ORIGINAL ARTICLE

Naphthalic anhydride increases tolerance of common bean to herbicides

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Abstract

The aim of this work was to evaluate the use of the naphthalic anhydride safener on the protection of common bean cultivars BRS-Estilo (carioca) and BRS-Esplendor (black) from negative effects of herbicides. Two experiments were conducted, one for each cultivar in a complete randomized design with five replications, in a 6 × 3 factorial scheme, with six herbicide treatments: bentazon, fluazifop-P + fomesafen, bentazon + imazamox, fomesafen, cloransulam, and control without application, and three naphthalic anhydride treatments: without application, foliar application, and application via seed treatment. Visible injuries at 7, 14 and 21 days after application, photosystem II electron transport rate, and plant dry weight were evaluated. The naphthalic anhydride applied via foliar, and seed treatment reduced significantly the visible injuries in relation to the control when using the herbicides bentazon, fluazifop-P + fomesafen, bentazon + imazamox, and cloransulam. The photosystem II electron transport rate was protected by anhydride applied via foliar and seed treatment when using the herbicides bentazon, fluazifop-P + fomesafen and bentazon + + imazamox. The application of naphthalic anhydride via seed treatment protected the BRS-Estilo and BRS-Esplendor common bean cultivars, with no reductions in the plant dry weight when using the herbicides fluazifop-P + fomesafen, and fomesafen. The use of naphthalic anhydride via seed treatment and foliar application protected BRS-Estilo and BRS-Esplendor common bean cultivars, from the negative effects of fluazifop-P + fomesafen and fomesafen herbicides. Thus, this practice has potential to be used in common beans.

Keywords: electron transport, *Phaseolus vulgaris*, protection, safeners

Introduction

Common bean is a staple food for the Brazilian population, and a source of income for large and small producers throughout the country. The three common bean (*Phaseolus vulgaris* L.) crops in the 2018–2019 crop season can reach approximately three million seeded hectares, producing approximately three million tons, and average yield of 978 kg · ha^{-1}, which is low when compared with some other producing regions, such as the South Brazil, whose average yield is 1,705 kg · ha^{-1} (Conab 2018).

The competition between plants and weeds is one of the factors that decreases yield in common bean. According to Salgado *et al.* (2007), common bean yield begins to be affected 17 days after emergence when coexisting with weeds. There can be a reduction of 67% when grown with weeds during the whole crop cycle. According to Scholten *et al.* (2011), weeds reduce common bean yield from 42 to 63%, depending on the crop spacing used and the weed density in the area.

The use of herbicides has increased over the last years due to losses caused by weeds in common bean yield (Procópio *et al.* 2009). However, the herbicides applied in common bean crops present selectivity problems. According to Procópio *et al.* (2009), common bean cultivars have high diversity of sensitivity to herbicides. Several scientific papers report visible injuries in common bean cultivars (carioca, black, and cowpea) caused by herbicides, and decreased yield of 9 to 48% due to the use of herbicides (fluazifop-P + fomesafen, bentazon, fomesafen, imazamox, fomesafen + imazamox, and fomesafen + cloransulam), even when using the recommended rates (Wilson 2005; Machado *et al.* 2006; Araújo *et al.* 2008; Procópio *et al.* 2009; Fontes *et al.* 2013).

Thus, a selectivity technique for the application of herbicides, especially those with high weed control efficiency, without causing phytotoxicity to crops would provide an alternative weed control strategy for farmers. Safeners can be used to protect plants from the negative effects of herbicides (Galon *et al.* 2011), and naphthalic anhydride, the first safener to be developed (Davies and Caseley 1999), is the most common one used in crops. The use of this safener with herbicides in crops has already been reported in soybean with metribuzin, and in cotton with clomazone (Yazbek Jr. *et al.* 2004), but not in common bean. Naphthalic anhydride increases the enzymes glutathione-S-transferase (GST) and cytochrome P-450 monoxigenase in plants (Ferreira and Cataneo 2001; Hirase and Molin 2001; Abu-Qare and Duncan 2002). The GST and cytochrome P-450 enzymes combine with the herbicides and their derivatives, resulting in catalysis of these compounds and detoxification of the herbicide in the plants (Ferreira and Cataneo 2001). The greater selectivity of the herbicide generated by using safeners is shown by the decrease in visible injuries, and increase in dry weight and grain yield of common bean plants; however, studies showing the protection of the photosystem II electron transport rate (ETR) cannot be found.

Thus, studies evaluating the potential of the naphthalic anhydride safener on the protection of common bean plants from visible injuries caused by herbicides, and its protective effect on the ETR, are necessary for this species. The aim of this study was to evaluate the use of the naphthalic anhydride safener via seed treatment and foliar application on the protection of common bean plants from negative effects of herbicides.

Materials and Methods

Experimental conditions

Two experiments were conducted with the same treatments, cultivars and evaluations, at different times in 2016, between September and December, in a greenhouse (22°50'31.8"S 48°25'30.5"W) of the Núcleo de Pesquisas Avançadas em Matologia (Nupam), located in the Universidade Estadual de São Paulo 'Júlio de Mesquita Filho' (UNESP), Faculdade de Ciências Agronômicas, Botucatu, São Paulo (SP), Brazil.

The first experiment was carried out with the BRS-Esplendor black common bean cultivar, and the second with the BRS-Estilo carioca common bean cultivar. The plant architecture of both cultivars is erect, and they are widely used in Brazil (Del Peloso and Melo 2005). The cultivars, which are used by farmers, were chosen because of their economic importance.

The experiments were conducted in a complete randomized design with five replications, in a 6 × 3 factorial scheme, with six herbicide treatments (five herbicides and one control) (Table 1), and three safener (naphthalic anhydride) treatments (without application, foliar application, and application via seed treatment).

Naphthalic anhydride was foliarly applied 5 days before the application of the herbicides at a rate of 25 $g \cdot ha^{-1}$ of the product F-80 Seed Protectant™ (91% naphthalic anhydride, FMC Corporation Agricultural Chemical Group, EUA). For seed treatment, the product was used at a rate of 0.5% ($w \cdot w^{-1}$) about 2 hours before sowing, and homogenized with the seeds in a plastic bag.

The experimental units consisted of 4-liter pots filled with a substrate [Carolina®, Carolina Soil do Brasil, Santa Cruz do Sul – Rio Grande do Sul (RS), Brazil], which consisted of sphagnum peat, vermiculite,

Table 1. Characteristics of the herbicide and rates used in the treatments

Chemical name	Trade name	Mechanism of action	Rate [$l/g \cdot ha^{-1}$]	Rate [$g \cdot ha^{-1}$ a.i.]
Control	–	–	–	–
Bentazon*	Basagran 480	Photosystem II	2.0	960
Fluazifop-p-butyl + fomesafen**	Fusiflex	ACCase + Protox	2.0	250 + 250
Bentazon + imazamox*	Amplo	Photosystem II + ALS	1.0	600 + 28
Fomesafen**	Flex	Protox	1.0	250
Cloransulam-methyl**	Pacto	ALS	47.6	30

*the mineral oil adjuvant was used at 0.5% $v\ v^{-1}$, **the non-ionic adjuvant was used at rate of 0.2%

and carbonized rice husk, with a pH of 5.7 ± 0.5. Ten common bean seeds were sown in each pot, and the plants were thinned after emergence, leaving one plant per pot. The pots were irrigated daily without the water contacting the leaves of the plants, in order to maintain field capacity. The conditions in the greenhouse were: average temperatures around 26ºC ± 2 and relative humidity of 60% in natural light conditions.

The application of herbicides and foliar application of naphthalic anhydride were carried out when the common bean plants were in the V3 stage (first trifoliate leaf in the plant), approximately 25 days after emergence. The application was carried out with a stationary sprayer equipped with a spray bar with four TeeJet XR 110.02 nozzles spaced 0.5 m apart, positioned at 0.5 m high from the plants, with a constant pressure of 2 bar, and spray velocity of 1 m · s^{-1}, representing a volume of 200 l · ha^{-1}. The average temperature and relative humidity at the time of application of the herbicides were 24ºC and 68% (BRS-Esplendor), and 20°C and 71% (BRS-Estilo), respectively.

Data collection

Visible injuries in the plants were analyzed at 7, 14 and 21 days after application (DAA), using a 0–100% scale, in which 0 represented a plant without injuries, and 100% represented a dead plant (SBCPD 1995). The electron transport rate (ETR) was evaluated at 1, 2, 4, 8, 12 and 16 DAA using a portable fluorometer (Multi-Mode Chlorophyll Fluorometer OS5p, Opti Sciences, Hudson, USA), using the yield protocol (Araldi *et al.* 2015), with readings in three points of the youngest, fully expanded leaf of each replication. The ETR data of the treatment without application was used as 100%, and was compared with the treatments applied. The plants were cut at 28 DAA, stored in paper bags and placed in a forced air circulation oven at 60°C, until constant weight. The plant dry weight was evaluated using a precision scale accuracy (0.0001 g).

Data analysis

Data were subjected to analysis of variance, and significant means to the *F* test ($p \leq 0.05$), and compared by the Tukey test ($p \leq 0.05$). The cultivars were analyzed separately. The ETR data were presented in percentages in relation to the control that received each method of application of naphthalic anhydride in comparison with each herbicide. The means of the ETR were presented as mean ± confidence interval using the equation $CI = (t \times SD)/\sqrt{n}$, wherein CI is the confidence interval, t is the t value at 5% probability, SD is the standard deviation, and $\sqrt{n}$ is the square root of the number of replications. The software Sisvar® (Ferreira 2014) was used.

Results and Discussion

Visible injury

According to the F values, the interaction between herbicides and naphthalic anhydride was significant for the data of visible injuries in the plants of the BRS-Estilo and BRS-Esplendor cultivars at 7, 14 and 21 days after application (DAA) (Table 2).

The use of naphthalic anhydride did not reduce significantly the visible injuries in the BRS-Estilo cultivar at 7 DAA, regardless of the application method, except in the treatment with the herbicide fluazifop-P + fomesafen, in which the use of anhydride naphthalic via seed treatment reduced significantly the injuries, compared to the herbicide applied without the safener and with naphthalic anhydride foliar application. The naphthalic anhydride applied via foliar and seed treatment at 14 DAA significantly reduced the visible injuries in relation to the control when using the herbicides bentazon, fluazifop-P + fomesafen, bentazon + + imazamox, and cloransulam (Table 2) for cultivar BRS. The most significant reduction was found with herbicide fluazifop-P + fomesafen, when the naphthalic anhydride was applied via foliar, and seed treatment reduced by 14 and 19% the visible injuries, respectively (Table 2).

The naphthalic anhydride at 7 DAA reduced significantly the percentage of visible injuries in the BRS-Esplendor cultivar, via seed treatment, reducing by 42% the injuries caused by the herbicide fluazifop-P + fomesafen, when compared to the treatment without application (Table 2). However, both forms of naphthalic anhydride application reduced the injuries caused by the application of the herbicide fluazifop-P + fomesafen by approximately 10% at 14 DAA in BRS-Esplendor cultivar (Table 2). The use of naphthalic anhydride applied via foliar, and seed treatment at 21 DAA decreased the visible injuries caused by the herbicides fluazifop-P + fomesafen, and cloransulam in both common bean cultivars (Table 2).

The results of the present work may suggest that the use of naphthalic anhydride increases the selectivity of the herbicides in the cultivars of common bean which were used in this work. These results may be connected to the use of safeners, the rapid metabolization of the herbicides, and the interaction between the safeners and herbicides at the sites of action (Galon *et al.* 2011). Naphthalic anhydride can catalyze reactions that lead to rapid metabolic detoxification of herbicides by enzymes of the P-450 cytochrome complex, and reactions due to their connection with the glutathione S-transferase (GST) and glucosyltransferase enzymes (Cataneo *et al.* 2013).

According to the effects of the herbicides on the BRS-Estilo and BRS-Esplendor cultivars at 7, 14 and

Table 2. Percentage of visible injuries in BRS-Estilo and BRS-Esplendor common bean cultivars at 7, 14 and 21 DAA of herbicides with application of naphthalic anhydride via foliar and via seed treatment, and without the use of naphthalic anhydride*

Herbicide	BRS-Estilo			BRS-Esplendor		
	Naphthalic anhydride					
	without application	foliar application	seed treatment	without application	foliar application	seed treatment
Injury of 7 DAA						
Control	0.0 Bb	2.2 Ab	1.7 Ab	0.0 Bc	3.5 Ab	0.0 Bc
Bentazon	2.5 Ab	2.5 Ab	2.0 Ab	2.5 Ab	2.5 Ab	2.5 Ab
Fluazifop + Fomesafen	12.5 Aa	10.5 Aa	7.5 Ba	13.0 Aa	12.5 Aa	7.5 Ba
Bentazon + Imazamox	2.5 Ab	2.5 Ab	2.0 Ab	2.5 Ab	2.5 Ab	2.5 Ab
Fomesafen	2.5 Ab	2.5 Ab	1.7 Ab	2.5 Ab	2.5 Ab	1.7 Abc
Cloransulam	2.5 Ab	2.5 Ab	2.0 Ab	2.5 Ab	2.5 Ab	1.5 Abc
MSD row		1.31			1.95	
MSD column		2.83			2.39	
F Herbicides (A)		67.06**			122.69**	
F naphthalic anhydride (B)		7.09**			14.13**	
F A × B		4.63**			5.63**	
CV%		17.40			11.82	
Injury of 14 DAA						
Control	0.0 Ad	0.0 Ad	0.0 Ac	0.0 Ad	0.0 Ab	0.0 Ab
Bentazon	4.0 Ac	1.2 ABcd	0.2 Bc	5.2 Ac	0.2 Bb	0.0 Bb
Fluazifop + Fomesafen	33.7 Aa	19.2 Ba	14.7 Ca	22.5 Aa	14.0 Ba	12.0 Ba
Bentazon + Imazamox	6.2 Ac	3.2 Bbcd	4.2 ABb	5.0 Ac	0.7 Bb	0.5 Bb
Fomesafen	4.0 Ac	4.5 Abc	3.5 Aab	6.7 Ac	4.0 ABb	0.7 Bb
Cloransulam	11.2 Ab	5.5 Bb	2.7 Bab	11.7 Ab	3.2 Bb	0.0 Bb
MSD row		2.92			3.30	
MSD column		3.57			4.05	
F Herbicides (A)		271.94**			108.01**	
F naphthalic anhydride (B)		70.31**			69.84**	
F A × B		19.66**			5.60**	
CV%		16.02			14.26	
Injury of 21 DAA						
Control	0.0 Ac	0.0 Ab	0.0 Ab	0.0 Ac	0.0 Ab	0.0 Ab
Bentazon	0.0 Ac	0.0 Ab	0.0 Ab	0.0 Ac	0.0 Ab	0.0 Ab
Fluazifop + Fomesafen	16.5 Aa	11.0 Ba	9.0 Ca	13.7 Aa	7.5 Ba	2.5 Ca
Bentazon + Imazamox	0.0 Ac	0.0 Ab	0.0 Ab	0.0 Ac	0.0 Ab	0.0 Ab
Fomesafen	0.0 Ac	0.0 Ab	0.0 Ab	0.0 Ac	0.0 Ab	0.0 Ab
Cloransulam	6.0 Ab	0.0 Bb	0.0 Bb	6.2 Ab	0.0 Bb	0.0 Bb
MSD row		1.15			1.21	
MSD column		1.42			1.49	
F Herbicides (A)		614.71**			237.27**	
F naphthalic anhydride (B)		76.44**			106.36**	
F A × B		31.51**			49.09*	
CV%		18.82			12.82	

*means followed by the same uppercase letters in the row, and same lowercase letters in the column not differ by Tukey's test at 5% probability, **significant at 5% probability by F test, MSD – minimum significant difference

21 DAA, in both application methods of naphthalic anhydride, the herbicide fluazifop-P + fomesafen caused greater visible injuries, differing significantly from the other herbicides tested and the control (Table 2). The other herbicides caused no severe visible injuries in the evaluated cultivars. Similar to the injury data obtained in this work for the herbicide fluazifop-P + fomesafen, other authors have reported visible injuries of 9 to 35% caused by the herbicide fluazifop-P + fomesafen (40–100 + 50–125 g · ha^{-1} a.i) in common bean crops (Machado *et al.* 2006; Fontes *et al.* 2013; Pereira *et al.* 2015). This demonstrates the importance and necessity of protecting common bean crops, and the a potential use of naphthalic anhydride.

Electron transport rate (ETR)

The photosystem II electron transport rate (ETR) found in plants treated with naphthalic anhydride (both application methods) and without application of herbicides were similar to the control without any application (Fig. 1A and B). The ETR found with foliar application of naphthalic anhydride were close to 100%, and the ETR found via seed treatment were higher than the control without any application 2 to 3% (BRS-Estilo), and 3 to 4% (BRS-Esplendor) (Fig. 1A and B) denoting that naphthalic anhydride at a rate of 0.5% (w · w^{-1}) had no toxic effects on common bean crops.

The application of fluazifop-P + fomesafen in plants without naphthalic anhydride reduced the ETR by 30% (BRS-Estilo at 1 DAA), and 8% (BRS-Esplendor at 2 DAA); and the ETR returned to values close to the ones found in the control without application only at 8 DAA for both cultivars (Fig. 1C and D).

The application of fomesafen in plants without treatment with naphthalic anhydride decreased the ETR by 6% (BRS-Estilo) and 8% (BRS-Esplendor) at 1 DAA (Fig. 1E and F). The herbicides fluazifop-P + fomesafen, and fomesafen, in general, did not affect the ETR from 8 DAA, presenting similar values to the ones found in the control. These herbicides had no effect on the ETR regardless of the anhydride application, when compared to the control, denoting the protective effect of naphthalic anhydride on common bean plants.

The possible explanation for the protection of naphthalic anhydride for the herbicides fluazifop-P + + fomesafen, and fomesafen, on ETR is based on increases of the enzymes glutathione-S-transferase (GST) and cytochrome P-450 monoxigenase (Ferreira and Cataneo 2001; Hirase and Molin 2001; Abu-Qare and Duncan 2002), and thus greater degradation of herbicides. There are no reports of specific degradation of the herbicide fluazifop-P + fomesafen, but herbicides of the same chemical group of the fomesafen, such as oxyfluorfen, acifluorophen, and fluorodifen, are degraded by higher GST activity in corn, wheat, and rice crops (Cataneo *et al.* 2002; Cho and Kong 2007). However, there are reports of degradation of the fenoxaprop-ethyl and clodinafop-propargyl herbicides ACCase inhibitor herbicides of the Fop's chemical group by the GST (Aly and Schroder 2008; Cummins *et al.* 2009).

The ETR was affected significantly at 1 DAA by the herbicides bentazon, and bentazon + imazamox, regardless of the application of anhydride, but it increased quickly over a few days. The ETR of plants treated with these herbicides and naphthalic anhydride application had a greater increase in relation to the herbicides applied without the safener (Fig. 2A, B, C, and D), regardless of the common bean cultivar used. The herbicide bentazon inhibits electron flow at PSII, decreasing rapidly the ETR; this decrease has also been reported in *Calophyllum brasiliense* (Araldi *et al.* 2015). The ETR increases after application of bentazon herbicide because the thylakoid was not damaged (Macedo *et al.* 2008).

The application of bentazon in treatments with naphthalic anhydride via seed increased the ETR of the cultivar BRS-Estilo by 30% at 4 DAA, and by approximately 10% at 8 DAA in relation to the application of bentazon without the safener (Fig. 2A). This increase was 35% at 4 DAA for the BRS-Esplendor, and like that of the BRS-Estilo at 8 DAA (Fig. 2B). The faster recovery of ETR may result in further increases in biomass, since ETR is related to plant photosynthesis (Araldi *et al.* 2015).

The application of bentazon + imazamox in treatments with naphthalic anhydride via seed treatment increased the ETR by 40% (BRS-Estilo) and by 25% (BRS- Esplendor) at 4 DAA in relation to the control without the safener (Fig. 2C and D). The application of cloransulam reduced the ETR by 5 to 8% in relation to the method of application of naphthalic anhydride in both cultivars (Fig. 2E and F). This lower reduction of ETR in naphthalic anhydride treatments can be correlated with increases in GST and P450 degradation of these herbicides (Hirase and Molin 2001; Abu-Qare and Duncan 2002; Ferreira and Cataneo 2001), resulting in fewer molecules reaching their site of action.

Chlorophyll fluorescence analysis shows the effect of herbicides on the photosynthetic performance of plants (Darwish *et al.* 2013), the mode of action of herbicides, and the sensitivity of each crop (Menegat *et al.* 2012). According to Araldi *et al.* (2011) and Araldi *et al.* (2015), the ETR can indicate the intoxication level of plants. Thus, the ETR results in the present study showed a return to its normal levels, following the pattern observed for the visible injuries. This meant greater selectivity of the herbicides in relation to the common bean cultivars studied.

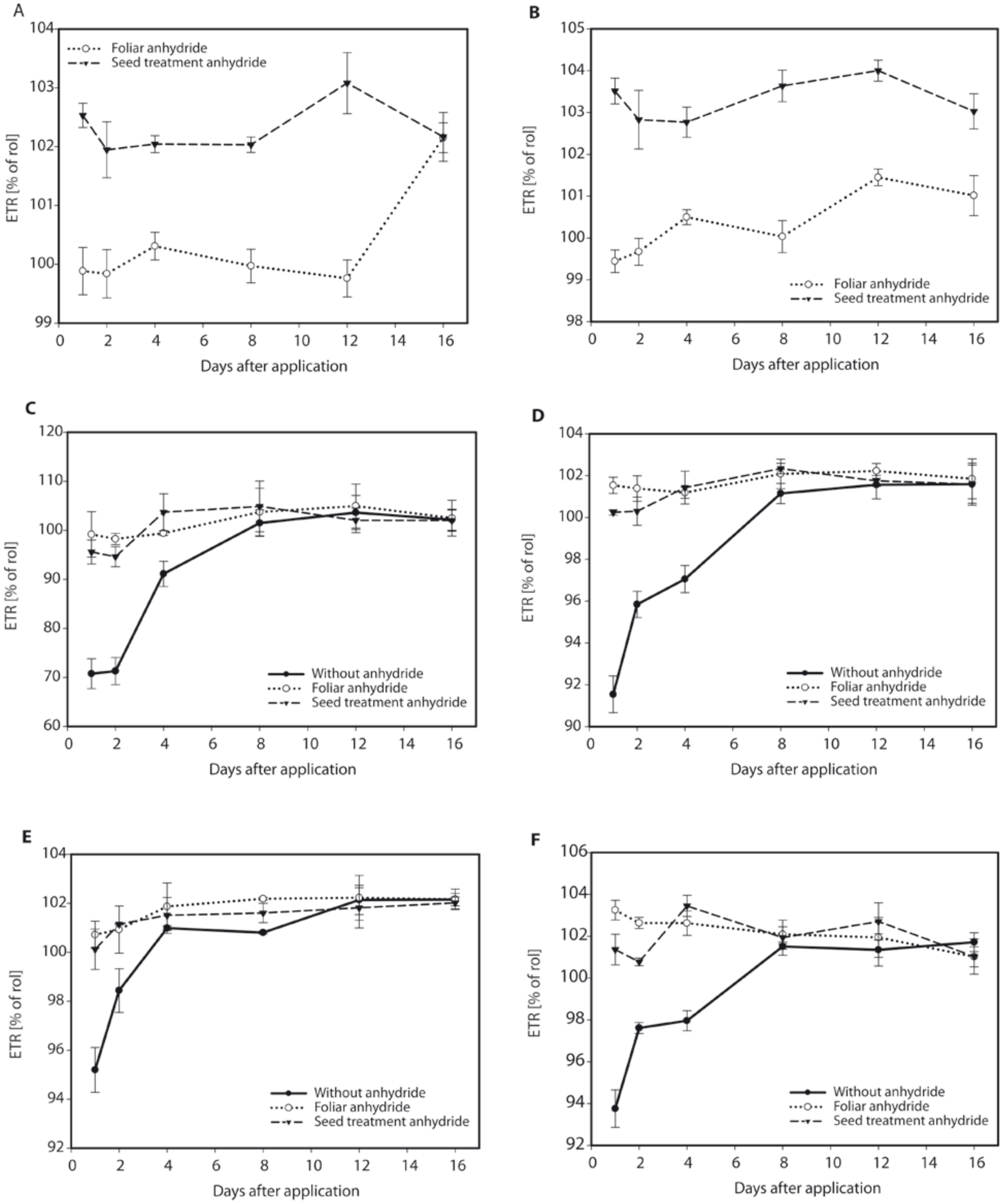

Fig 1. Percentage of electron transport rate of photosystem II (ETR) in relation to each control without application of herbicides in common bean plants of the cultivars BRS-Estilo (A, C, and E) and BRS-Esplendor (B, D, and F) at 1, 2, 4, 8, 12 and 16 DAA. Treatments without herbicide (A and B); treatments with application of fluazifop-P + fomesafen (C and D) and fomesafen (E and F), with different application methods of naphthalic anhydride

Dry mass

In general, the use of herbicides reduced the dry weight of plants of the BRS-Estilo cultivar when applied in treatments without the naphthalic anhydride; however, the plant dry weight in the treatment with fomesafen was statistically similar to the control without the safener (Table 3).

The use of cloransulam herbicide reduced plant dry weight in relation to the control without the safener to BRS-Estilo, but did not differ significantly from the other herbicides via foliar application. The herbicides fluazifop-P +

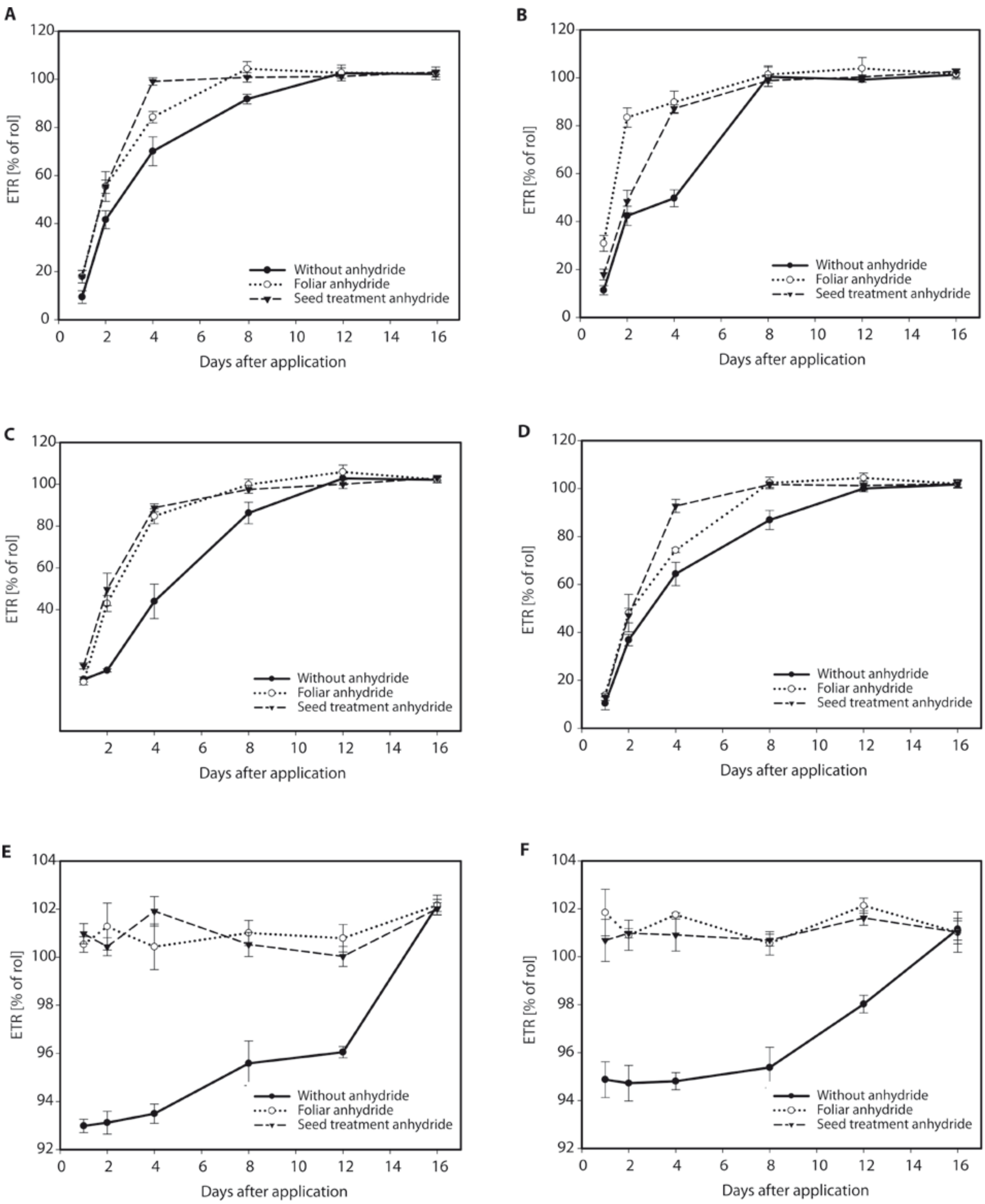

Fig 2. Percentage of electron transport rate of photosystem II (ETR) in relation to each control without application of herbicides in common bean plants of the cultivars BRS-Estilo (A, C, and E) and BRS-Esplendor (B, D, and F) at 1, 2, 4, 8, 12 and 16 DAA. Treatments with the herbicides bentazon (A and B), bentazon + imazamox (C and D) and cloransulam (E and F), with different application methods of naphthalic anhydride

+ fomesafen, bentazon + imazamox, and cloransulam decreased the dry weight of plants of the BRS-Esplendor cultivar, when compared to the control without the safener, and to the treatment with naphthalic anhydride via foliar application. The application of the herbicides with naphthalic anhydride via seed treatment did not reduce the plant dry weight when compared to the control without the safener.

The use of naphthalic anhydride via seed treatment increased by 16% the dry weight of plants of the BRS-Esplendor cultivar in treatments with fomesafen, when compared to treatment without the safener

Table 3. Plant dry weight (g · plant^{-1}) of common bean plants of the BRS-Estilo and BRS-Esplendor cultivars at 21 days after application of herbicides, with application of naphthalic anhydride via foliar and via seed treatment, and without naphthalic anhydride*

Herbicide	BRS-Estilo			BRS-Esplendor		
	Naphthalic anhydride					
	without application	foliar application	seed treatment	without application	foliar application	seed treatment
Control	7.34 Aa	7.07 Aa	7.08 Aa	6.30 Aa	6.34 Aa	6.38 Aab
Bentazon	4.81 Ab	5.00 Aab	5.01 Aab	6.03 Aab	6.00 Aab	6.61 Aab
Fluazifop-p-butyl + Fomesafen	3.55 Bb	4.96 ABab	5.62 Aab	5.20 Bbc	5.20 Bbc	6.28 Aab
Bentazon + Imazamox	4.66 Ab	4.72 Aab	4.88 Aab	4.77 Ac	4.97 Ac	5.57 Ab
Fomesafen	5.03 Aab	5.00 Aab	5.90 Aab	6.01 Bab	6.18 ABab	6.97 Aa
Cloransulam-methyl	4.31 Ab	4.24 Ab	4.30 Ab	5.18 Abc	5.26 Abc	5.60 Ab
MSD row		2.01			0.87	
MSD column		2.46			1.07	
F Herbicides (A)		11.43**			15.31**	
F Naphthalic anhydride (B)		0.18 ns			4.80**	
F A x B		0.075 ns			0.88 ns	
CV%		13.37			8.92	

*means followed by the same uppercase letters in the row, and the same lowercase letters in the column not differ by Tukey's test at 5% probability, **significant at 5% probability by F test, ns – not significant, MSD – minimum significant difference

(Table 3). This increase in biomass may be connected to the maintenance of normal levels of ETR (Araldi *et al.* 2015), even after the application of these herbicides (Fig. 1E and F). The use of naphthalic anhydride via seed treatment has also shown a protective effect in other crops, such as maize, rice, sorghum, pea, soybean, and cotton (Yazbek Jr. *et al.* 2004; Galon *et al.* 2011; Maciel *et al.* 2012). The use of naphthalic anhydride did not protect the plants from the negative effects of the other herbicides on the plant dry weight of common bean.

Thus, the use of naphthalic anhydride only via seed treatment can increase the selectivity of the fluazifop-P + fomesafen, and fomesafen herbicides to common bean crops, especially for the BRS-Estilo and BRS-Esplendor cultivars. This effect is probably due to the high activity of the GST enzyme in the degradation of these herbicides in the plant. However, further research should be developed for the recommendation of naphthalic anhydride in common beans.

The use of naphthalic anhydride via seed treatment and foliar application protected BRS-Estilo and BRS-Esplendor common bean cultivars from the negative effects of fluazifop-P + fomesafen and fomesafen herbicides. Thus, this practice can potentially be used in common beans to make weed control more selective in this crop.

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