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Interaction between nitrogen, soil water condition and herbicides in *Urochloa plantaginea* control in irrigated rice crop[1]

Interação entre nitrogênio, condição hídrica do solo e herbicidas no controle de *Urochloa plantaginea* no cultivo do arroz irrigado

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HIGHLIGHTS:

Management with nitrogen fertilization and irrigation depth helps some herbicides to control papua plants.
Nitrogen did not show an isolated effect for the herbicide Imazetapir, but when combined with irrigation depth it is effective.
Most of the herbicides tested in the study showed positive effects only with the use of nitrogen.

ABSTRACT: The present study sought to verify the existence of interactions between the soil water conditions, nitrogen and herbicides commonly used to control alexandergrass in irrigated rice crop. The experimental design was completely randomized, arranged in a 2 x 3 x 4 factorial scheme, corresponding to two soil water conditions (5 cm water depth and 100% soil water holding capacity [WHC]), three nitrogen doses (0, 80 and 160 kg of N ha^{-1}) and four doses of herbicides (0, 0.5, 1 and 2 times the registration dose). The herbicides evaluated were cyhalofop-butyl, imazapyr + imazapic and imazethapyr. The treatments were repeated four times. Phytotoxicity and dry mass were evaluated 28 days after application. For cyhalofop-butyl and imazapyr + imazapic, the phytotoxicity at 100% WHC and 5 cm water depth conditions was higher in treatments with nitrogen fertilization. However, for imazethapyr under the 100% WHC condition of soil increased phytotoxicity in the absence of nitrogen fertilization. For the flooded condition, from the dose of 35 g of a.i. ha^{-1}, the result in the control for the herbicide imazethapyr was optimized under the conditions of fertilization with 80 and 160 kg of N ha^{-1}. Cyhalofop-butyl and imazapyr + imazapic undergo synergistic interaction with nitrogen fertilization and water status in the control efficiency, yet with imazethapyr, the synergistic interaction only occurs under 100% of soil WHC.

Key words: soil flooding, chemical management, rice

RESUMO: Buscou-se constatar a existência de interações entre condições hídricas do solo, nitrogênio e herbicidas comumente utilizados para controle de papuã no cultivo do arroz irrigado. O delineamento experimental utilizado foi inteiramente casualizado, arranjado em um esquema fatorial 2 x 3 x 4, sendo duas condições hídricas do solo (lâmina d'água de 5 cm e 100% de capacidade de retenção de água do solo), três doses de nitrogênio (0, 80 e 160 kg do solo de N ha^{-1}) e doses de herbicidas (0, 0,5, 1 e 2 vezes a dose de registro). Os herbicidas avaliados foram cyhalofop-butyl, imazapyr + imazapic e imazethapyr. Os tratamentos foram repetidos quatro vezes. Avaliou-se a fitotoxicidade e a massa seca aos 28 dias após a aplicação. Para cyhalofop-butyl e imazapyr + imazapic, a fitotoxicidade nas condições de 100% da capacidade de retenção de água do solo e lâmina d'água foi superior nos tratamentos com adubação nitrogenada. Entretanto, para imazethapyr na condição de 100% da capacidade de retenção de água do solo houve aumento de 45% da fitotoxicidade na ausência de adubação nitrogenada em comparação à condição com adubação. Para a condição de alagamento, a partir da dose de 35 g de i.a. ha^{-1}, o resultado no controle para o herbicida imazethapyr foi otimizado nas condições de adubação com 80 e 160 kg de N ha^{-1}. Cyhalofop-butyl e imazapyr + imazapic sofrem interação sinérgica com a adubação nitrogenada e a condição hídrica na eficiência do controle, já com imazethapyr, a interação sinérgica só ocorre em 100% da capacidade de retenção de água do solo.

Palavras-chave: alagamento do solo, manejo químico, arroz

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Introduction

Observations in rice cropping areas indicate a variation in the chemical control of weeds, which can be explained by the interaction between nitrogen fertilization, soil water conditions and herbicide doses (Gealy et al., 2014). In view of this problem, management alternatives or studies to elucidate these practices should be highlighted and conducted, aiming at diversification in the methods of weed species control and guidance of the technical team in charge.

Among the weeds found in rice crop, alexandergrass (*Urochloa plantaginea*) has highly competitive ability compared to the crop, in competition for both physical space and nutrients (Galon et al., 2014). Some abiotic factors may alter a plant's response to the herbicide; thus, it is necessary to obtain responses to the interaction between herbicide management practices and efficiency. A study conducted by Kohrt et al. (2016) found reduction in the resistance factor from 27.8 to 4.7 in a *Amaranthus tuberculatus* biotype resistant to glyphosate in corn.

Differences in herbicide efficacy, resulting from the varied concentrations of nitrogen available in the soil, may alter the structure of the weed community in agricultural areas (Blackshaw et al., 2003; Cathcart et al., 2004).

Studies point to evidence of the influence of nitrogen on the efficacy of herbicides (Cathcart et al., 2004; Kohrt et al., 2016; Mithila et al., 2008; Queiroz et al., 2013). In studies conducted by Brosnan et al. (2010), increase in the translocation of flazasulfuron was observed in annual plants of *Poa annua* fertilized with nitrogen, which promoted 50% increase in visual control in the field. Studies about the release of nitrogen by the inoculation of *Bradyrhizobium* in soybean were carried out by Bossolani et al. (2018), who found that the RR soybean crop did not show phytotoxicity after application of the herbicide glyphosate. In addition, studies with the association of nitrogen sources with the application of nicosulfuron have demonstrated the occurrence of phytotoxicity in corn hybrids (Cavalieri et al., 2008).

Thus, the aim of this study was to analyze the existence of interactions between soil water conditions, nitrogen and herbicides in the control of alexandergrass (*Urochloa plantaginea*) in irrigated rice crop.

Material and Methods

The experiment was carried out in a greenhouse of the Biology Department of the Federal University of Santa Maria (29º 42' 52.3" S and 53º 43' 8.01" W, and altitude of 115 m), located in the municipality of Santa Maria, RS, Brazil, from October to December 2017. The treatments were applied in a 2 x 3 x 4 factorial arrangement. Factor A was composed of two soil water conditions: 5 cm water depth and 100% soil water holding capacity (WHC). Factor B corresponded to three doses of nitrogen: 0, 80 and 160 kg of N ha^{-1} (SOSBAI, 2018). Factor C consisted of doses of herbicides corresponding to 0, 0.5, 1, and 2 times the recommended dose. The herbicides evaluated were cyhalofop-butyl (0, 95, 190 and 380 g e.a. ha^{-1}), imazapyr + imazapic (0, 36.75 + 12.25, 73.5 + 24.5 and 147 + 49 g a.i. ha^{-1}) and imazethapyr (0, 50, 100 and 200 g a.i. ha^{-1}). The treatments were repeated four times, totaling 96 experimental units. *Urochloa plantaginea* propagules were collected in rice fields (lowland) located in the municipality of Itaqui, RS, Brazil (29° 15' 6.2" S and 56° 22' 0.9" W). *Urochloa plantaginea* caryopsis were propagated in polyethylene pots with 0.5 L soil capacity. When plants reached the stage of three to four leaves, the herbicides, nitrogen fertilization and, later, water conditions were applied. Nitrogen fertilization was performed using urea (46% nitrogen). Plants were maintained under the 100% WHC condition until the time of application of herbicides, nitrogen fertilization and water conditions. Herbicides were applied using a CO_2 pressurized backpack sprayer, equipped with a 0.5-m-long bar with application rate of 150 L ha^{-1} and with a fan nozzle.

WHC was determined by drying in an oven at 60 °C until reaching constant mass. After observing that the soil mass remained constant, the soil water holding capacity was determined. In the pot used, containing a known soil mass, irrigation was performed until soil saturation occurred. Thus, the difference between mass of the pot with dry soil and the mass of the pot with moist soil was used to obtain the value of the amount of water to reach 100% water holding capacity. Irrigations were performed daily, after weighing each pot, adding water until reaching the total predetermined mass (pot + dry soil + water volume to reach 100% WHC).

The dry mass (DM) of plant shoots was determined at 28 days after application (DAA), a period long enough to visualize the symptoms of phytotoxicity in target plants. Visual analysis was performed according to the scale of the Brazilian Society of Weed Science (SBCPD, 1995) at 28 DAA. For DM determination, the samples were dried in an oven at 60 ºC until constant mass. The dose-response curves were obtained by analyzing the percentage of dry mass and phytotoxicity compared to the zero dose.

The experimental errors were tested for normality (Shapiro-Wilk test) and homogeneity of variances (Bartlett test). Subsequently, analysis of variance and Scott-Knott test were performed to group the means at $p \leq 0.05$, using the statistical program Sisvar® 5.3 (Ferreira, 2011). Dry mass data were converted to percentage based on the control. After conversion, the data were subjected to regression analysis, considering the model with the highest adjusted R^2 value. The graphs were generated in the program SigmaPlot® version 11.

Results and Discussion

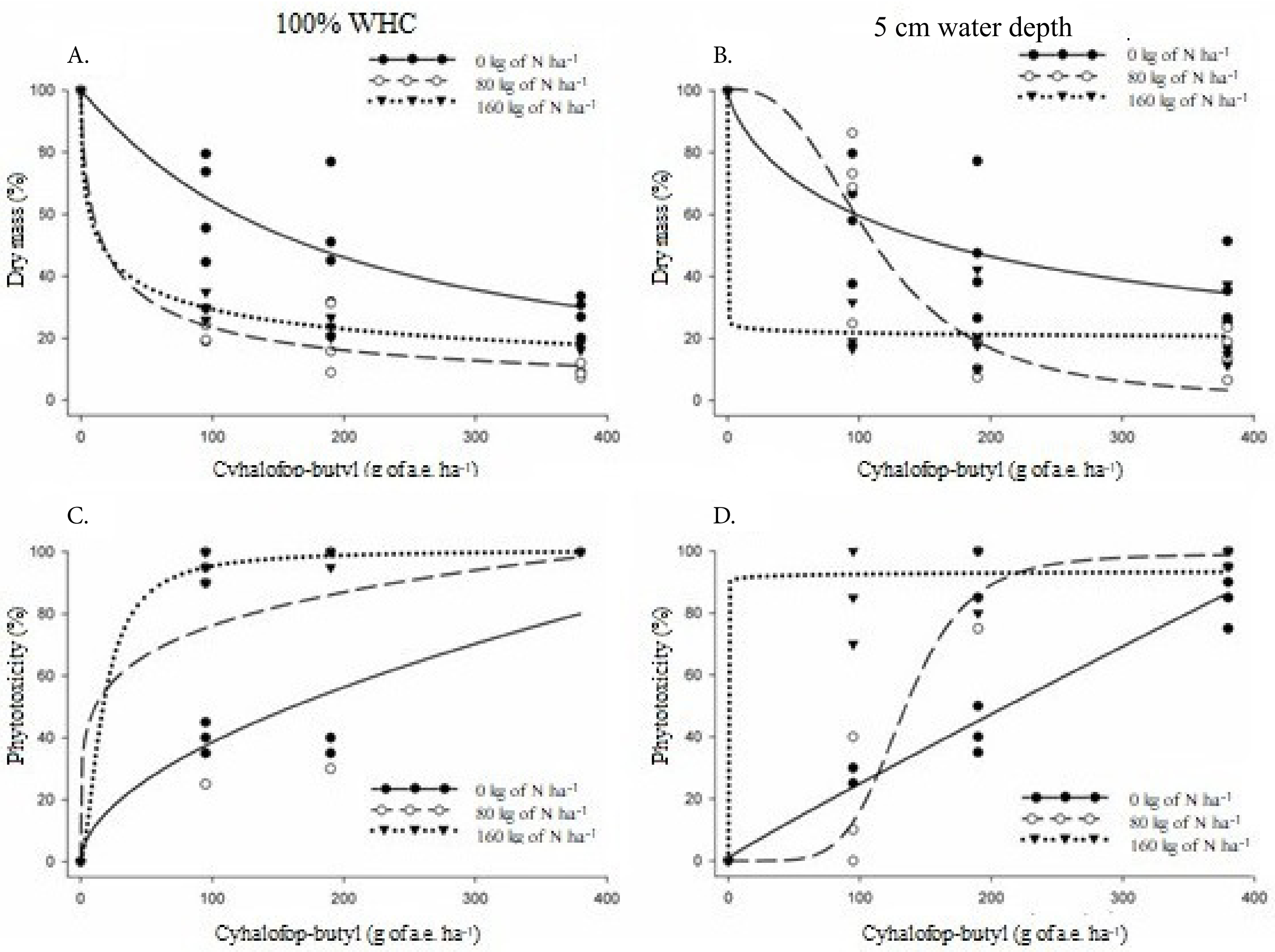
Significant triple interaction was observed between soil water condition, nitrogen doses and cyhalofop-butyl herbicide doses for both dry mass and phytotoxicity of *U. plantaginea* plants. Under both water conditions, nitrogen doses of 80 and 160 kg ha^{-1} reduced dry mass accumulation compared to the treatment without nitrogen (Figures 1A and B). The reduction in dry mass accumulation with the increase in cyhalofop-butyl dose became more evident under the 100% WHC condition. Phytotoxicity in *U. plantaginea* plants subjected to the 100% WHC condition was higher in treatments with nitrogen fertilization (Figure 1C). The same occurred for the water depth condition (Figure 1D), which indicates or suggests an optimization of herbicide efficiency associated with nitrogen doses.

The GR_{50} under the 100% WHC condition was 10.03 (80 kg of N ha^{-1}) and 10.95 (160 kg of N ha^{-1}) times lower compared to that obtained in the treatment without nitrogen (Table 1). Under the condition of flooding, the highest nitrogen dose led to a reduction of 503.75 times in the cyhalofop-butyl dose necessary to reduce dry mass by 50% (Table 1). These results indicate that the increase in nitrogen dose associated with the application of cyhalofop-butyl, both in flooded environment and under 100% WHC, caused lower dry mass accumulation in alexandergrass plants.

In a study carried out with the herbicide glyphosate (360 g ha^{-1}) in the control of morning glory (*Ipomoea triloba* L.) and johnsongrass (*Sorghum halepense* (L.) Pers.) species(s), it was found that the previous soil fertilization with 3 kg ha^{-1} of ammonium sulfate promoted greater control when compared to the others that used the same dose, in the evaluations carried out at 21 DAA (Carvalho et al., 2011). This result is similar to that observed by Sonderskov et al. (2012) in control of *Album chenopodium L.* and *Tripleurospermum inodorum* (L.) Schultz *Bip*. These authors found that the use of nitrogen promoted increments in the efficiency of the systemic herbicides tribenuron-methyl (500 g a.i. kg^{-1}) ioxynil + bromoxynil (Oxitril®, 200 + 200 g a.i. L^{-1}). Lower control at points of low nitrogen concentration was also observed by Sonderskov et al., 2012.

The use of nitrogen fertilization caused considerable reduction in the cyhalofop-butyl dose required to obtain efficient control (F_{80} = Phytotoxicity ≥ 80.0%) of *U. plantaginea* (Table 2). This suggests that, as the nitrogen dose was increased in fertilization, there was an increase in herbicide efficiency. Under the 100% WHC condition, the fertilizations of 80 and 160 kg of N ha^{-1} led to reductions in F_{80} of 2.88 and 9.71 times, respectively, compared to the treatment without nitrogen fertilization (Table 2). Similarly, reductions were observed in F_{80} under the water depth condition according to the increase in nitrogen fertilization (Table 2).

Nitrogen fertilization may favor herbicide translocation and absorption in some plant species, which varies according



Curves were fitted by the logistic model, and the equation parameters are described in Tables 1 and 2

Figure 1. Dry mass compared to the control (A and B) and visual phytotoxicity (C and D) of *Urochloa plantaginea* subjected to the condition of 5 cm water depth (B and D) and 100% soil water holding capacity - WHC (A and C), as a function of cyhalofop-butyl herbicide doses for three nitrogen doses

Table 1. Estimated parameters a, b and X_0, coefficient of determination (adjusted R^2) of the log-logistic model fitted for dry mass of *Urochloa plantaginea* as a function of cyhalofop-butyl doses and the relation between nitrogen doses from the data of GR_{50} and soil water condition

Soil water condition	Nitrogen dose (kg of N ha^{-1})	a	b	$X_0 = GR_{50}$ (g a.e. ha^{-1})	R^2adj	Relation between GR_{50}
100% WHC	0	99.75	1.07	173.23	0.81	-
	80.0	99.99	0.67	17.27	0.97	10.03*
	160.0	100.0	0.47	15.81	0.99	10.95*
5 cm water depth	0.0	100.0	0.76	166.24	0.74	-
	80.0	100.4	2.77	112.22	0.84	1.48*
	160.0	100.0	0.04	0.33	0.93	503.75*

WHC - Soil water holding capacity; GR_{50} - Herbicide dose at which 50% of dry mass is reached; a - Upper limit; b - Slope of the curve at the inflection point; * - D0/Dn; Dn - Nitrogen dose at which GR_{50} compared with the control; D0 - control dose

Table 2. Estimated parameters a, b and X_0, F_{80} and coefficient of determination (adjusted R^2) of the log-logistic model fitted for cyhalofop-butyl and phytotoxicity of *Urochloa plantaginea* under different soil water conditions and nitrogen doses

Soil water condition	Nitrogen dose (kg of N ha^{-1})	a	b	$X_0 = F_{50}$ (g a.e. ha^{-1})	F_{80} (g a.e. ha^{-1})	R^2adj
100% WHC	0	100.0	0.54	161.22	382.17	0.99
	80.0	100.1	0.19	11.71	132.54	0.72
	160.0	100.5	1.65	16.02	39.32	0.99
5 cm water depth	0.0	85.10	0.95	221.62	350.82	0.95
	80.0	99.06	5.54	134.69	175.62	0.94
	160.0	116.11	0.02	1.16	1.99	0.95

WHC - Soil water holding capacity; F_{50} - herbicide dose at which 50% phytotoxicity is reached; F_{80} - Herbicide dose at which 80% phytotoxicity is reached; a - upper limit; b - slope of the curve at the inflection point

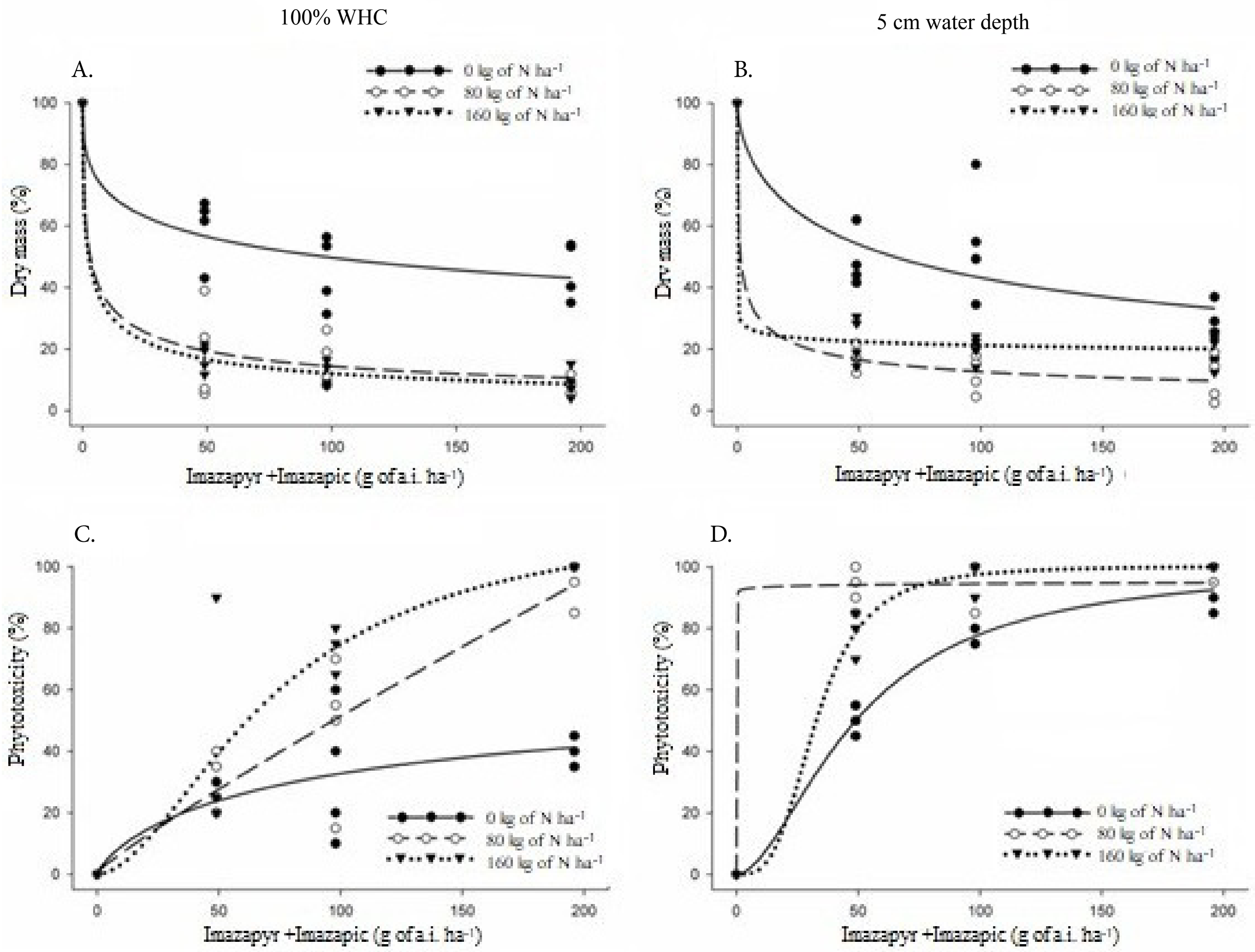
to the herbicide characteristics (Mithila et al., 2008). A study conducted by Dickson et al. (1990) found that nitrogen fertilization increased the translocation of the ACCase-inhibitor herbicides by about two to three times compared to the condition without nitrogen fertilization. Additionally, soil flooding after herbicide application favors herbicide efficiency and increase in rice crop yield (Gealy et al., 2014).

There was a triple interaction between the factors soil water condition, nitrogen doses and imazapyr + imazapic herbicide doses for phytotoxicity in *U. plantaginea* plants. Under the conditions of both 100% WHC and 5 cm water depth, the use of nitrogen fertilization caused greater reduction of dry mass with the increase in imazapyr + imazapic doses when compared to the treatment without nitrogen (Figures 2A and B). The efficiency of imazapyr + imazapic, under the 100% WHC condition, was optimized with the use of nitrogen fertilizer from the dose of 24.49 g of a.i. ha^{-1} (18.37 g of imazapyr and 6.12 g of imazapic) (Figure 2). Under the condition of flooded soil, a similar response was observed at the lowest doses of the herbicides imazapyr + imazapic (Figure 2).

In the analysis of dry mass data related to the application of imazapyr + imazapic herbicides and nitrogen doses, greater reduction in dry mass was observed under the conditions with nitrogen fertilization (Table 2). Under the 100% WHC condition, where there was no fertilization with nitrogen, the dose needed to reduce 50% of the dry mass of alexandergrass plants showed considerable difference from the fertilized conditions (Table 3). Under the condition of 80 and 160 kg of N ha^{-1}, there were reductions in GR_{50} of 31.04 and 38.28 times, respectively, compared to the condition of 0 kg of N ha^{-1}. A similar situation was observed under the flooding condition, where reductions in GR_{50} of 47.39 and 54.56 were respectively observed in treatments with 80 and 160 kg of N ha^{-1}, compared to the treatment where there was no application of nitrogen fertilizer (Table 3). However, the imazapyr + imazapic dose necessary to reduce by 50% the dry mass of *U. plantaginea* plants in an environment without nitrogen fertilization, was lower under water depth condition with a dose of 64.93 g of a.i. ha^{-1} (48.70 g of imazapyr and 16.23 g of imazapic) compared to 100% WHC with 96.85 g of a.i. ha^{-1} (72.64 g of imazapyr and 24.21 g of imazapic) (Table 3).

The results regarding phytotoxicity indicate higher efficiency of imazapyr + imazapic herbicides under nitrogen fertilization, regardless of the soil water condition evaluated. Under the 100% WHC condition, the fertilization of 80 and 160 kg of N ha^{-1} caused reduction in F_{80} compared to the treatment without nitrogen fertilization (Table 4). In the treatment with 100% WHC soil water condition without fertilization, F_{80} cannot be estimated due to the behavior of the curve, which showed a tendency to stabilize after the dose of 450 g of a.i. ha^{-1}. In the analysis of the response for F_{50}, there was optimization of the control of this herbicide association as a function of the inclusion of nitrogen in the system under the 100% WHC soil water condition. In this case, F_{50} was reduced by 4.96 and 7.32 times for the doses of 80 and 160 kg of N ha^{-1}, respectively, compared to the condition without fertilization (Table 4). For the water depth condition, similar behaviors of imazapyr + imazapic herbicides combined with nitrogen fertilization management were observed for the control of *U. plantaginea* (Table 4).

The positive effect of nitrogen on weed control is dependent on species – active ingredient interaction. In *Amaranthus retroflexus*, the doses of nicosulfuron necessary to reduce the dry mass by 50% were 3.0 to 3.5 times lower under the condition with nitrogen fertilization (Cathcart et al., 2004). Soil flooding interferes with the action of herbicides; in most cases, it favors weed control due to physiological disturbances involving the reduction of oxygen flow to the roots and the production of reactive oxygen species (Ismail et al., 2012). In fact, it was observed in the present study that the soil water



Curves were fitted by the logistic model, and the equation parameters are described in Tables 3 and 4

Figure 2. Dry mass compared to the control (A and B) and visual phytotoxicity (C and D) of *Urochloa plantaginea* plants subjected to the condition of 5 cm water depth (B and D) and 100% soil water holding capacity - WHC (A and C), under different doses of the herbicide imazapyr + imazapic and nitrogen

Table 3. Estimated parameters a, b and X_0, coefficient of determination (R^2) of the log-logistic model fitted for imazapyr + imazapic doses and dry mass of *Urochloa plantaginea* and the relation between nitrogen doses from the data of GR_{50} and soil water condition

Soil water condition	Nitrogen dose (kg of N ha^{-1})	a	b	$X_0 = GR_{50}$ (g a.e. ha^{-1})	R^2adj	Relation between GR_{50}
100% WHC	0	100.04	0.39	96.85	0.84	-
	80.0	99.99	0.51	3.12	0.95	31.04*
	160.0	100.0	0.54	2.53	0.99	38.28*
5 cm water depth	0.0	99.79	0.62	64.93	0.79	-
	80.0	100.0	0.45	1.37	0.98	47.39*
	160.0	100.0	0.09	1.19	0.97	54.56*

WHC - Soil water holding capacity; GR_{50} - Herbicide dose at which 50% of dry mass is reached; a - Upper limit; b - Slope of the curve at the inflection point; * - D0/Dn; Dn - Nitrogen dose at which GR_{50} compared with the control; D0 - control dose

Table 4. Estimated parameters a, b and X_0, F_{80} and coefficient of determination (R^2) of the log-logistic model fitted for imazapyr + imazapic and phytotoxicity of *Urochloa plantaginea* under different soil water conditions and nitrogen doses

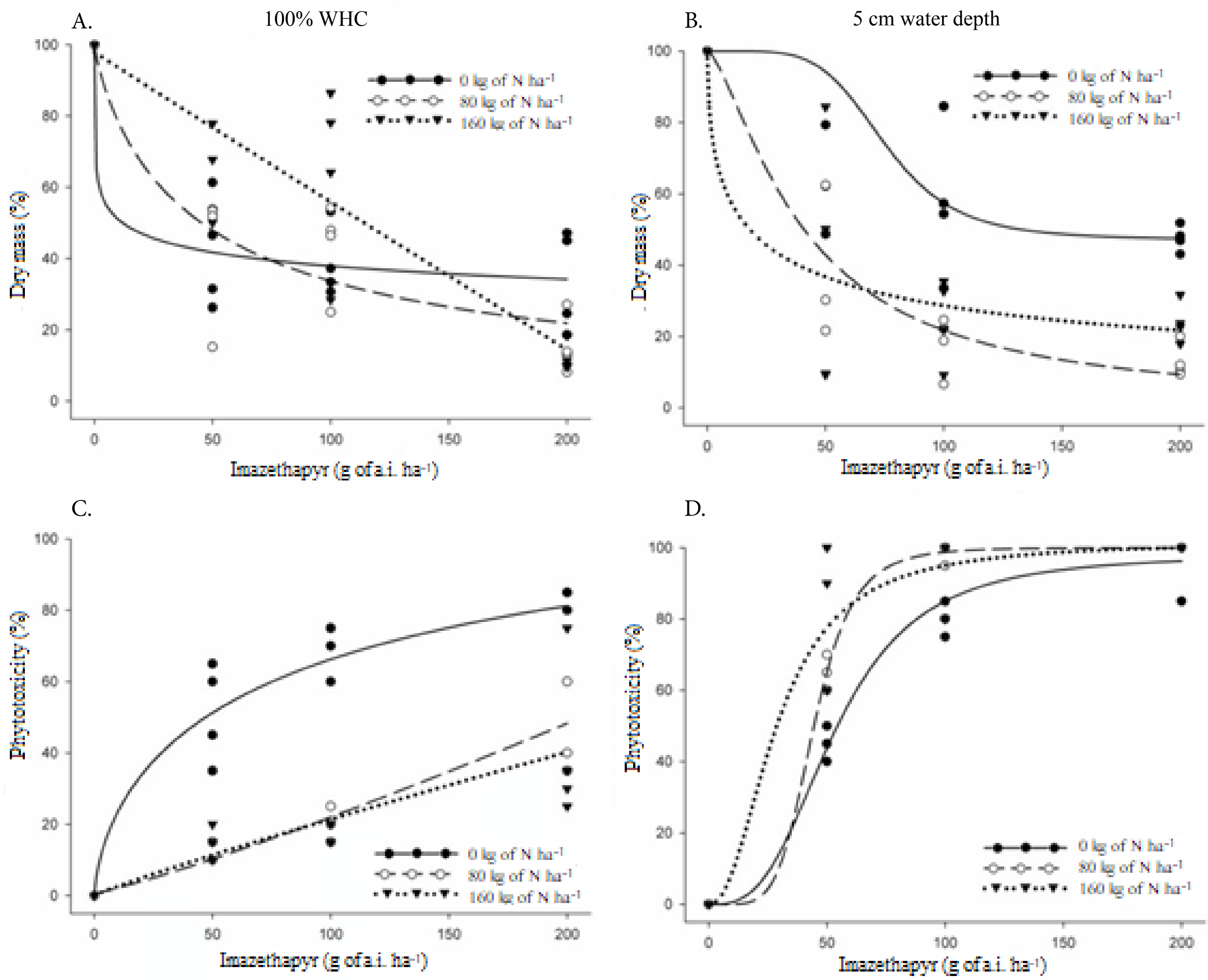
Soil water condition	Nitrogen dose (kg of N ha^{-1})	a	b	$X_0 = F_{50}$ (g a.e. ha^{-1})	F_{80} (g a.e. ha^{-1})	R^2adj
100% WHC	0	65.0	-0.79	456.12	-	0.99
	80.0	93.1	0.90	97.07	163.19	0.87
	160.0	117.07	-1.7	62.27	112.21	0.84
5 cm water depth	0.0	100.0	-1.76	49.35	106.81	0.98
	80.0	131.39	-0.01	0.41	0.68	0.98
	160.0	100.3	-3.25	32.89	51.92	0.99

WHC - Soil water holding capacity; F_{50} Herbicide dose at which 50% phytotoxicity is reached; F_{80} - Herbicide dose at which 80% phytotoxicity is reached; a - Upper limit; b - Slope of the curve at the inflection point condition with water depth caused greater phytotoxicity to alexandergrass plants and, consequently, a more efficient control.

For the herbicide imazethapyr, a triple interaction was observed between the factors soil water condition, nitrogen doses and imazethapyr doses, both for dry mass and phytotoxicity of alexandergrass plants. *U. plantaginea* plants of the treatments with imazethapyr in flooded soil showed lower dry mass accumulation when fertilized with 80 and 160 kg of N ha^{-1} (Figure 3B). However, under the condition of 100% WHC, there was a greater increase in dry mass where nitrogen fertilization was applied, which was observed up to 70.0 g of a.i. ha^{-1} of imazethapyr and not verified at higher doses of this herbicide (Figure 3A). When 148.0 g a.i. ha^{-1} of imazethapyr were sprayed in *U. plantaginea* plants under the 100% WHC condition, lower dry mass values were verified at the two doses of nitrogen to the detriment of the condition without nitrogen (Figure 3A).

The response of alexandergrass plants to phytotoxicity caused by imazethapyr at the different nitrogen doses varied between the two soil water conditions evaluated. First, in the 100% WHC condition, the herbicide imazethapyr caused greater phytotoxicity in alexandergrass where there was no nitrogen fertilization. However, under the condition of flooding, it was observed that, from 35 g a.i. ha^{-1} of imazethapyr, there was an optimization in the control of alexandergrass with this herbicide when fertilization with 80 and 160 kg of N ha^{-1} was performed.

The differences between the response of alexandergrass plants to the herbicide imazethapyr subjected to the soil water conditions and nitrogen doses become evident. In an ideal soil water condition (100% WHC) for the species, it can be inferred that nitrogen fertilization negatively interfered in the action of the herbicide in question (Table 5). When compared with the treatment without the presence of nitrogen fertilizer, there were increases of 3.81 (80 kg of N ha^{-1}) and 9.57 (160 kg of N ha^{-1}) in the imazethapyr dose required to reduce by 50% the dry mass of the target plants (Table 5). According to the above, under the condition of soil with 5.0 cm water depth, an inverse situation was observed, with doses of 80 and 160 kg of N ha^{-1} promoting increase in the herbicide control efficiency. Under this condition, reductions of 3.16 and 7.20 times in GR_{50} were observed for the treatment of 80 kg of N ha^{-1} and 160



Curves were fitted by the logistic model, and the equation parameters are described in Tables 5 and 6

Figure 3. Dry mass compared to the control (A and B) and visual phytotoxicity (C and D) of *Urochloa plantaginea* subjected to the condition of 5 cm water depth (B and D) and 100% soil water holding capacity - WHC (A and C), under different doses of the herbicide imazethapyr and nitrogen

Table 5. Estimated parameters a, b and X_0, coefficient of determination (R^2) of the log-logistic model fitted for imazethapyr doses and dry mass of *Urochloa plantaginea* and the relation between nitrogen doses from the data of GR_{50} and soil water condition

Soil water condition	Nitrogen dose (kg of N ha^{-1})	a	b	$X_0 = GR_{50}$ (g a.e. ha^{-1})	R^2adj	Relation between GR_{50}
100% WHC	0	99.99	0.23	11.94	0.85	-
	80.0	99.79	0.85	45.60	0.83	3.81*
	160.0	98.84	-0.98	114.30	0.78	9.57*
5 cm water depth	0.0	99.3	5.07	129.17	0.45	-
	80.0	100.0	1.43	40.86	0.90	3.16**
	160.0	100.0	0.53	17.93	0.73	7.20**

WHC - Soil water holding capacity; GR_{50} - Herbicide dose at which 50% of dry mass is reached; a - Upper limit; b - Slope of the curve at the inflection point; * - Dn/D0; ** - D0/Dn; Dn - Nitrogen dose at which GR_{50} compared with the control; D0 - control dose

Table 6. Estimated parameters a, b and X_0, F_{80} and coefficient of determination (R^2) of the log-logistic model fitted for imazethapyr and phytotoxicity of *Urochloa plantaginea*

Soil water condition	Nitrogen dose (kg of N ha^{-1})	a	b	$X_0 = F_{50}$ (g a.e. ha^{-1})	F_{80} (g a.e. ha^{-1})	R^2adj
100% WHC	0	100.5	-0.66	47.22	180.42	0.94
	80.0	100.2	-1.12	215.34	318.21	0.87
	160.0	100.0	-0.91	259.32	444.19	0.60
5 cm water depth	0.0	98.08	-3.01	53.73	88.67	0.97
	80.0	100.03	-5.37	44.56	57.82	0.99
	160.0	101.52	-2.17	29.17	53.32	0.93

WHC - Soil water holding capacity; F_{50} - Herbicide dose at which 50% phytotoxicity is reached; F_{80} - Herbicide dose at which 80% phytotoxicity is reached; a - Upper limit; b - Slope of the curve at the inflection point

kg of N ha^{-1}, respectively, compared to the treatment without fertilization (Table 5).

The results of visual control of alexandergrass corroborate the results of dry mass, indicating an interaction between the factors soil water condition, nitrogen doses and imazethapyr herbicide doses (Table 6). On the other hand, the negative interaction in the visual control occurred under 100% WHC water condition, where the addition of nitrogen fertilization hampered the control of the plants by the herbicide. This increase in F_{80} was 1.76 times for the dose of 80 kg of N ha^{-1} compared to the treatment without nitrogen, and 2.46 times for the dose of 160 kg of N ha^{-1} (Table 6).

The results of this study show a relationship between active ingredient and the species under study, in which under the 100% WHC condition the imazethapyr showed an inverse behavior in its efficiency compared with imazapyr + imazapic and cyhalofop-butyl compared to the presence of nitrogen. The results also suggest that other physiological processes are involved in the relationship between nitrogen, herbicide and species.

It is theorized that the lower efficiency of imazethapyr when nitrogen is included in the management may be related to the increase of herbicide metabolization by the alexandergrass plant under this condition. Nitrogen fertilization promotes an increase in activity of enzymes, among which the enzymes of the cytochrome P450 monooxygenase family stand out, which play a crucial role in the inactivation via hydroxylation of herbicide molecules (Kreuz et al., 1996; RWerck-Reichhart et al., 2000). The literature reports that, depending on the species, cytochrome P450 levels may increase when the plant absorbs high concentrations of nitrogen (Chandna et al., 2015).

Nitrogen fertilization also increases the concentration of sugars, thus increasing the availability of glucoses for this reaction (Kohrt et al., 2016; Mithila et al., 2008). However, the effect of the enzyme P450 on herbicide molecules may vary according to the active ingredient in question, although they have the same mechanism of action and the application occurs under similar environmental conditions (Queiroz et al., 2013). This fact exemplifies why some herbicide compounds are more easily metabolized and others are not. In addition, it could explain the differences in alexandergrass control observed under the conditions with nitrogen fertilization for imazethapyr and imazethapyr in association with imazapic, all herbicides that inhibit ALS (Acetolactate synthase).

Conclusions

1. Soil water conditions and nitrogen fertilization cause positive interference in the chemical control of *Urochloa plantaginea*.

2. The efficiency of the herbicide imazethapyr decreases when associated with nitrogen fertilization, but the herbicides cyhalofop-butyl and imazapyr + imazapic have synergistic effect when associated with nitrogen fertilization.

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