped with a boom with four nozzles, TT11002 type flat-fan jet tips, spaced every 0.50 m apart, with a pressure of 240 kPa and flow rate of 150 L ha^{-1} of the herbicide solution.

Before desiccating the area where the bean seeds would be planted, a phytosociological survey of the weeds at the site was performed. This analysis was carried out at each experimental plot at 60 DAE and 30 days after application of the herbicides. The phytosociological survey was carried out using the inventory square method, whereby one 0.5 x 0.5 m quadrat (0.25 m^2) was placed at random twice in a representative area of each plot (Erasmo et al., 2004). The weeds contained within the quadrat were collected and identified and then taken into a forced-air circulation oven for 72 hours at a temperature of 60 ºC for determination of the dry matter mass per sampled species.

After the plants identification, phytosociological indices were determined as proposed by Mueller-Dombois and Ellenberg (1974), namely: relative frequency (RFR), relative density (RDE), relative dominance (RDO) and importance value index (IVI). To calculate these indices, the following formulas were used:

$$RFR\ (\%) = \frac{Species\ frequency\ (SFR) x\ 100}{Total\ species\ frequency}$$

$$\text{RDE (\%)} = \frac{Species\ density\ (SDE) x\ 100}{Total\ species\ density}$$

$$\text{RDO (\%)} = \frac{Species\ dry\ matter\ (SDM) x\ 100}{Total\ species\ dry\ matter}$$

$$IVI = RFR + RDE + RDO$$

The Sorensen similarity index (SI) (Sorensen, 1972) was also calculated according to this formula:

$$\text{SI (\%)} = \left(\frac{2a}{b+c} \right) \text{x } 100$$

Where: a = number of species common to both sites; b and c = total number of species in the respective comparative sites. This index achieves the maximum value (100%) when all weed species are common to the sites, and minimum (0%) when there are no species in common.

At 90 DAE (60 days after application) bean yields (t ha^{-1}) were determined. Data were subjected to analysis of variance and for significant effects the means were compared using the Tukey ($p \leq 0.05$) and/or Dunnett' test ($p \leq 0.05$) (when comparisons with the control were deemed necessary).

Results and Discussion

Prior to desiccation of the experimental site, 22 species of weeds were identified, and *Coronopus didymus* was the plant that had the highest importance value index (IVI) (Figure 1 A).

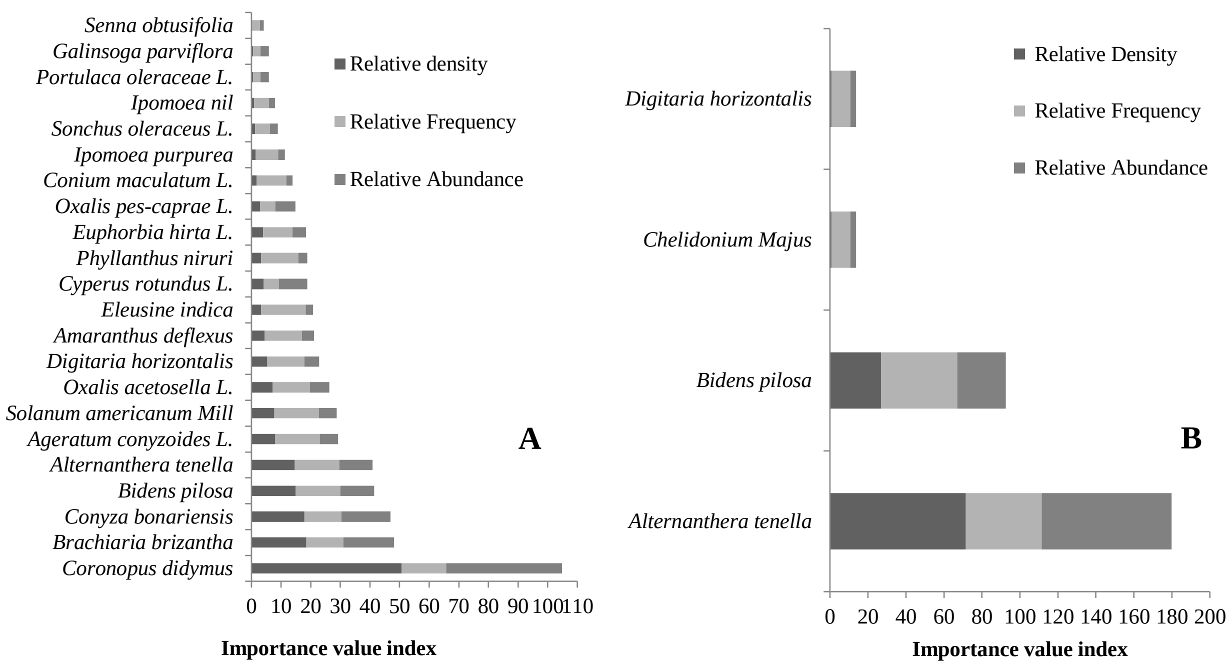

Figure 1. Phytosociological indices of the site before planting beans (A) and in the control treatment (no weeds control) cultivated with the crop (B).

Sixty days after emergence of the bean seedlings, time for the phytosociological survey, in the control treatment (without weeds control) only four species were found, and the species with the highest IVI were *Alternanthera tenella* and *Bidens pilosa* (Figure 1B), which indicates that the broadleaf weeds are better adapted to bean crops. The treatment without weeding exhibited a greater establishment of some well-adapted species to the bean crop. This dominant species wiped out the other plants and infested the site, diminishing the weeds diversity. Furthermore, the weed species that dominated the area have greater competitive ability, causing more interference with bean crops (Pollnac et al., 2009).

The importance of weeds of the family *Poaceae* was severely reduced with application of fluazifop-p-butyl. With 0.20 and 0.30m of nozzle heights, these weeds were not found, and at 0.40 and 0.50 m high their presence was inexpressive (Figure 2).

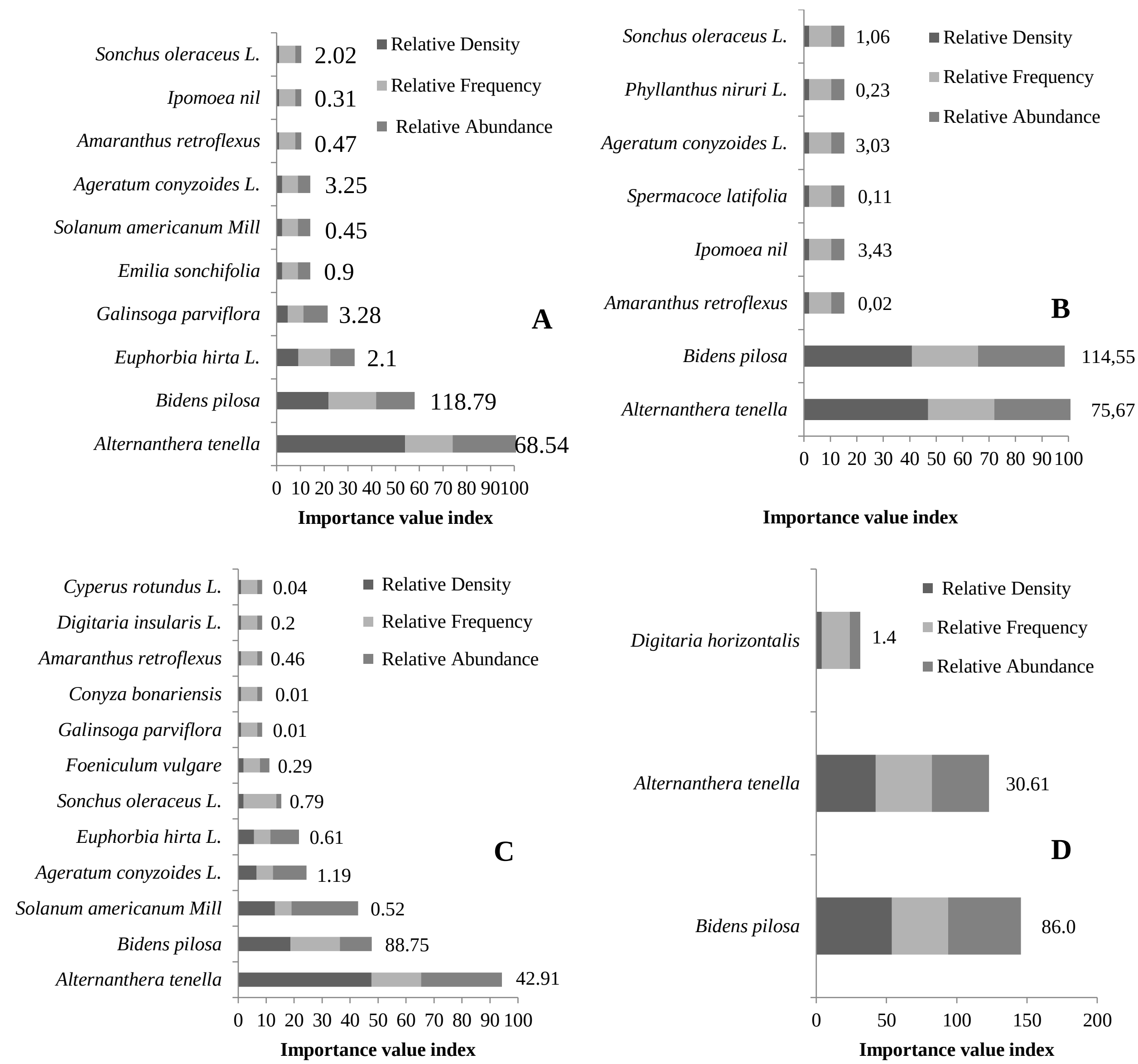

Figure 2. Phytosociological indices of weeds in the beans crop after application of fluazifop-p-butyl herbicide with boom heights 20 (A), 30 (B), 40 (C) and 50 (D) cm above target.

When the herbicide was applied 0.50 m above the target, only three plants remained in the plot: *B. pilosa*, *A. tenella* and *Digitaria horizontalis*. This was an expected result since this is the recommended height for proper formation of the distribution profile and due to the spectrum of action of fluazifop-p-butyl in the control of weeds of the family *Poaceae*. As a result, the dicot species with higher development potential dominated the area and impeded the development of other species. The highest IVI found was for *B. pilosa*, which is considered a highly competitive species (Rizzardi et al., 2003; Santos and Cury, 2011), exhibiting a lower permanent point of wilting than the bean plants (Procópio et al., 2004) and a greater phosphorus absorption and utilization (Procópio et al., 2005). It was found a reduction of up to 66% of dry matter and 59, 61 and 63% of N, P and K of a bean plant competing with *B. pilosa* (Cury et al., 2011; Cury et al., 2013).

Lowering the nozzle height for fomesafen application reduced the importance of the dicot species, and the lowest IVIs for the broadleaf species were achieved with 0.20 m of boom height, where only the species *B. pilosa* and *Ipomoea nil* were found (Figure 3).

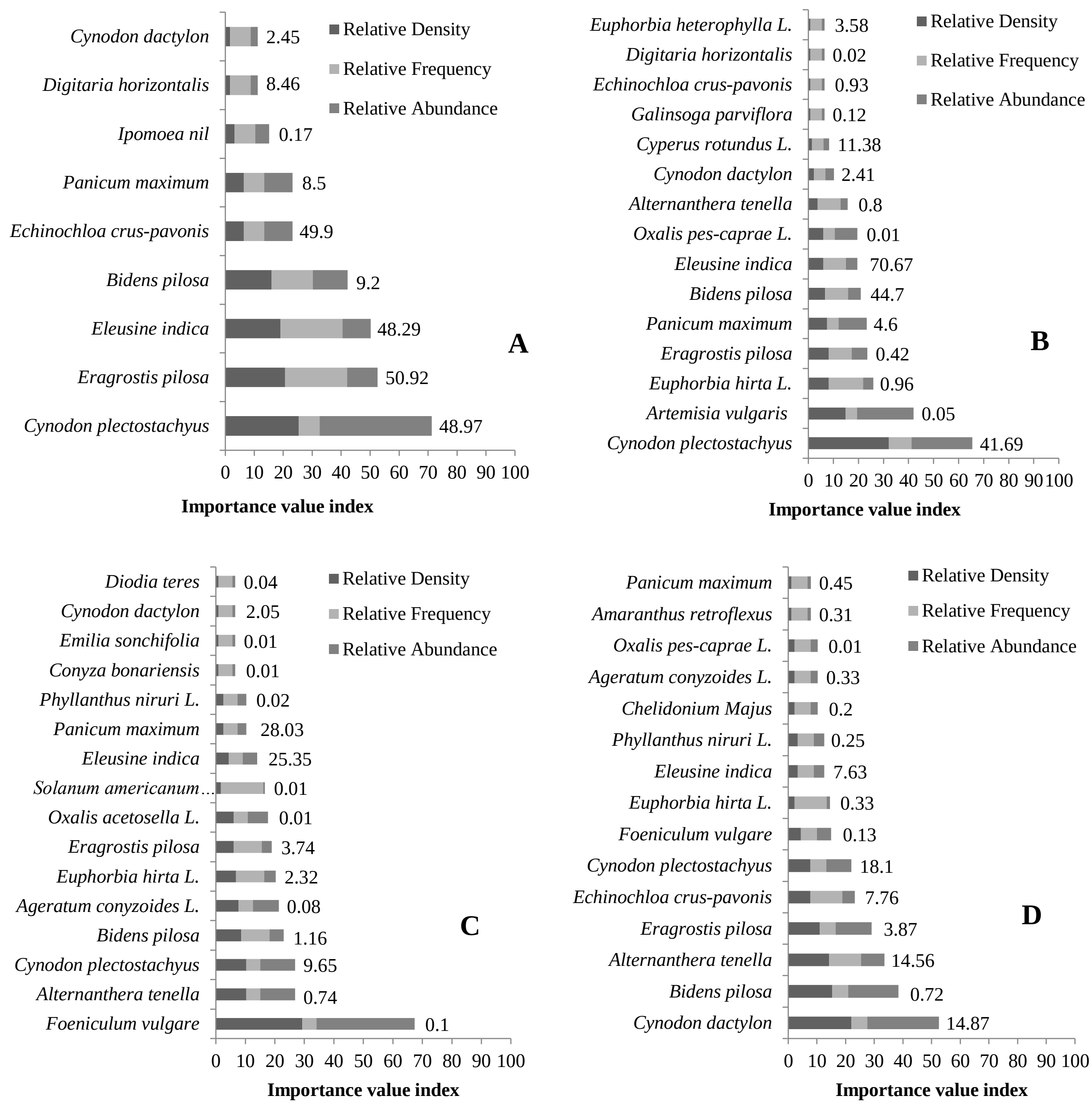

Figure 3. Phytosociological indices of weeds in the beans crop after application of fomesafen herbicide with boom heights 20 (A), 30 (B), 40 (C) and 50 (D) cm above target.

This result is explained by greater herbicide concentrations in some sites of the distribution profile caused by decreased height. In addition, the tips were positioned between the planting rows, so that a larger amount of the herbicide solution reached the target at the center, as described by Freitas et al, (2005) and Viana et al, (2007). One of the advantages of positioning the sprayer boom at lower heights in relation to the target is a drift reduction of the spray liquid.

In the plots that received application of the fomesafen + fluazifop-p-butyl mixture, the number of broadleaf weeds was higher than narrow-leaf plants for all boom heights (Figure 4). Fluazifop-p-butyl is a systemic herbicide that is effective in the control of diverse perennial and annual grasses (Weller, 2000; Freitas et al., 2004), unlike fomesafen, which is a contact product that has little movement in plant (Vidal, 2002) and, consequently, requires better leaf cover when the product is applied.

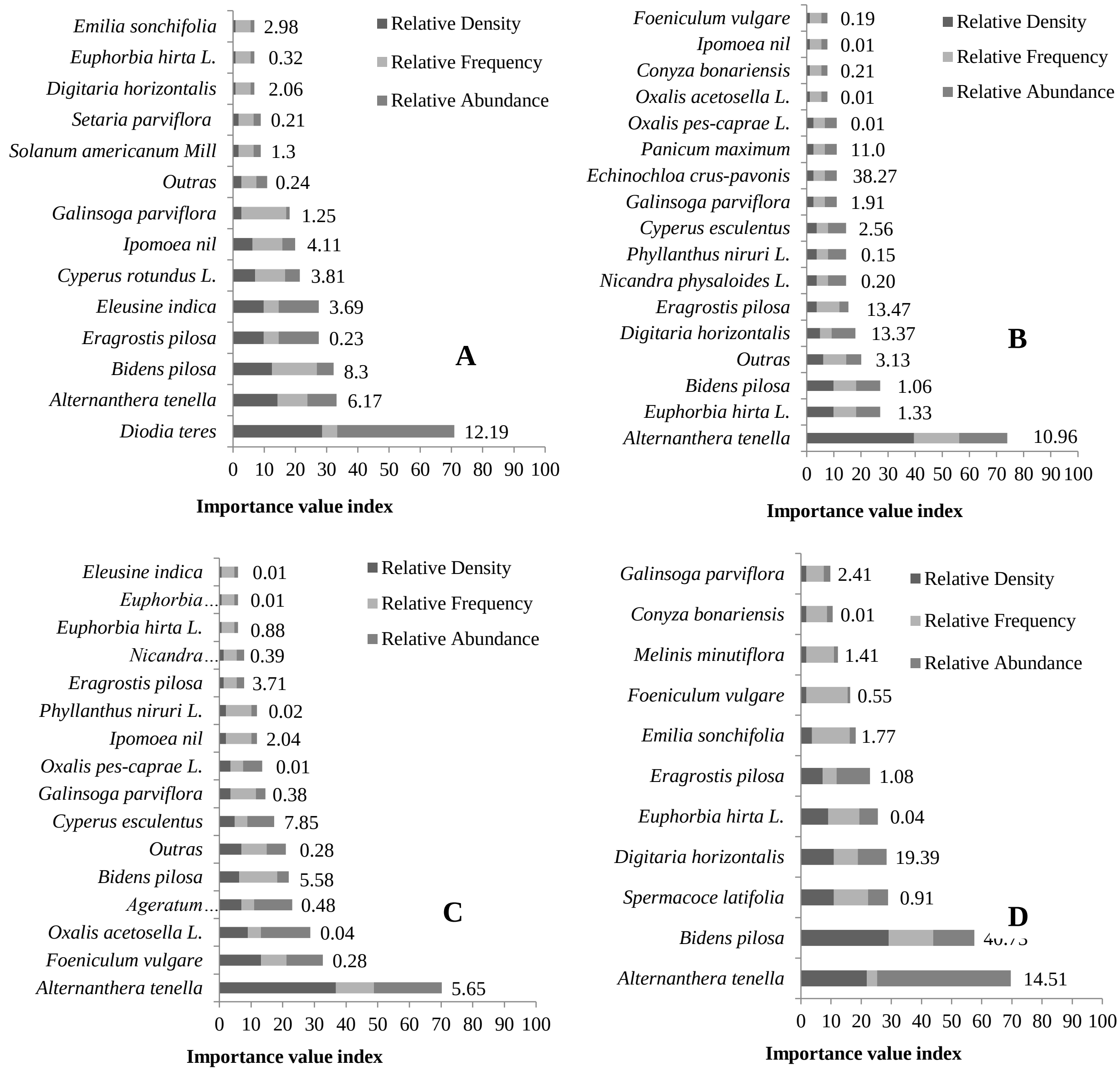

Figure 4. Phytosociological indices of weeds after application of fomesafen + fluazifop-p-butyl with different boom heights.

A. tenella was one of the main weeds found in the treatments that received the herbicides mixture, with emphasis on its high relative density, which represents the number of plants per plot in relation to total plants (Braga et al., 2012). Other species that also exhibited high IVI was *B. pilosa*, in this case its high relative dominance, indicating that this species has high growth rates and dry matter accumulation, as already mentioned (Figure 4).

The Similarity Index (SI) between the plot without weeds control and the other plots varied from 20 to 40%, which can be considered a low similarity between the plots (Araújo et al., 2007), except for the fluazifop-p-butyl application with 0.50 m boom height (Table 1), which had 85.7% of similarity. The similarity between the weeds present before desiccation and after application of the treatments ranged from 23.1 to 52.9%, which indicates that the herbicides application and beans crop management cause great changes in the community of infesting plants present in the area, as described by Pereira and Velini (2003) and Vaz de Melo et al. (2007).

Table 1. Similarity indices for the treatments tested: prior to the herbicides application, control treatment (non-weeded), applications of fomesafen and fluazifop-p-butyl alone and combined (mixture) with different boom heights (0.2; 0.3; 0.4, and 0.5 m).

	Before	Fomes - 0.2	Fomes - 0.3	Fomes - 0.4	Fomes - 0.5	Fluaz - 0.2	Fluaz - 0.3	Fluaz - 0.4	Fluazi - 0.5	Mixture 0.2	Mixture 0.3	Mixture 0.4	Mixture 0.5
Fomes - 0.2	25.8	-	-	-	-	-	-	-	-	-	-	-	-
Fomes - 0.3	43.2	66.7	-	-	-	-	-	-	-	-	-	-	-
Fomes - 0.4	47.4	48.0	51.6	-	-	-	-	-	-	-	-	-	-
Fomes - 0.5	37.8	56.0	66.7	71.0	-	-	-	-	-	-	-	-	-
Fluaz - 0.2	50.0	21.1	32.0	46.2	40.0	-	-	-	-	-	-	-	-
Fluaz - 0.3	40.0	23.5	17.4	33.3	43.5	66.7	-	-	-	-	-	-	-
Fluaz - 0.4	52.9	9.5	37.0	50.0	44.4	72.7	50.0	-	-	-	-	-	-
Fluaz - 0.5	24.0	33.3	33.3	21.1	22.2	30.8	36.4	50.0	-	-	-	-	-
Mixture 0.2	50.0	43.5	53.3	51.6	34.5	58.3	27.3	46.2	35.3	-	-	-	-
Mixture 0.3	51.3	48.0	56.3	54.5	56.3	29.6	32.0	40.0	30.0	45.2	-	-	-
Mixture 0.4	52.6	32.0	51.6	56.3	58.1	46.2	41.7	42.9	21.1	53.3	78.8	-	-
Mixture 0.5	36.4	30.0	46.2	51.9	38.5	47.6	31.6	52.2	42.9	53.8	57.1	57.1	-
Control	23.1	30.8	31.6	20.0	31.6	28.6	33.3	25.0	85.7	33.3	28.6	28.6	40.0

In general, the SI for the different herbicides and different boom heights were low, indicating that the applications of different herbicides and different boom heights resulted in infestations of different plants populations. Monquero and Christoffoleti (2005) and Kuva et al. (2007) also reported great variations in invasive weeds communities as a function of herbicides application.

There was an interaction between the weeds treatment and boom height factors for bean yields (Table 2). In the comparison of different boom heights for each treatment, there was a decline in yields as the boom approached the target. The herbicides mixture had better results when the application was 0.30 m above the ground, corroborating the study conducted by Freitas et al., (2005), who stated that better distribution profiles are achieved for this kind of tip over 0.30 m high. The yield variations found for different boom heights are due to the increased competition between the culture and weeds caused by poor formation of the herbicide distribution profile in the area, corroborating the phytosociological analyses.

The weeds reduced by 72.76 % the crop yields as compared to the manually weeded treatments, which was also found by Salgado et al., (2007); and Borchartt et al., (2011). Irrespective of the chemical management adopted, crop yield was not different from the weeded treatment, when the boom was positioned 0.5 m above target (Table 2), which was not expected since the weeds community was comprised of monocot and dicot plants, and the fomesafen and fluazifop-p-butyl herbicides have a larger spectrum of action on broadleaf species and narrow-leaf species, respectively. However, independent application of herbicides 0.5 m above crop was sufficient to control part of the weeds, and the bean plants exercised cultural control on the other weed species.

Table 2. Bean yields (t ha^{-1}) in the weeded plot, non-weeded plot and application of fomesafen and fluazifop-p-butyl alone and mixed at different boom heights.

Management	Boom height (m)			
	0.2	0.3	0.4	0.5
Weeded	2.68 A	2.68 A	2.68 A	2.68 A
Non-weeded	0.73 B	0.73 B	0.73 B	0.73 B
Mixture	2.15 bA	2.66 aA	3.22 aA	2.84 aA
Fomesafen	1.61 bB	1.57 bB	2.15 aA	2.68 aA
Fluazifop-p-butyl	1.81 bB	1.84 bB	1.36 bB	2.58 aA
CV (%)	26.53			

Means followed by different lowercase letters in rows differ by the Tukey's test ($p \leq 0.05$), and different uppercase letters in columns differ by the Dunnett's test ($p \leq 0.05$).

From the practical point of view, in order not to affect negatively the bean crop yield when dicot weeds are controlled only with fomesafen, the recommended boom height is 0.4 to 0.5 m over target. In the control of monocot with application of fluazifop-p-butyl only, the spray height should be 0.5 m. The herbicides mixture can be recommended when the boom is adjusted to 0.3 to 0.5 m above target.

Conclusions

Common bean cultivation reduces the weeds diversity in croplands. Positioning the fomesafen sprayer boom at lower heights allows higher efficiency in the control of dicot plants.

Application of fomesafen + fluazifop-p-butil herbicides reduces the diversity of invasive weeds in bean crops. Application of different herbicides and different boom heights can change the weeds infestation and the productivity gains.

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