Original Article

WEEDS CONTROL WITH HERBICIDES APPLIED IN PRE-EMERGENCE IN POTATO CULTIVATION

CONTROLE DE PLANTAS DANINHAS COM HERBICIDAS APLICADOS EM PRÉ-EMERGÊNCIA NA CULTURA DA BATATA

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ABSTRACT: There are few pre-emergent herbicides that are selective and registered for potato crop. Thus, this study aimed to evaluate the control of weeds with pre-emergent herbicides, as well as their effects on potato crop. The treatments consisted of a control, a hoed control (manual weed removal), metribuzin (240 g ha^{-1}), linuron (450 g ha^{-1}), diclosulan (25,2 g ha^{-1}), imazetapir (700 g ha^{-1}), prometryn (1000 g ha^{-1}), clomazone + carfentrazone (300 + 7.5 g ha^{-1}), clomazone + carfentrazone (600 + 15 g ha^{-1}) and sulfentrazone (125 g ha^{-1}). A randomized complete block design (RCB) was used with four replications. Largest stem, phytotoxicity, and weed control were measured at 10 and 30 days after stem emergence (DAE), which coincided with the periods before and after hilling, respectively. Soluble solids content, yield and tuber classification were determined after harvesting. The results were compared by a Tukey test (5% significance). The evaluated herbicides did not affect the number of stems per meter and length of the largest stem. Regarding weed control, clomazone + carfentrazone (600 + 15 g ha^{-1}) controlled *C. benghalensis* (Behghal dayflower)*, E. heterophyla* (milkweed) and *R. raphanistrum* (wild radish)*,* better than the other herbicides, which provided little control over *E. heterophyla* and *R. raphanistrum.* The strongest symptoms of phytotoxicity were observed with metribuzin, diclosulan and imazethapyr, which were also associated with lower levels of soluble solids, total yield, and yield of "special" tubers. Therefore, these herbicides were considered less selective. Linuron and clomazone did not produce phytotoxicity, did not affect levels of soluble solids, and did not reduce total or "special" tuber yield, and were thus considered more selective for this potato cultivar.

KEYWORDS: *Solanum tuberosum*. Herbicides. Selectivity.

INTRODUCTION

There are few pre-emergent herbicides that are selective and registered for potato crop, this becomes more difficult the control of weed species. Metribuzin is one of the principle herbicides used to control mono and dicotyledonous weeds in potato crops, but may be phytotoxic to some potato varieties (RODRIGUES; ALMEIDA, 2011).

Weed management interventions are required during the planting and growth stages of potato crops (*Solanum tuberosum* L.). These undesirable plants can be controlled by removing clumps, tussocks, or escapes, by the mechanical method of hilling, or by herbicides. Nevertheless, chemical controls predominate in commercial potato production (CONSTANTIN, 2011) because main weed effects are due to reductions in yield and quality.

The weed interference period for the potato crop determined the 20-day period prior to interference (PPI) and the 21-day total period of interference prevention (TPIP) (COSTA et al., 2008). The critical weed-free period for Russet Norkotah potato wasfrom 10 - 24 days after emergence where the crop should remain free of weeds to only suffer a yield reduction not greater than 5% (HUTCHINSON, 2014).

Given that most of the herbicides registered for potato crops are desiccants or only control post-emergence grasses, pre-emergence herbicides are extremely important because they allow the crop to complete initial development without competition from weeds. Furthermore, using pre-emergence herbicides with prolonged residual effects helps improve the efficacy of weed control during this critical period of competition (INOUE et al., 2012).

Therefore, this study aimed to evaluate the control of weeds with pre-emergent herbicides, as well as their effects on potato crop.

MATERIAL AND METHODS

The experiment was conducted in a commercial potato field with central pivot irrigation, located in the 19°19'43''S, 47°23'44'' W. The soil was classified as a Oxysol Red with a clayey texture

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(52% clay) (EMBRAPA, 2013), and chemical characteristics were described following table 01.

Table 1. Chemical characteristics soil at a depth of 0.0-0.2 m

pH	P Resina	S	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	T	V
$CaCl_2$	-$mgdm^{-3}$ --		----------	$cmol_c dm^{-3}$	----------					%
5,6	164	8,0	0,18	3,5	0,7	0,0	2,50	4,41	6,91	64

pH $CaCl_2$; Ca, Mg e Al - Extrator KCl 1 mol L-1;P; K - Extrator Mehlich (HCl 0,05 N + H_2SO_4 0,025 N); SB -Soma de bases; H +Al- acidez potencial conforme Embrapa (1999).

The soil was prepared conventionally by plowing once and harrowing twice. Furrows were then plowed to a depth of 0.30m using a tractorized disc furrow. Afterwards, the soil was fertilized with 50-300-80 kg ha^{-1} of N-P_2O_5-K_2O, respectively (SOUZA; LOBATO, 2004). The potatoes were planted mechanically on August 13, 2014 at a depth of 0.12m with spacing of 0.3 m between plants and 0.8 m between rows. . The Innovator cultivar was used which has a 120-day cycle and is intended for the food processing industry

The experiment was set up in a randomized complete block design with ten treatments and four replicates. The treatments were: T1 = Control, T2 = Hoed control, T3=0.5 L ha^{-1} Sencor (240 g ha^{-1} metribuzin), T4=1.0 L ha^{-1} Afalon 450 SC (450 g ha^{-1} linuron), T5= 0.03 L ha^{-1} Spider (25.2 g ha^{-1} diclosulan), T6=1.0 L ha^{-1} Vezir (700 g ha^{-1} imazethapyr), T7= 2.0 L ha^{-1} Gesagard (1000 g ha^{-1} prometryn), T8= 0.5 L ha^{-1} Profit (300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone), T9= 1.0 L ha^{-1} Profit (600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone), T10= 0.25 L ha^{-1} Boral 500 SC (125 g ha^{-1} sulfentrazone). Each experimental plot measured 30 m^2 (3 x 10 m), encompassing an evaluation area of 12.8 m^2

While the herbicides Spider, Vezir, Profit and Boral 500 SC are not registered potato cultivation, they are used for soybeans, which frequently precede potato crops in irrigated areas. Nevertheless, little is known about the effect of these herbicides on potato crops.

The treatments were applied one day before planting, at the pre-emergent stage of the crop and weeds. The control was not submitted to any method of weed-control; however, weeds were removed from the hoed-control by hoeing. The herbicides were applied in the morning (between 7:00 and 8:35 am). The applications were performed using a compressed air sprayer (pressurized to 2.5 bar) connected to a 3m bar with six flat-jet nozzles (XR110.02), spaced 0.5m, and spraying 200 L ha^{-1}.

Potato stems emerged ten days after the herbicide applications. Hilling was conducted 20 days after emergence. Full crop development (when the potato stems completely covered the ground) occurred 35 days after emergence. The potato stems were desiccated at 105 days after emergence using a non-selective contact herbicide (Gramoxone 2,0 L ha^{-1}) and the potatoes were harvested at 120 days after emergence.

The following variables were analyzed: herbicide phytotoxicity weed control were performed at ten and thirty days after emergence (DAE), The tubers were harvested at the end of the crop cycle and then productivity, commercial classification and soluble solids content were determined.Yield of tubers classified by their greatest transverse diameter (42 to 70 mm (special), 33 to 42 mm (first) and 28 to 33 mm (second)).

The results were submitted to analysis of variance using the statistical program SISVAR (FERREIRA, 2014). When an F test was significant, the averages were compared by the Scott Knott test at 5% significance.

RESULTS AND DISCUSSION

At 10 DAE, T5= diclosulan (25.2 g ha^{-1}) caused the greatest phytotoxicity (visual damage) in the potato crop followed T6=imazethapir (700 g ha^{-1}) and T7=prometryn (1000 g ha^{-1}). The only herbicides that caused potato crop phytotoxicity at 30 DAE, were diclosulan (25.2 g ha^{-1}). The symptoms caused by these products persisted from the beginning of crop development to 30 DAE (Figure 01).

T4=Linuron (450 g ha^{-1}), T10=Sulfentrazone(125 g ha^{-1}) and T8 and T9=clomazone + carfentrazone (both rates) did not cause any damage to the potato crop at either of the evaluations (Figure 01) and were thus considered the most selective for the Innovator potato cultivar

This was due the herbicides Spider (diclosulan), Vezir (imazethapyr) and Gesagard (prometryn) are not registered potato cultivation. In contrast, the Boral (sulfentrazone) are not registered too, but was metabolized probably because the dosage applied was low. Recovery of the crop over time demonstrates that the selectivity of this

herbicide for the Innovator cultivar is dependent on application rate. According to Oliveira; Bacarin (2011), a selective herbicide is one that kills or severely restricts the growth of weeds without harming the crop, assuming an acceptable level of recovery.

The plots treated with T3=metribuzin (240 g ha^{-1}) showed symptoms of damage at 10 DAE, but, showed no symptoms of damage at 30 DAE (Figure 01), demonstrating that there is a difference in selectivity for the Innovator cultivar, regarding application rate, since the Innovator cultivar recovers as it develops . A susceptible potato variety does not break the herbicide down quickly enough or at all before injury symptoms.

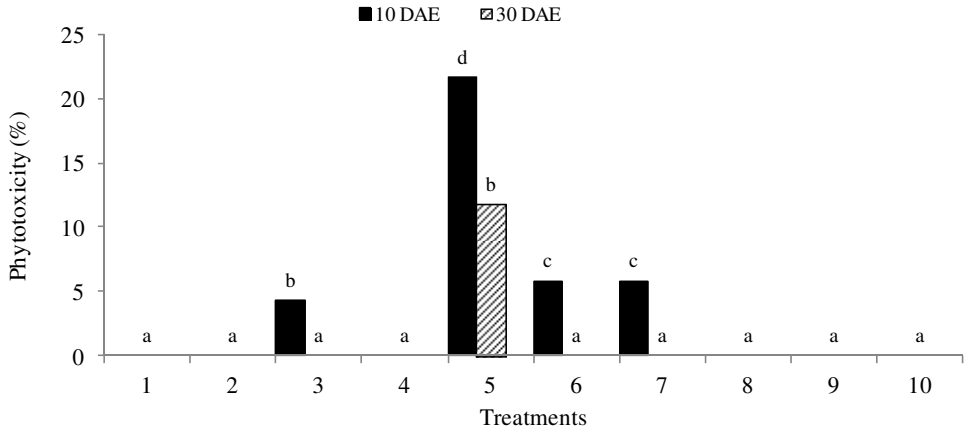

Figure 1. Phytoxicity in potato plants caused by pre-emergence herbicide applications (Perdizes, MG, Brazil - August, 2014).Means followed by unique letters within a column differ by the Scott Knott test at 5%. Herbicide induced phytoxicity symptoms (chlorosis, necrosis, discoloration, reduction of size, atrophy, and deformation) scored from zero (no symptoms) to 100 (crop death).T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

The following weeds occurred uniformly in all plots. In the control treatment was observed 6.8 plants/m^2 (10 DAE) and 12.2 plants/m^2 (30 DAE) of *Commelina benghalensis*, was observed 3.4 plants/m^2 (10 DAE) and 7.1 plants/m^2 (30 DAE) of *Euphorbia heterophylla* and was observed 2.3 plants/m^2 (10 DAE) and 5. plants/m^2 (30 DAE) of *Raphanus raphanistrum.*

Weed control in potato crops occurs within 10 - 24 days after emergence (HUTCHINSON, 2014), 21 days after planting (COSTA et al., 2008).Therefore, we evaluated weed control for 30 days after emergence, which included the stage immediately after complete crop coverage and the total period of interference prevention (TPIP).

T6=Imazetapir (700 g ha^{-1}) was the least effective at controlling *Commelina benghalensis*, followed by T4=linuron (450 g ha^{-1}). The other products provided 100% efficacy in controlling this species (Figure 2). The most effective control of *Euphorbia heterophylla* (control of 100%) were T5=Diclosulan (25.2 g ha^{-1}), T6=imazetapir (700 g ha^{-1}) and T9=clomazone + carfentrazone (600 + 15 g ha^{-1}). The T7=Prometryn(1000 g ha^{-1}) showed intermediate efficacy in both evaluations(77% 10 DAE and 73% 30DAE) while the remaining products showed low efficacy (Figure 3).

Scariot et al. (2013) studied pre-emergence herbicides in cassava and found that sulfentrazone (600 g ha^{-1}), and mixtures of clomazone + flumioxazin (900 + 50 g ha^{-1}), clomazone + sulfentrazone (900 + 500 g ha^{-1}), and clomazone + S-metolachlor (900 + 1.440 g ha^{-1}) were the most effective at controlling *Commelina benghalensis* and *Euphorbia heterophylla.*

The most effective control 100% against *Raphanus raphanistrum* was provided by T9=clomazone + carfentrazone (600 + 15 g ha^{-1}). The remaining products showed limited control efficacy (<60%) (Figure 04). This study the herbicide diclosulam (25.2 g ha^{-1}) provided control 23% (10 DAE) and 28 % (30 DAE) of *Raphanus raphanistrum* (Figure 04). Diclosulam (30, 35 and 40 g ha^{-1}) provided good control (>97%) of *Raphanus raphanistrum* (OLIVEIRA JR, 2002).

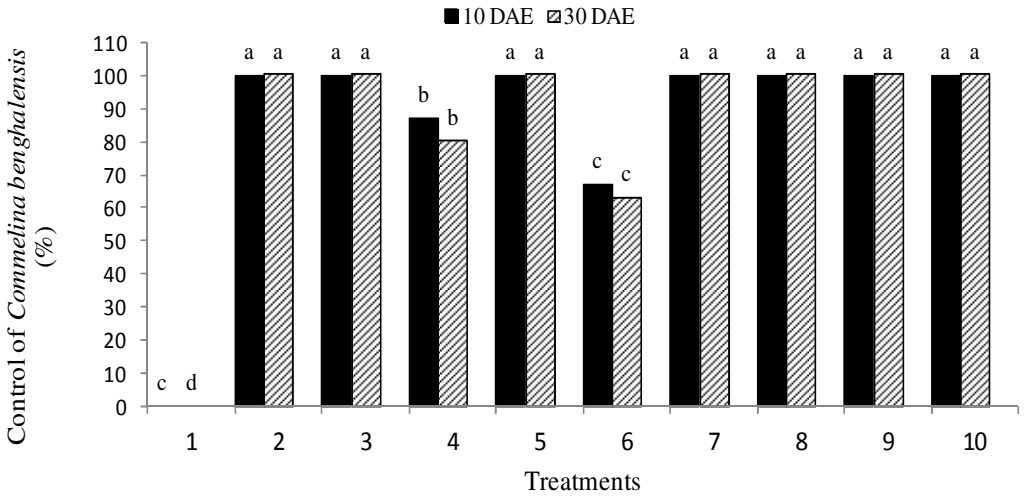

Figure 2. Control of *Commelina benghalensis,* in potatoes after pre-emergence herbicide application. (Perdizes, MG, Brazil - September, 2014).Means followed by unique letters within a column differ by the Scott Knott test at 5%. Weed control = 0 (no control) to 100 (complete weed death). T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

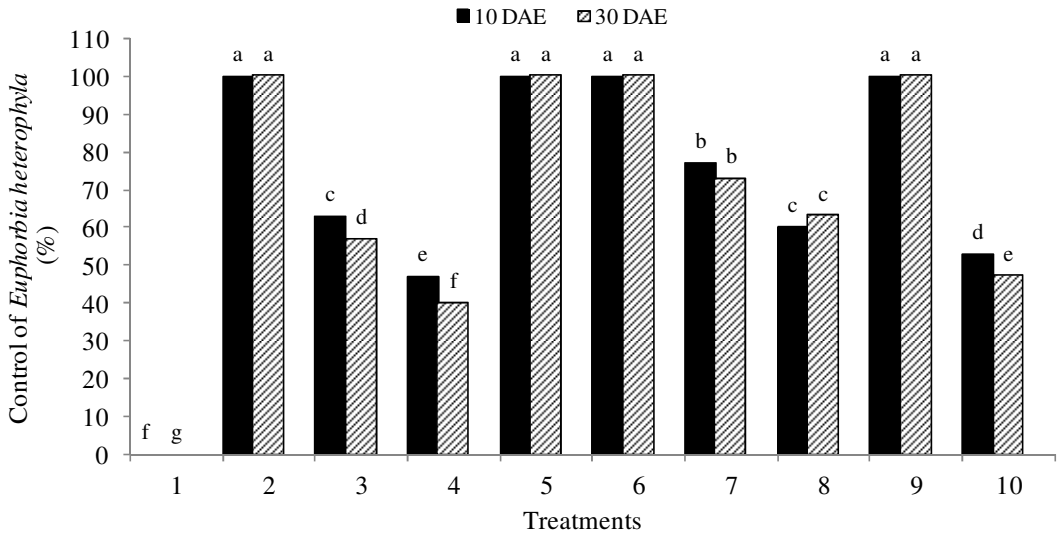

Figure 3. Control of *Euphorbia heterophyla* in potatoes after pre-emergence herbicide application. (Perdizes, MG, Brazil - September, 2014).Means followed by unique letters within a column differs by the Scott Knott test at 5%. Weed control = 0 (no control) to 100 (complete weed death). T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

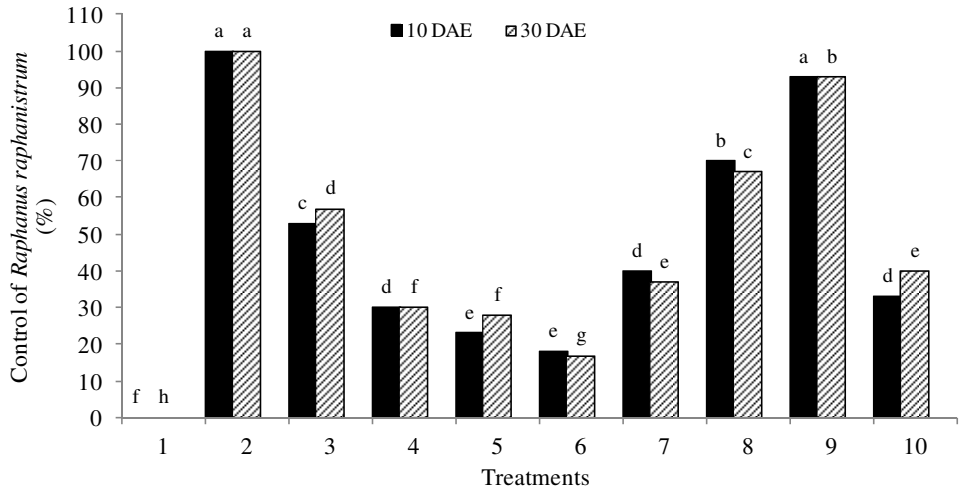

Figure 4.Control of *Raphanus raphanistrum* in potatoes after pre-emergence herbicide application. (Perdizes, MG, Brazil - September, 2014).Means followed by unique letters within a column differs by the Scott Knott test at 5%. Weed control = 0 (no control) to 100 (complete weed death). T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

Soluble solids are mainly composed of sugars and indicate the quantity of solids dissolved in the pulp (FERNANDES et al., 2010).Some of the herbicides influenced soluble solids content in the potatoes. The strongest influence was caused by T3=metribuzin (240 g ha^{-1}), T6=imazetapir (700 g ha^{-1}), T7=prometryn (1000 g ha^{-1}), and T5=diclosulan (25.2 g ha^{-1}). Diclosulan (25.2 g ha^{-1}) caused the greatest reduction in soluble solids for this cultivar. Conversely, T4=linuron (450 g ha^{-1}), T8 and T9=clomazone + carfentrazone (both application rates) did not influence levels of soluble solids (Figure 5).

The Innovator cultivar is well known and used worldwide in the processed potato industry (ABBA, 2016). Cultivars that are normally used in processed foods have higher levels of soluble solids. Thus, it is essential that any herbicide applied to control weeds does not affect the soluble solids content of potatoes.

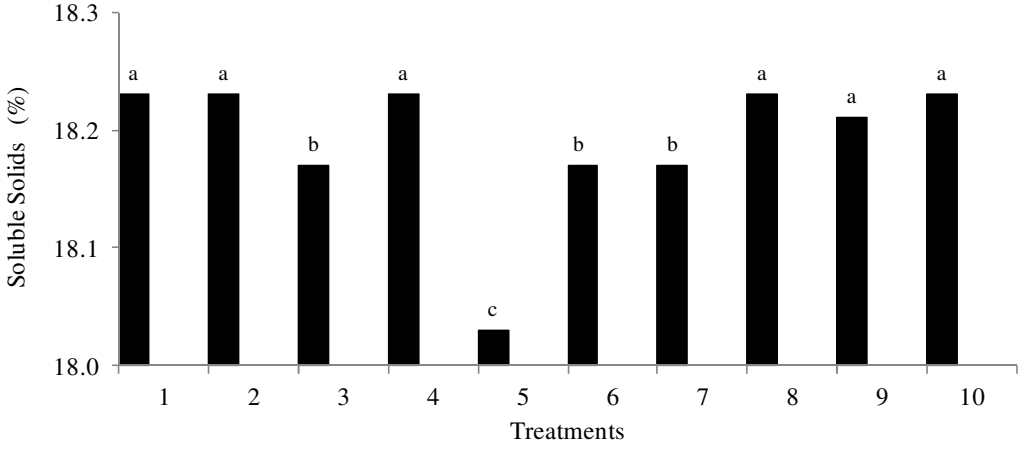

Figure 5. Soluble solids levels in potatoes as a function of pre-emergence herbicide applications. (Perdizes, MG, Brazil - September, 2014).Means followed by unique letters within a column differs by the Scott Knott test at 5%. T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

T5=Diclosulan (25.2 g ha^{-1}) showed the greatest reduction in yield, followed by T3=metribuzin (240 g ha^{-1}), and T6=imazetapir(700 g ha^{-1}). The highest yield was found in the treatment with T9=clomazone + carfentrazone (600+15 g ha^{-1}) that total yield was 5,21 t ha^{-1} more than that of the in the T1=control (neither manual weed removal nor herbicide application) (Figure 6). Regarding commercial classification, the herbicide T5=diclosulan (25.2 g ha^{-1}) produced the lowest yield of the "special" class of tubers, followed by T6=imazetapir (700 g ha^{-1}). The T8=.Clomazone + carfentrazone (300 + 7.5 g ha^{-1}) showed the best yield of this class with the "special" and "frist" class of tubers (Figure 7). This result agrees with Boydston (2010) who found that weeds caused lower potato quality, lower final yield, and required control measures.

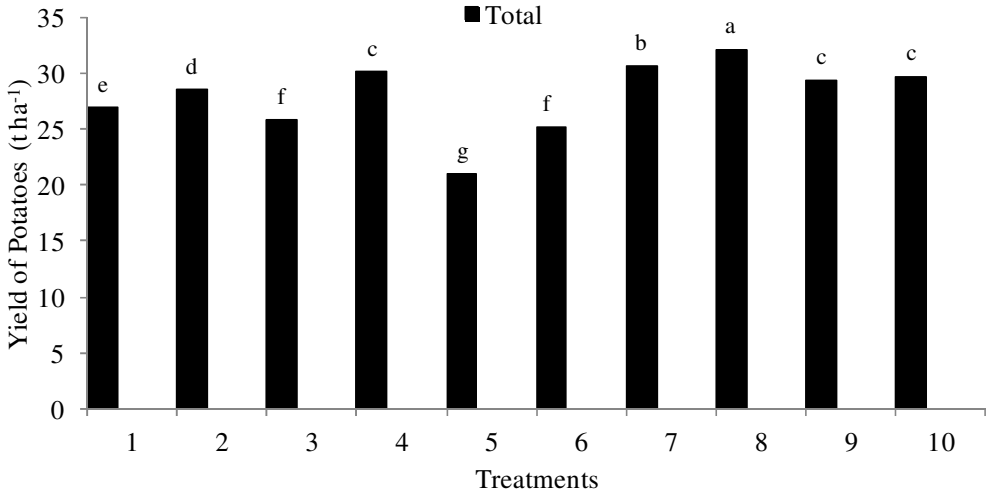

Figure 6. Yield of potatoes as a function of pre-emergence herbicide applications. (Perdizes, MG, Brazil - September, 2014). Means followed by unique letters within a column differ by the Scott Knott test at 5%. Potatoes classified by diameter: from 42 to 70 mm (Special), 33 to 42 mm (First) and 28 to 33 mm (Second). T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

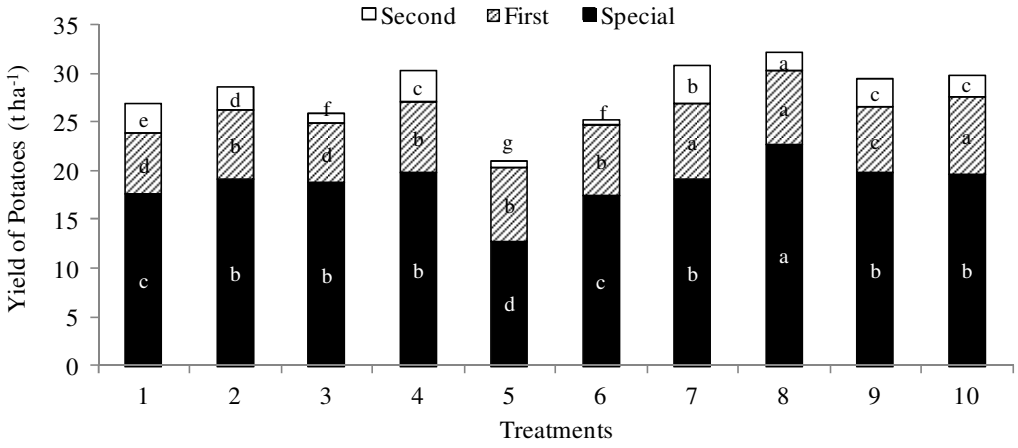

Figure 7. Commercial classification of potatoes as a function of pre-emergence herbicide applications. (Perdizes, MG, Brazil - September, 2014). Means followed by unique letters within a column differ by the Scott Knott test at 5%. Potatoes classified by diameter: from 42 to 70 mm (Special), 33 to 42 mm (First) and 28 to 33 mm (Second). T1= Control, T2 = Hoed control, T3=240 g ha^{-1} metribuzin, T4=450 g ha^{-1} linuron, T5= 25.2 g ha^{-1} diclosulan, T6=700 g ha^{-1} imazethapyr, T7=1000 g ha^{-1} prometryn, T8=300 g ha^{-1} clomazone + 7.5 g ha^{-1} carfentrazone, T9= 600 g ha^{-1} clomazone + 15 g ha^{-1} carfentrazone, T10=125 g ha^{-1} sulfentrazone.

CONCLUSIONS

Clomazone + carfentrazone (600 + 15 g ha^{-1}) controlled *C. benghalensis, E. heterophyla* and *R. raphanistrum* better than the other tested herbicides, furthermore, potato yield was 2,47 t ha^{-1} more than that of the in the control (neither manual weed removal nor herbicide application).

Clomazone + carfentrazone (300 + 7.5 g ha^{-1}) controlled *C. benghalensis* , however it was controlled 63 % of *E. heterophyla* and 67 % *R. raphanistrum.* Besides, this class with the highest of "special" class tubers and "frist" class of tubers and showed the best yield of potato yield was 5,21 t ha^{-1} more than that of the in the control

The strongest phytotoxic symptoms and lowest levels of soluble solids, total yield, and yield of "special" class tubers were observed in plots treated with diclosulan.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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RESUMO: Existem poucos herbicidas pré-emergentes registrados e seletivos à cultura da batata. Assim, este estudo teve como objetivo avaliar o controle de plantas daninhas com herbicidas pré-emergente, bem como seus efeitos na cultura da batata. Os tratamentos foram testemunha, testemunha capinada, metribuzin (240 g ha^{-1}), metribuzin (480 g ha^{-1}), linuron (450 g ha^{-1}), linuron (990 g ha^{-1}), diclosulan (25,2 g ha^{-1}), imazetapir (700 g ha^{-1}), prometryn (1000 g ha^{-1}), clomazone (360 g ha^{-1}), clomazone + carfentrazone (300 + 7,5 g ha^{-1}), clomazone + carfentrazone (600 + 15 g ha^{-1}) e sulfentrazone (125 g ha^{-1}). O delineamento experimental utilizado foi o de blocos casualizados (DBC), com quatro repetições totalizando 52 parcelas. Foram realizadas avaliações número e comprimento da maior haste, fitotoxicidade e controle de plantas daninhas aos 10 e 30 dias após emergência das hastes (DAE), que correspondem ao período antes e após da operação de amontoa, respectivamente. Após a colheita foram avaliados o teor de sólidos solúveis, produtividade e classificação. Os resultados obtidos foram comparados pelo teste de Tukey a 5% de significância A ocorrência de plantas daninhas proporcionou redução de produtividade. Os herbicidas avaliados não afetaram o número de hastes por metro e comprimento da maior haste. No controle de plantas daninhas, os herbicidase clomazone + carfentrazone (600 + 15 g ha^{-1}) controlaram *C. benghalensis, E. heterophyla e R. raphanistrum,* se destacando frente aos demais, que apresentaram baixo controle das espécies *E. heterophyla e R. raphanistrum.* Os sintomas de fitotoxicidade mais elevados foram observados com metribuzin, diclosulan e imazetapir, que também apresentaram menor teor de sólidos solúveis, produtividade total e de tubérculos classe "especial", sendo assim considerados menos seletivos. Linuron e clomazone, não proporcionaram fitotoxicidade e redução de produtividade total e de tubérculos classe "especial", não afetaram o teor de sólidos sendo considerados mais seletivos para esta cultivar.

PALAVRAS-CHAVE: *Solanum tuberosum*. Herbicidas. Seletividade.

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