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Influence of glyphosate underdoses on the suppression of *Panicum maximum* cultivars

Subdoses de glifosato na supressão de cultivares de **Panicum maximum**

Suzete Fernandes Lima[1]*, Leandro Spíndola Pereira[1], Gustavo Dorneles Sousa[1], Simonny Araújo Vasconcelo[1], Adriano Jakelaitis[1], José Franklin Athayde Oliveira[1]

ABSTRACT: The use of herbicide underdoses allows minimizing the competition of grasses on annual crops, enabling simultaneous cultivation. In this context, the objective of this study was to investigate glyphosate underdoses on the suppression of the initial growth of three *Panicum maximum* cultivars aiming at the integrated cultivation, in addition to the effects of forage species on the incidence and development of weeds. Three field experiments were conducted. The experimental design was a randomized block design with four replications and eight treatments consisting of increasing glyphosate doses (0, 54, 108, 270, 378, 540, 756, and 1,080 g a.e. ha^{-1}). An atrazine dose of 1,200 g a.i. ha^{-1} was added to each treatment. Plant phytotoxicity assessments were performed at 7, 14, 21, and 28 days after application. At 80 and 125 days after sowing, the assessments of total dry matter production, leaf dry matter, stem dry matter, and leaf to stem ratio were carried out, in addition to density and dry matter production of weed community. Glyphosate underdoses below 215, 65, and 90 g a.e. ha^{-1} have a potential to be investigated aiming at the management of *P. maximum* cv. Atlas, *P. maximum* cv. Mombasa, and *P. maximum* cv. Tanzania under intercropping. The three forage species are effective in suppressing weeds.

KEYWORDS: Atlas; Tanzania; Mombasa; crop-livestock integration system; weeds.

RESUMO: A utilização de subdoses de herbicidas permite amenizar a competição exercida pelas gramíneas sobre a cultura anual, viabilizando o cultivo simultâneo. Neste contexto, objetivou-se pesquisar subdoses de glifosato na supressão do crescimento inicial de três cultivares de *Panicum maximum*, almejando o cultivo integrado, além dos efeitos das forrageiras sobre a incidência e o desenvolvimento das plantas daninhas. Foram conduzidos três ensaios em campo. O delineamento experimental utilizado foi em blocos casualizados, com quatro repetições e oito tratamentos, formados por doses crescentes do herbicida glifosato (0; 54; 108; 270; 378; 540; 756 e 1.080 g de e.a. ha^{-1}). Em todos os tratamentos foram adicionados 1.200 g de i.a. ha^{-1} de atrazine. Foram realizadas avaliações de fitointoxicação de plantas aos 7, 14, 21 e 28 dias após a aplicação. Aos 80 e 125 dias após a semeadura foram realizadas avaliações de produção de matéria seca total, matéria seca de folha, matéria seca de colmos e relação folha: colmo, além da densidade e produção de matéria seca da comunidade de plantas daninhas. Subdoses de glifosato abaixo de 215, 65 e 90 g de e.a. ha^{-1} possuem potencial para serem pesquisadas visando ao manejo de *Panicum maximum* cv. Atlas, *Panicum maximum* cv. Mombaça e *Panicum maximum* cv. Tanzânia em consórcio. As três forrageiras são eficientes na supressão de plantas daninhas.

PALAVRAS-CHAVE: Atlas; Tanzânia; Mombaça; integração lavoura-pecuária; plantas daninhas.

[1]Instituto Federal de Educação, Ciência e Tecnologia Goiano – Rio Verde (GO), Brazil
*Corresponding author: suzete.lima@yahoo.com.br
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INTRODUCTION

Integrated production systems are considered innovative, aiming to maintain the sustainability of agricultural areas over the years. The adoption of intercropping systems makes crop rotation, increase of straw production for the no-tillage system, reduction of weed occurrence, and pasture supply during the off-season feasible (ALVES et al., 2013; CARMEIS FILHO et al., 2014; SILVA et al., 2015; MACHADO et al., 2017). These systems are complex and dynamic since there is more than one species occupying the same area, so the integration success depends on several factors.

Intercropping between annual crops and grasses stands out as a viable option (GARCIA et al., 2012). With the purpose of obtaining soil cover and straw, it benefits the crop in succession, resulting in a higher productivity (CHIODEROLI et al., 2010), in addition to influencing the weed dynamics (LIMA et al., 2014). Soybean planting during the season may be favored by intercropping due to the suppression of weed emergence exerted by the straw related to a fast growth of these cover species after harvesting the grain production crop (BORGHI et al., 2008).

Perennial species are more efficient when a higher biomass production during second season cultivations is sought (MACHADO et al., 2010). In this context, species of the genus *Panicum* are viable options to be inserted in these production systems due to their high nutritional value biomass related to a high percentage of leaves (EUCLIDES et al., 2010).

In southwestern Goiás State, the integrated corn-grass cultivation is an agronomic technique that enables the production of corn grains and increases straw production in the soybean-corn succession in order to guarantee the sustainability of the no-tillage system over the years (OLIVEIRA et al., 2016; QUEIROZ et al., 2016; ALMEIDA et al., 2017). However, intercropped forages may compete with corn and interfere with grain yield, making this cultivation system economically unfeasible (ALVES et al., 2013; FERRAZZA et al., 2016). This competition may lead to a reduction of up to 45% in corn productivity (ADEGAS et al., 2011).

Agronomic techniques can minimize the competition between crops simultaneously grown. Among them, the application of herbicide underdoses to suppress the initial forage growth is promising (CECCON et al., 2010; SILVA et al., 2014; GRIGOLLI et al., 2017). Thus, the success of an integrated cultivation between annual grain production crops and forages depends on the initial competitive advantage of the grain crop by environmental resources such as water, light, and nutrients.

With the emergence of genetically modified crops Roundup Ready (RR), the herbicide glyphosate became selective for these crops, allowing its application in the post-emergence period. This herbicide is used in the pre-sowing management for desiccation of spontaneous vegetation, especially in no-tillage areas. It is also used for weed management in perennial crop rows, as well as in post-emergence applications in genetically modified crops resistant to this molecule (PETTER et al., 2007; GOMES; CHRISTOFFOLETI, 2008; GALLI, 2009; CORREIA; DURIGAN, et al., 2010; ALBRECHT et al., 2014).

Considering that, glyphosate has the potential to be used in the management of forage species integrated with RR corn since its underdose applications promote important effects on growth and development of plants. However, information on the behavior of forage grasses submitted to glyphosate underdose application is still scarce. In this context, the objective of this study was to investigate glyphosate underdoses on the suppression of the initial growth of three *Panicum maximum* cultivars aiming at the integrated cultivation, in addition to the suppression in the incidence of weeds exerted by forages.

MATERIAL AND METHODS

The experiments were conducted in the field, in southwestern Goiás state, Brazil. Regional climate is Aw according to Köppen's classification, a mesothermal, savannah tropical climate, with rain in the summer and drought in the winter. Climatological data during the experimental period are shown in Figure 1. The soil of the experimental area is classified as a Hapludox (Soil Taxonomy; dystroferric Red Latosol, Brazilian Soil Classification). Before starting the experiments, soil samples were collected at a depth of 0–20 cm for chemical and physical analyses. Soil analysis results showed a pH of 6.2 (SMP), Ca of 4.64 $cmol_c$ dm^{-3}, Mg of 2.50 $cmol_c$ dm^{-3}, Al^{3+} of 0.04 $cmol_c$ dm^{-3}, H+Al of 4.5 $cmol_c$ dm^{-3}, CEC of 12.1 $cmol_c$ dm^{-3}, K of 0.46 $cmol_c$ dm^{-3}, P (Melich) of 13.1 mg dm^{-3}, Cu of 2.3 mg dm^{-3}, Fe of 13 mg dm^{-3}, Mn of 59.3 mg dm^{-3}, OM of 3.62 mg dm^{-3}, Zn of 4.5 mg dm^{-3}, base saturation of 62.8%, aluminum saturation of 0.5%, clay of 64.5%, silt of 10.0%, and sand of 25.5%.

Three experiments were conducted with different cultivars of the genus *Panicum* (*P. maximum* cv. Atlas, *P. maximum* cv. Mombasa, and *P. maximum* cv. Tanzania). Before installing the experiments, spontaneous weed was chemically desiccated with glyphosate (1,440 g ha^{-1}). After 15 days, soil tillage was performed by means of a plowing and two harrowing.

The experimental design was a randomized block design with eight treatments and four replications composed of increasing glyphosate doses (0, 54, 108, 270, 378, 540, 756, and 1,080 g a.e. ha^{-1}) of the commercial formulation Transorb® 480 g L^{-1}. A dose of 1,200 g a.i. ha^{-1} of atrazine (Atrazine Nortox® 500 SC) was added to each treatment to control dicotyledonous weeds.

The experimental plots consisted of five rows of 3 m in length and a distance of 1 m between blocks. The useful area consisted of the two central rows, but without the borders of 0.5 m on both sides. Sowing was carried out on October 21, 2016, using 5 kg ha^{-1} of viable pure seeds sown in rows spaced 0.50 m at a depth of 0.05 m. Sowing fertilization consisted of using 150 kg ha^{-1} of the formulation 04–28–16.

Thirty days after sowing (DAS), on November 11, 2016, treatments were applied using a CO_2 pressurized sprayer equipped with a TT11002 four-nozzle boom spaced at 0.50 m, positioned at 0.5 m height from the plant surface, with a spray solution volume of 150 L ha^{-1}, and a working pressure of 200 KPa. The application was performed in the morning between 7:00 and 9:30 a.m, with a registered air temperature of 27°C, relative air humidity of 76%, wind speed of 1.0 m s^{-1}, and moist soil at the surface. Adjacent plots were protected with a plastic canvas during the application in order to avoid drift.

The percentage of plant phytotoxicity was assessed at 7, 14, 21, and 28 days after treatment application (DAA), being established a percentage scale of 0 to 100%, in which 0 represents no plant injury symptoms and 100 represents plant death (SBCPD, 1995).

Forage dry matter production was assessed at 80 and 125 DAS, on January 09 and February 23, 2017, respectively. For this, 1.5 m of *P. maximum* of the central row of each experimental unit was cut at 0.25 m height. Subsequently, forage fresh matter was measured and a sample of about 0.5 kg was taken for dry matter determination. This sample was separated into leaves, stems, and dead material, packed in paper bags, and dried in a forced air circulation chamber at 65°C for 72 hours for subsequent dry matter determination. In both assessment periods, the leaf to stem ratio (LSR) was calculated by dividing the dry matter values of leaves and stems.

After the first plant collection (80 DAS), a standardization cut was performed in the total experimental area by using a cleaver. The interval between the first and second forage cuttings was 45 days, period at which the cutting height of grasses was reached again.

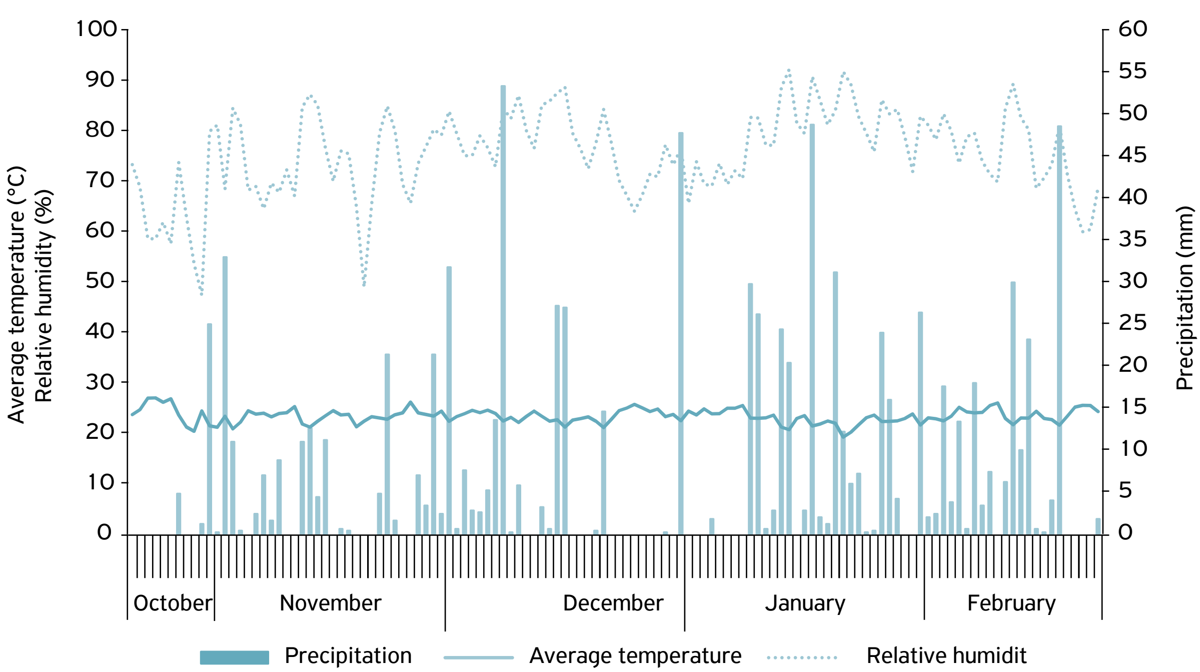
In both periods (80 and 125 DAS), weed assessments were also performed. For this, two square frames of 0.25 m^2 were randomly placed in each experimental unit, totaling 0.5 m^2, being the weed species identified, separated, and counted. Subsequently, weeds were cut close to the soil and packed in paper bags to measure the dry matter, which was carried out in an analytical balance after drying in a forced air circulation chamber at 65°C for 72 hours.

The results were submitted to analysis of variance, with their means compared by the F-test ($p<0.05$) using the statistical program Systems for Statistical Analysis (SAEG) version 9.0 (RIBEIRO JÚNIOR, 2007). In the case of statistical significance, a regression analysis was performed with the program Sigmaplot (SISTAT SOFTWARE, version 12.0, San Jose). The data were fitted to a three-parameter sigmoidal nonlinear regression equation, as Equation 1, or to a two-parameter exponential nonlinear equation, as Equation 2.

$$y=a/\left(1+exp\left(-\frac{x-x_0}{b}\right)\right) \quad (1)$$

$$y=a \times \exp(-b \times x) \quad (2)$$

Where:
y is the response variable, x is the herbicide dose, and a, x_0, and b are the equation parameters, where a in Equation 1 is the difference between the maximum and minimum points of the curve, a in Equation 2 is the maximum value estimated for the response variable, x_0 is the dose that provides 50% response to the variable, and b is the slope of the curve.



Source: INMET (2016/2017)

Figure 1. Average air temperature, relative air humidity, and total daily precipitation during the experimental period.

RESULTS AND DISCUSSION

The parameters of the fitted sigmoidal model and the coefficients of determination for the percentage of phytotoxicity of forage species as a function of glyphosate underdoses are shown in Table 1. The data presented a good fit, with an R^2 between 92.12 and 99.96%. The three *P. maximum* cultivars presented similar behavior, with a lower percentage of injuries at lower doses, while at higher doses plants were controlled, not presenting regrowth.

At the lowest doses of up to 200 g a.e. ha^{-1}, the highest plant phytotoxicity occurred up to 14 DAA. After this period, injury symptoms began to decrease and plants resumed their vegetative growth, with new leaf emissions. These results demonstrate that there was only a stoppage of grass growth and soon they resume their growth.

The coefficient *a* of the equations was above 91% for the three species in the four assessment periods. This indicates that from 7 to 28 DAA, low injury symptoms were observed in plants at lower underdoses, and high injury symptoms, even the control, were observed at higher underdoses, i.e. doses higher than 550 g a.e. ha^{-1}.

In *P. maximum* cv. Mombasa and *P. maximum* cv. Atlas, glyphosate underdoses of 220 and 334 g a.e. ha^{-1}, respectively, provided 50% plant phytotoxicity at 7 DAA. However, at 28 DAA, underdoses of 109 and 220 g a.e. ha^{-1}, respectively, provided 50% phytotoxicity, indicating that the initial injury symptoms at higher underdoses at 7 DAA are intensified up to 28 DAA. In *P. maximum* cv. Tanzania, on the other hand, this change did not occur between 7 and 28 DAA and the underdose of 215 g a.e. ha^{-1} provided 50% phytotoxicity in plants.

At 7 DAA, the coefficient *b* of the equation presented a higher value when compared to that observed at 28 DAA, which shows that at the beginning of the assessment, the slope of the curve was lower, i.e. plants presented injuries at the lower doses and had not yet been controlled at the highest doses. Over time, the slope of the curve tended to be more pronounced, indicating that plants recovered from phytotoxicity at the lowest doses and were controlled at the highest doses.

Glyphosate underdoses above 180, 315, and 410 g a.e. ha^{-1} controlled *P. maximum* cv. Mombasa, *P. maximum* cv. Tanzania, and *P. maximum* cv. Atlas, respectively, leading them to death at 28 DAA. The cultivar Mombasa was more sensitive to glyphosate effect, presenting greater injury symptoms with the lowest underdose. Researching the desiccation efficiency of forage plants, FERREIRA et al. (2010) found a greater ease in the desiccation of *P. maximum* cv. Mombasa when compared to *P. maximum* cv. Tanzania with glyphosate herbicide. Thus, the cultivars of the genus *Panicum* have different susceptibility to the same herbicide.

Table 2 shows the data of total dry matter, leaf to stem ratio, leaf dry matter, stem dry matter, and dead material dry matter at 80 DAS, i.e. at the first grass cutting. The highest dry matter productions were obtained up to the glyphosate underdose of 215, 67, and 85 g a.e. ha^{-1} for *P. maximum* cv. Atlas, *P. maximum* cv. Mombasa, and *P. maximum* cv. Tanzania, respectively. From these underdoses, a more marked reduction in forage production is observed. Therefore, lower underdoses, in which the reduction in biomass production was less than 20%, should be investigated aiming at grass management.

In *P. maximum* cv. Atlas and *P. maximum* cv. Mombasa, the underdose that promoted 50% visual symptoms of plant phytotoxicity (220 and 109 g a.e. ha^{-1}, respectively) was lower than the underdose that promoted 50% reduction in biomass production (288 and 160 g a.e. ha^{-1}, respectively). This indicates that even without leaf chlorosis, the action of glyphosate herbicidal effect promoted a delay in forage development, leading to a lower biomass production.

The three grasses presented the same behavior for the leaf to stem ratio, leaf dry matter, and stem dry matter, with higher values for lower glyphosate underdoses and lower values for higher glyphosate underdoses. The highest values of leaf to stem ratio at the lowest underdoses are related to a higher biomass production and absence of flowering, which leads to a lower emission and elongation of stems.

The data of total dry matter, leaf to stem ratio, leaf dry matter, stem dry matter, and dead material dry matter in the

Table 1. Parameters of the regression equations obtained by fitting the sigmoidal model and coefficient of determination (R^2) applied to the means of phytotoxicity percentage of *Panicum maximum* cv. Atlas, *P. maximum* cv. Tanzania, and *P. maximum* cv. Mombasa at 7, 14, 21, and 28 days after application as a function of glyphosate doses (0, 54, 108, 270, 378, 540, 756, and 1,080 g a.e. ha^{-1}) associated with atrazine (1,200 g a.i. ha^{-1}).

Variable	Parameter[1]			R^2
	a	*b*	x_0	
Panicum maximum cv. Atlas				
7 DAA[2]	98.7905	165.2166	334.3608	97.69*
14 DAA	95.9162	41.1133	109.6432	98.62*
21 DAA	98.6353	46.4424	161.4505	99.87*
28 DAA	99.4634	44.8494	220.8363	99.96*
Panicum maximum cv. Tanzania				
7 DAA	96.9497	119.1313	200.3558	96.49*
14 DAA	98.9736	47.7468	133.4072	99.64*
21 DAA	99.1265	38.2439	169.1719	99.75*
28 DAA	99.0903	22.3151	215.3763	99.93*
Panicum maximum cv. Mombasa				
7 DAA	91.7476	142.9868	220.4926	92.12*
14 DAA	97.1228	46.5283	107.4651	99.20*
21 DAA	98.9298	49.8437	145.9896	99.53*
28 DAA	98.9006	15.1247	109.1944	99.86*

[1]Model: $y=a/(1+\exp(-(x-x_0)/b))$; [2]DAA: days after application; *significant by the F-test ($p\leq0.05$)

second cut, performed at 125 DAS, with a 45-day interval from the first cut, are shown in Table 3. In the second cut, a lower biomass production was observed for the three forage species when compared to the first cut.

Panicum maximum cv. Tanzania showed the greatest potential for regrowth among the three forage species, with a 24% reduction in biomass production from the first to the second cut. On the other hand, *P. maximum* cv. Mombasa and *P. maximum* cv. Atlas showed a reduction of 29 and 35%, respectively. This result should be related to the intrinsic growth potential of each species, in addition to the effects of the glyphosate action, which provided different levels of stress in the forage species, influencing their vegetative development and consequent emission of new leaves.

Table 2. Parameters of the regression equations obtained by fitting the sigmoidal and exponential models and coefficient of determination (R^2) applied to the means of total dry matter (kg ha^{-1}), leaf to stem ratio, leaf dry matter (kg ha^{-1}), stem dry matter (kg ha^{-1}), and dead material dry matter (kg ha^{-1}) in the cultivation of *Panicum maximum* cv. Atlas, *P. maximum* cv. Tanzania, and *P. maximum* cv. Mombasa at 80 days after sowing (DAS) as a function of glyphosate doses (0, 54, 108, 270, 378, 540, 756, and 1,080 g a.e. ha^{-1}) associated with atrazine (1,200 g a.i. ha^{-1}).

Variable	Parameters of the sigmoidal fit[1]			R^2
	a	*b*	x_0	
Panicum maximum cv. Atlas				
TDM[2]	5040.8844	-52.7859	288.5447	97.91*
LSR[3]	2.7599	-91.0798	525.7273	88.68*
LDM[4]	3577.8230	-57.2052	285.6710	98.56*
SDM[5]	1404.5405	-48.9079	296.8892	91.72*
DMDM[6]	76.6409	-5.8960	251.7175	96.60*
Panicum maximum cv. Tanzania				
TDM	8156.8295	-61.8432	147.4425	98.97*
LSR	2.2350	-197.1967	313.6012	93.74*
LDM	5156.4556	-61.1038	141.7043	98.72*
SDM	2610.4552	-53.6753	175.8434	98.70*
	Parameters of the exponential fit[7]			R^2
	a	*b*		
DMDM	266,9231	0,0143		99,45*
Panicum maximum cv. Mombasa				
TDM	4446.0390	0.0043		87.31*
LSR	4.7396	0.0037		84.32*
LDM	3408.5909	0.0044		86.36*
SDM	840.2267	0.0039		90.34*
DMDM	199.3830	0.0042		84.62*

[1]Model: $y=a/(1+\exp(-(x-x_0)/b))$; [2]TDM: total dry matter; [3]LSR: leaf to stem ratio; [4]LDM: leaf dry matter; [5]SDM: stem dry matter; [6]DMDM: dead material dry matter; [7]model: $y=a\times\exp(-b\times x)$; *significant by the F-test ($p\leq0.05$)

The herbicidal effect of glyphosate is less pronounced at 125 DAS when compared to 80 DAS. At the first assessment period, underdoses of 288, 147, and 160 g a.e. ha^{-1} promoted a 50% reduction in biomass production for *P. maximum* cv. Atlas, *P. maximum* cv. Tanzania, and *P. maximum* cv. Mombasa, respectively. For the same percentage of reduction at 125 DAS, underdoses of 488, 376, and 289 g a.e. ha^{-1} were required for *P. maximum* cv. Atlas, *P. maximum* cv. Tanzania, and *P. maximum* cv. Mombasa, respectively, which shows their potential for recovering from the herbicidal effect.

The data of density and dry matter of weeds at 80 and 125 DAS are shown in Table 4. The main weeds in the experimental area were *Commelina benghalensis*, *Cenchrus echinatus*, *Digitaria horizontalis*, *Eleusine indica*, *Cyperus rotundus*, *Alternanthera tenella*, *Nicandra physaloides*, *Ipomoea grandifolia*, *Ricinus communis*, and *Vigna angularis*. A low density and dry matter production of weeds were observed in the three grasses at 80 DAS.

Table 3. Parameters of the regression equations obtained by fitting the sigmoidal model and coefficient of determination (R^2) applied to the means of total dry matter (kg ha^{-1}), leaf to stem ratio, leaf dry matter (kg ha^{-1}), stem dry matter (kg ha^{-1}), and dead material dry matter (kg ha^{-1}) in the cultivation of *Panicum maximum* cv. Atlas, *P. maximum* cv. Tanzania, and *P. maximum* cv. Mombasa at 125 days after sowing as a function of glyphosate doses (0, 54, 108, 270, 378, 540, 756, and 1,080 g a.e. ha^{-1}) associated with atrazine (1,200 g a.i. ha^{-1}).

Variable	Parameter[1]			R^2
	a	*b*	x_0	
Panicum maximum cv. Atlas				
TDM[2]	4352.5174	-1.0783	488.4844	95.48*
LSR[3]	13.1919	-113.8163	124.3607	69.09*
LDM[4]	3288.0511	-3.5524	491.0252	95.59*
SDM[5]	1039.5508	-4.2009	487.7343	67.58*
DMDM[6]		$\bar{Y}$=0.00		*ns*[7]
Panicum maximum cv. Tanzania				
TDM	5691.3971	-1.6006	376.7705	99.71*
LSR	6.7183	-169.9263	58.7023	96.36*
LDM	3583.6559	-47.6065	367.7009	94.56*
SDM	2129.2086	-4.2450	373.9636	81.32*
DMDM		$\bar{Y}$=10.37		*ns*
Panicum maximum cv. Mombasa				
TDM	5895.5532	-6.8020	589.1171	96.85*
LSR	4.3834	-16.5481	279.5821	95.49*
LDM	2292.6390	-7.6583	284.1551	97.68*
SDM	600.5643	-0.2450	341.0704	89.18*
DMDM		$\bar{Y}$=19.63		*ns*

[1]Model: $y=a/(1+\exp(-(x-x_0)/b))$; [2]TDM: total dry matter; [3]LSR: leaf to stem ratio; [4]LDM: leaf dry matter; [5]SDM: stem dry matter; [6]DMDM: dead material dry matter; [7]not significant; *significant by the F-test ($p\leq0.05$)

The absence of a statistical difference at 80 DAS is related to the application of the herbicide atrazine, which controls the germination of weed seeds in the soil seed bank, in addition to exerting influence on the development of some weeds when applied at the beginning of their development. When using atrazine in the corn-brachiaria intercropping, CECCON et al. (2010) found only stunted weeds in the harvest period, which were later suppressed.

At 125 DAS, we noticed a higher density and biomass production of weeds at higher glyphosate underdoses due to a reduction in the development or even death of grasses, leaving the soil uncovered, which favors germination and development of weed seeds already present in the soil. In this period, there is no longer the influence of the herbicide atrazine on the weed community, whose half-life time, a parameter used to estimate its persistence in the soil, is 55 days (RODRIGUES; ALMEIDA, 2005). However, the residual effect is highly influenced by edaphoclimatic conditions (ULBRICH et al., 2005). The accumulation of a precipitation of 244 mm in December 2016 and 288 mm in January 2017 (Fig. 1) may have contributed to reducing the residual effect of the atrazine herbicide.

On the contrary, at lower glyphosate underdoses, the grasses expressed their suppression potential on the weed community. The development of grasses, with a consequent soil cover, reduces density and development of weeds, being an alternative for straw production for sowing the crop in succession (CECCON et al., 2010; LIMA et al., 2014; LIMA et al., 2016). Grass growth, with consequent soil cover, inhibited weed growth, evidencing the importance of using cultural practices for the integrated management of weeds.

CONCLUSIONS

Glyphosate underdoses below 215, 67, and 85 g a.e. ha^{-1} have potential to be investigated aiming at the management of *P. maximum* cv. Atlas, *P. maximum* cv. Mombasa, and *P. maximum* cv. Tanzania under intercropping.

Forages species had a strongly inhibited growth, with phytotoxicity symptoms above 50% for glyphosate underdoses above 220, 109, and 215 g a.e. ha^{-1} for *P. maximum* cv. Atlas, *P. maximum* cv. Mombasa, and *P. maximum* cv. Tanzania, respectively.

The grasses *P. maximum* cv. Atlas, *P. maximum* cv. Mombasa, and *P. maximum* cv. Tanzania are effective in suppressing weeds.

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Table 4. Parameters of the regression equations obtained by fitting the sigmoidal model and coefficient of determination (R^2) applied to the means of weed density (plants m^{-2}) and weed dry matter (g m^{-2}) in the cultivation of *Panicum maximum* cv. Atlas, *P. maximum* cv. Tanzania, and *P. maximum* cv. Mombasa at 80 and 125 days after sowing as a function of glyphosate doses (0, 54, 108, 270, 378, 540, 756, and 1,080 g a.e. ha^{-1}) associated with atrazine (1,200 g a.i. ha^{-1}).

Variable		Parameter[1]			R^2
		a	*b*	x_0	
Panicum maximum cv. Atlas					
80 DAS[2]	D[3]		$\bar{Y}$ = 3.88		*ns*[5]
	DM[4]		$\bar{Y}$ = 1.55		*ns*
125 DAS	D	28.1231	147.8042	374.9644	92.12*
	DM	1022.5395	222.8827	884.9224	99.41*
Panicum maximum cv. Tanzania					
80 DAS	D		$\bar{Y}$ = 8.56		*ns*
	DM		$\bar{Y}$ = 1.39		*ns*
125 DAS	D		$\bar{Y}$=10		*ns*
	DM	512.7761	105.1919	407.2303	99.55*
Panicum maximum cv. Mombasa					
80 DAS	D		$\bar{Y}$=8.69		*ns*
	DM		$\bar{Y}$=1.69		*ns*
125 DAS	D	16.6000	4.7498	110.7031	75.54*
	DM	348.3691	24.9604	299.8774	95.69*

[1]Model: $y=a/(1+\exp(-(x-x_0)/b))$; [2]DAS days after sowing; [3]D: weed density; [4]DM: weed dry matter; [5]not significant; *significant by the F-test ($p \leq 0.05$)

REFERENCES

ADEGAS, F. S.; VOLL, E.; GAZZIERO, D. L. P. Manejo de plantas daninhas em milho safrinha em cultivo solteiro ou consorciado à braquiária ruziziensis. *Pesquisa Agropecuária Brasileira*, v.46, n.10, p.1226-1233, 2011.

ALBRECHT, A. J. P.; ALBRECHT, L. P.; BARROSO, A. A. M.; VICTORIA FILHO, R. O milho RR2 e o glyphosate: uma revisão. *Revista Brasileira de Herbicidas*, v.13, n.1, p.58-67, 2014. 10.7824/rbh.v13i1.279

ALMEIDA, R. E. M. de; GOMES, C. M.; LAGO, B. C.; OLIVEIRA, S. M. de; PIEROZAN JÚNIOR, C.; FAVARIN, J. L. Corn yield, forage production and quality affected by methods of intercropping corn and *Panicum maximum*. *Pesquisa Agropecuária Brasileira*, v.52, n.3, p.170-176, 2017. http://dx.doi.org/10.1590/s0100-204x2017000300004

ALVES, V. B.; PADILHA, N. de S.; GARCIA, R. A.; CECCON, G. Milho safrinha consorciado com *Urochloa ruziziensis* e produtividade da soja em sucessão. *Revista Brasileira de Milho e Sorgo*, v.12, n.3, p.280-292, 2013.

BORGHI, E.; COSTA, N. V.; CRUSCIOL, C. A. C.; MATEUS, G. P. Influência da distribuição espacial do milho e da *Brachiaria brizantha* consorciados sobre a população de plantas daninhas em sistema plantio direto na palha. *Planta Daninha*, v.26, n.3, p.559-568, 2008. http://dx.doi.org/10.1590/S0100-83582008000300011

CARMEIS FILHO, A. C. de A.; CUNHA, T. P. L. da; MINGOTTE, F. L. C.; AMARAL, C. B. do; LEMOS, L. B.; FORNASIERI FILHO, D. Adubação nitrogenada no feijoeiro após palhada de milho e braquiária no plantio direto. *Revista Caatinga*, Mossoró, v.27, n.2, p.66-75, 2014.

CECCON, G.; MATOSO, A. O.; NETO NETO, A. L.; PALOMBO, L. Uso de herbicidas no consórcio de milho safrinha com *Brachiaria ruziziensis*. *Planta Daninha*, v.28, n.2, p.359-364, 2010. http://dx.doi.org/10.1590/S0100-83582010000200015

CHIODEROLI, C. A.; MELLO, L. M. M.; GRIGOLLI, P. J.; SILVA, J. O. R.; CESARIN, A. L. Consorciação de braquiárias com milho outonal em plantio direto sob pivô central. *Engenharia Agrícola*, Jaboticabal, v.30, n.6, p.1101-1109, 2010. http://dx.doi.org/10.1590/S0100-69162010000600011

CORREIA, N. M.; DURIGAN, J. C. Controle de plantas daninhas na cultura de soja resistente ao glyphosate. *Bragantia*, v.69, n.2, p.319-327, 2010. http://dx.doi.org/10.1590/S0006-87052010000200009

EUCLIDES, V. P. B.; VALLE, C. B. do; MACEDO, M. C. M.; ALMEIDA, R. G. de; MONTAGNER, D. B.; BARBOSA, R. A. Brazilian scientific progress in pasture research during the first decade of XXI century. *Revista Brasileira de Zootecnia*, Viçosa, v.39, (Suppl. spe), p.151-168, 2010. http://dx.doi.org/10.1590/S1516-35982010001300018

FERRAZZA, R. de A.; LOPES, M. A.; ALBUQUERQUE, C. J. B. Avaliação bioeconômica do consórcio de sorgo com diferentes espécies forrageiras para sistema de integração lavoura-pecuária em Nova Porteirinha, MG. *Boletim de Indústria Animal*, v.73, n.2, p.94-102, 2016.

FERREIRA, A. C. de B.; LAMAS, F. M.; CARVALHO, M. da C. S.; SALTON, J. C.; SUASSUNA, N. D. Produção de biomassa por cultivos de cobertura do solo e produtividade do algodoeiro em plantio direto. *Pesquisa Agropecuária Brasileira*, v. 45, n. 6, p. 546-553, 2010.

GALLI, A. J. B. A molécula glyphosate e a agricultura brasileira. In: VELLINI, E. D.; MESCHEDE, D.; CARBONARI, C. A.; TRINDADE, M. L. B. *Glyphosate*. Fepaf: Botucatu, 2009. p. 17-19.

GARCIA, C. M. de P.; ANDREOTTI, M.; TARSITANO, M. A. A.; TEIXEIRA FILHO, M. C. M.; LIMA, A. E. da S.; BUZETTI, S. Análise econômica da produtividade de grãos de milho consorciado com forrageiras dos gêneros *Brachiaria* e *Panicum* em sistema plantio direto. *Revista Ceres*, v.59, n.2, p.157-163, 2012. http://dx.doi.org/10.1590/S0034-737X2012000200002

GOMES JÚNIOR, F. G.; CHRISTOFFOLETI, P. J. Biologia e manejo de plantas daninhas em áreas de plantio direto. *Planta Daninha*, v.26, n.4, p.789-798, 2008. http://dx.doi.org/10.1590/S0100-83582008000400010

GRIGOLLI, J. F. J.; GITTI, D. de C.; LOURENÇÃO, A. L. F. Controle de plantas de soja e supressão do capim em milho consorciado com *Brachiaria ruziziensis*. *Arquivos do Instituto Biológico*, v.84, e0592015, 2017. http://dx.doi.org/10.1590/1808-1657000592015

INMET. Instituto Nacional de Meteorologia. 2016. Available from: <http://www.inmet.gov.br>. Accessed on: March, 2017.

LIMA, S. F.; TIMOSSI, P. C.; ALMEIDA, D. P.; SILVA, U. R. Palhada de braquiária ruziziensis na supressão de plantas daninhas na cultura da soja. *Revista Agrarian*, v.7, n.26, p.541-551, 2014.

______. Métodos de semeadura e aplicação de 2,4-D na formação de braquiária ruziziensis para plantio direto. *Cultura Agronômica*, Ilha Solteira, v.25, n.2, p.175-186, 2016.

MACHADO, L. A. Z.; ASSIS, P. G. G. de. Produção de palha e forragem por espécies anuais e perenes em sucessão à soja. *Pesquisa Agropecuária Brasileira*, v.45, n.4, p.415-422, 2010.

MACHADO, L. A. Z.; CECATO, U.; COMUNELLO, E.; CONCENÇO, G.; CECCON, G. Estabelecimento de forrageiras perenes em consórcio com soja, para sistemas integrados de produção agropecuária. *Pesquisa Agropecuária Brasileira*, v.52, n.7, p.521-529, 2017.

OLIVEIRA, B. P. de; FERREIRA, J. O.; SILVA, C. F. da; SILVA, A. C.; CEDRO, D. A. B. de; ALBINO, J. L. D. Diferentes forrageiras em consórcio com milho destinado a silagem. *Interdisciplinar: Revista Eletrônica da UNIVAR*, n. 15, v. 1, p. 170-173, 2016.

PETTER, F. A.; PROCÓPIO, S. O.; CARGNELUTTI FILHO, A.; BARROSO, A. L. L.; PACHECO, L. P. Manejo de herbicidas na cultura da soja Roundup Ready®. *Planta Daninha*, v. 25, n. 3, p. 557-566, 2007. http://dx.doi.org/10.1590/S0100-83582007000300015

QUEIROZ, R. F. de; CHIODEROLI, C. A.; FURLANI, C. E. A.; HOLANDA, H. V. de; ZERBATO, C. Maize intercropped with *Urochloa ruziziensis* under no-tillage system. *Pesquisa Agropecuária Tropical*, v.46, n.3, p.238-244, 2016. http://dx.doi.org/10.1590/1983-40632016v4640464

RIBEIRO JÚNIOR, J. I. *Análises estatísticas no SAEG*. Viçosa: UFV, 2007. 301p.

RODRIGUES, B. N.; ALMEIDA, F. S. *Guia de herbicidas*. 5. ed. Londrina: Edição dos Autores, 2005. 592p.

SILVA, P. I. B.; FONTES, D. R.; MORAES, H. M. F.; GONÇALVES, V. A.; SILVA, D. V.; FERREIRA, L. R.; FELIPE, R. S. Crescimento e rendimento do milho e da braquiária em sistema consorciado com diferentes manejos de plantas daninhas. *Planta Daninha*, v.32, n.2, p.301-309, 2014. http://dx.doi.org/10.1590/S0100-83582014000200007

SILVA; A. G. da; HORVATH NETO, A.; TEIXEIRA, I. R.; COSTA, K. A. P. da; BRACCINI, A. L. Seleção de cultivares de sorgo e braquiária em consórcio para produção de grãos e palhada. *Semina: Ciências Agrárias*, v. 36, n. 5, p. 2951-2964, 2015.

SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS (SBCPD). *Procedimentos para instalação, avaliação e análise de experimentos com herbicidas*. Londrina: SBCPD, 1995. 42p.

ULBRICH, A. V.; SOUZA, J. R. P.; SHANER, D. Persistence and carryover effect of imazapic and imazapyr in Brazilian cropping systems. *Weed Technology*, v. 19, n. 4, p. 986-991, 2005. https://doi.org/10.1614/WT-04-208R2.1