LEVELS OF NUTRIENTS AND GRAIN YIELD OF MAIZE INTERCROPPED WITH SIGNALGRASS (BRACHIARIA) IN DIFFERENT ARRANGEMENTS OF PLANTS[1]

Teores de Nutrientes e Produção de Grãos do Milho Consorciado com a Braquiaria em Diferentes Arranjos de Plantas

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ABSTRACT - Competition between maize and signalgrass can economically cripple the intercropping by the reduced yield of maize and dry matter content of the forage. In seeking to define plant arrangements which make this system more efficient, this research was held with the objective of assessing the effects of interference of densities of signalgrass (*Urochloa Brizantha*) on nutrition and on maize grain yield. Two field experiments were conducted in a randomized block design with four replications. Treatments were arranged similarly in both experiments, in a 2 x 4 factorial design, the first factor being the dose of Nicosulfuron herbicide applied (0 and 8 g ha^{-1}) and the second factor being the forage seeding rates (0, 2, 4 and 6 kg of seeds per hectare). The interference of signalgrass reduced foliar nitrogen, potassium and phosphorus content in maize plants intercropped with the forage. Higher values of grain yield were observed with the reduction of the spacing and the application of the recommended herbicide underdose (8 g ha^{-1}). It was concluded that, regardless of the seeding density of *U. Brizantha*, reducing the maize seeding inter-rows spacing, combined with the application of an underdose of Nicosulfuron, caused a positive effect by reducing the initial forage growth, resulting in less interference of *Urochloa brizantha* on nutrient uptake by the maize plants and grain yield of the crop.

Keywords: Nicosulfuron, competition in intercropping, cropping spacing.

*RESUMO - A competição entre o milho e a braquiaria pode inviabilizar economicamente o consórcio devido à redução na produção de grãos do milho e de matéria seca da forrageira. Na busca por definir arranjos de plantas que permitam tornar esse sistema mais eficiente, realizou-se esta pesquisa com o objetivo de avaliar os efeitos da interferência de densidades de braquiária (**Urochloa brizantha**) na nutrição e produção de grãos do milho. Foram realizados dois experimentos de campo, no delineamento de blocos casualizados com quatro repetições. Os tratamentos foram arranjados de modo semelhante nos dois experimentos, em esquema fatorial 2 x 4, sendo o primeiro fator a dose aplicada do herbicida Nicosulfuron (0 e 8 g ha^{-1}) e o segundo as densidades de semeadura da forrageira (0, 2, 4 e 6 kg de sementes por hectare). A interferência da braquiária reduziu os teores foliares de nitrogênio, potássio e fósforo nas plantas de milho consorciadas com a forrageira. Maiores valores de produção de grãos foram verificados com a redução do espaçamento e a aplicação da subdose recomendada do herbicida (8 g ha^{-1}). Concluiu-se que, independentemente da densidade de semeadura de **Urochloa brizantha**, a redução do espaçamento entre linhas do milho, aliada à aplicação da subdose do Nicosulfuron, causou efeito positivo por reduzir o crescimento inicial da forrageira, resultando em menor interferência de **Urochloa brizantha** no acúmulo de nutrientes pelas plantas de milho e na produtividade de grãos da cultura.*

Palavras-chave: Nicosulfuron, competição em consórcios, espaçamento de plantio.

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INTRODUCTION

The use of annual crops in rotation or in intercropping with forage species has constituted one of the main strategies of formation and reform of pastures in Brazil. Various cultures have been used in intercropping with forage, specifically of the genus *Urochloa*, but there is a preference for maize, due to its tradition of farming, the large number of commercial cultivars adapted to different ecological regions of Brazil and the excellent adaptation in this management system.

The simultaneous cultivation of two species promotes interspecific competition for growth resources such as water, light and nutrients, which may result in the yield reduction of both. This mutual interference between the plants varies depending on the species present in the area (Carvalho et al., 2011a), the population level (Vidal et al., 2004), emergence time (Jakelaitis et al., 2008) and the competitive characteristics of the cultivars.

In the case of intercropping, competitiveness can be mitigated by adopting cultivation practices, such as the spatial arrangement of plants (Oliveira et al., 1996), to slow the growth of a species during the period of interspecific competition. Reducing the spacing between rows of maize contributes to a better utilization of solar radiation and the fastest soil shading. However, it is believed that, in wider inter-row spacings, planting signalgrass (brachiaria) in maize row can enhance the competition between species, requiring the use of herbicides in underdoses to reduce the growth rate of forage, until it is shaded by the maize (Jakealitis et al., 2005).

Forage can interfere with the nutritional status of crops and hence in the final grain yield. The magnitude of this interference depends on the soil and climate conditions, the cultivars used and management employed (Silva et al., 2004). The intercropping between the maize and forage cultivation will be feasible when these plants have different initial growth rate and nutritional demand peaks at different stages. That way, it is possible to meet the requirements of different species without exceeding the maximum rate at which nutrients can be supplied by the soil.

The ability to remove soil nutrients and the amounts required will vary not only with the cultivar, but also with the degree of competition (Carvalho et al., 2011b). In this sense, the information obtained in the nutritional analysis of plants becomes essential for knowledge of the different interactions between the species in intercropping. Moreover, these results can be used to plan new planting arrangements that favor the full development of the species at the appropriate time.

Thus, the objective was to assess the effect of different arrangements of maize plants associated with *Urochloa brizantha* seeding density, with and without the application of the herbicide Nicosulfuron in nutrient content and yield of maize grains.

MATERIALS AND METHODS

There were two field experiments in the Brazilian city of Viçosa, MG, during the months of October 2011 to April 2012, in a soil classified as Red-Yellow Podzolic. Fertilization was done according to preliminary analysis of the soil (Table 1), using 400 kg ha^{-1} of formulated 8-28-16 (NPK), distributed in the maize plant row. On the coverage fertilization 120 kg of N were applied as urea at 40 days after culture seeding. Rainfall and the average weekly temperatures that occurred during the trial period are shown in Figure 1.

The two experiments were conducted in a randomized block design with four replications. The first trial was conducted with maize grown in the spacing of 0.50 m inter-rows, and the second one with 1.00 m inter-rows of maize, keeping the population of 60,000 plants ha^{-1} in both experiments. The treatments of the two trials were arranged in a 2 x 4 factorial design, and the first factor was the application or not of an underdose of Nicosulfuron (8.00 g ha^{-1}), and the second one of the signalgrass (brachiaria) seeding densities (0, 2, 4 and kg ha^{-1}, with VC = 76%).

The maize seeding was carried out in the tillage system, with prior desiccation of the experimental area by applying the mix in a

Table 1 - Chemical and physical characteristics of the soil of the experimental area

Soil	pH	P	K	Ca	Mg	Al	H+Al	SB	(t)	(T)	V	m	MO
	(H_2O)	(mg dm^{-3})		($cmol_c$ dm^{-3})							(%)		(dag kg kg^{-1})
Podzolic	5.6	5.9	64	2.0	0.8	0.3	3.3	2.96	2.96	6.26	47	0	2.6
Physical characteristics (%)													
Texture (%)	Clayey	Clay = 43					Silt = 14				Sand = 43		

Analyses carried out at Laboratório de Análises de Solo Viçosa (Laboratory of Soil Analysis in the Brazilian city of Viçosa), according to the methodology of Empresa Brasileira de Pesquisa Agropecuária (The Empresa Brasileira de Pesquisa Agropecuária (Brazilian Corporation of Agricultural Research) – Embrapa (1997).

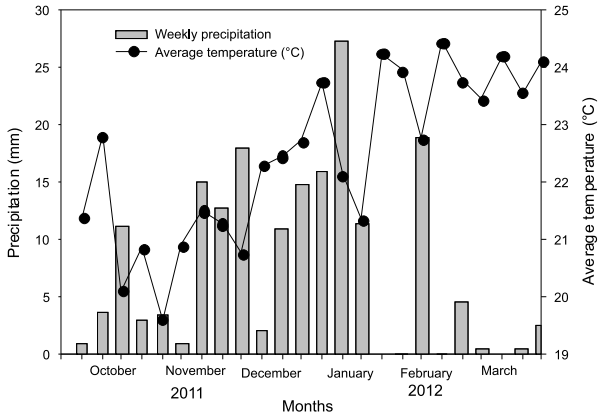

Figure 1 - Rainfall and average weekly temperatures during the period when the experiments were carried out.

tank of glyphosate herbicides (1,080 g ha^{-1}) + 2.4-D (540 g ha^{-1}) at seven days before planting the crops. The DKB 390 maize hybrid was sown on October 20, 2011, using a Semeato SHM 11/13 multiple seeder, with five planting rows for a spacing of 0.50 m and three planting rows for a spacing of 1.00 m.

On the same date of planting maize, manual seeding of *Urochloa brizantha* (BRS Piatã) was also held. In the experiment where maize had a spacing of 0.50 m, the signalgrass (brachiaria) was manually sown on the row of the culture, and in the trial of 1.00 m the forage seeding was carried out on the row and on the inter-row of the maize, keeping for the experiments the same distance of 0.50 m on the inter-rows of forage. The amount of *Urochloa brizantha* seeds was calculated respecting the specifications of each treatment.

The weed control was done with the application of the herbicide Atrazine at a dose of 1,500 g ha^{-1} at 20 days after planting the crop in all the treatments of the experiment, when the maize plants had four to six fully expanded leaves and plants of *U. brizantha* with three to five leaves.

The experimental plots of the two experiments were composed of 6 and 12 maize rows 5 m long for the trial in the spacing of 1.00 m and 0.5 m, respectively, both with a floor area of 12 m^2. At 60 days after emergence (DAE), during the appearance of the female inflorescence (silking), the opposite and below the top leaves of the top cob of ten maize plants were collected per plot for assessment of nitrogen (N), phosphorus (P) and potassium (K) contents; at 150 days after planting the floor area of each plot was harvested to assess the mass of the maize grains.

The leaves collected were dried in a forced air circulation oven (70 ± 2 °C) until reaching a constant weight and then milled (< 1.00 mm) and subjected to nutritional analysis. N was determined by Kjeldahl distilling after sulfuric digestion of the plant material (Tedesco et al., 1995). The plant material was submitted to nitro-perchloric digestion for determination of P content by colorimetry (Braga & De Felipo, 1974) and of K content by spectrometry and flame emission (Tedesco et al., 1995).

At the time of harvesting maize, there was a sample to determine the dry matter of signalgrass (brachiaria) in both experiments. For this, four samples were taken randomly by cutting signalgrass (brachiaria) at ground

level, using a metal square of 0.50 m in the sides. This material was dried in an oven with forced air circulation (70 ± 2 °C) until reaching a constant weight, after which heavy dry matter of *Urochloa brizantha* was weighed on a precision weighing balance 0.01 g.

The analysis of variance of the two experiments was performed to interpret the data. The data were analyzed by analysis of variance and regression. For qualitative factors, the means were compared using the Tukey test, adopting a level of 5% probability. As to the quantitative factor, the model was chosen based on the significance of the regression coefficient using the t-test at 5% probability, in the coefficient of determination (R^2 =S.Q.Reg/S.Q.Trat) and in the biological behavior observed.

RESULTS AND DISCUSSION

In the study variables, the relationship between the largest and the smallest mean square of the waste was less than seven in the two planting spacings, meeting the requirement for the implementation and interpretation of the analysis of variance (Pimentel Gomes, 1990).

Significance of the factors of signalgrass (brachiaria) density and spacing was found for maize nitrogen content. Greater distance (1.00 m) gave higher N content compared to plants grown at 0.5 m on inter-rows (Table 2), contrary to Broghi & Crusciol (2007), who have seen no difference in N content of maize sown in the spacings of 0.45 and 0.90 m. The application of Nicosulfuron did not affect the accumulation of this nutrient, regardless of signalgrass (brachiaria) density (Figure 2).

The increase in *Urochloa brizantha* density caused a linear reduction in N content in the maize plants (Figure 2). According to Jakelaitis et al. (2006a), the main factors responsible for the interference of *Urochloa brizantha* in crop yield are the rapid development of its root system and the high nitrogen uptake. This nutrient in maize is the main limiting factor for grain yield, as well as the biomass production of other forage grasses (poaceae, also called gramineae or true grasses), especially those belonging to the genus *Urochloa* (Abreu & Monteiro, 1999; Cecato et al., 2000). Thus, according to Rajcan & Swanton (2001), the presence of the competitor agent during the development and initial growth of maize can affect the availability of N in the soil and its distribution in the plant.

Table 2 - Average nitrogen content in dag kg^{-1} in maize plants grown in the spacings of 0.5 and 1.00 m between rows

Spacing	Average
1.00 m	2.95 A
0.50 m	2.79 B

Means followed by the same uppercase letters do not differ by F test at 5% probability.

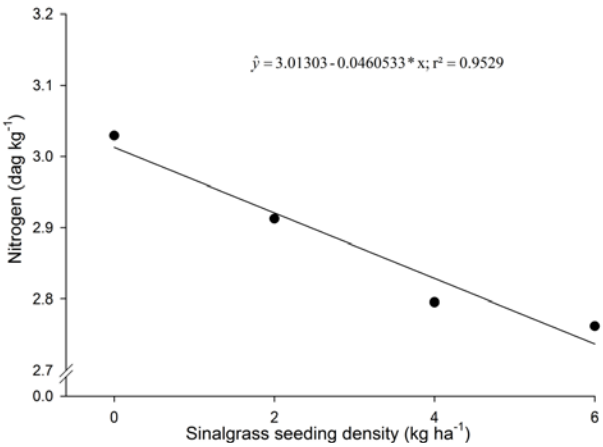

Figure 2 - Nitrogen content in maize leaves grown in intercropping, according to the seeding density of *Urochloa brizantha*.

There was a significant interaction between signalgrass (brachiaria) density, maize spacing and application of Nicosulfuron to the phosphorus content of maize. For the spacing of 1.00 m, smaller P concentrations were observed in the maize plants in the absence of herbicide, while for spacing of 0.50 m there was no significant difference (Table 3). When Nicosulfuron was applied, increased levels of P were found in maize with 1.00 m in inter-rows. However, in the absence of Nicosulfuron there was no difference between the spacings (0.50 and 1.00 m) for the variable.

As the *Urochloa brizantha* seeding density was increased, there was a linear decrease

Table 3 **-** Average phosphorus content in dag kg^{-1} in maize plants grown in two planting spacing and in the presence (Pres) and absence (Abs) of Nicosulfuron herbicide (Herb)

Herb	Seeding density of *Urochloa brizantha* (kg ha^{-1})							
	0		2		4		6	
	Spacing (m)							
	1.00	0.50	1.00	0.50	1.00	0.50	1.00	0.50
Pres	0.334 Aa	0.303Ab	0.294 Aa	0.287 Aa	0.313 Aa	0.285 Ab	0.297 Aa	0.294Aa
Abs	0.298 Ba	0.294 Aa	0.289 Aa	0.293 Aa	0.275 Ba	0.289 Aa	0.274 Ba	0.271 Ba

Means followed by the same lowercase letters in the row and uppercase letters in the column do not differ by Tukey test at 5% probability.

in the levels of P in all treatments, except for maize with a spacing of 0.50 m with Nicosulfuron (Figure 3). This may be due to the inhibitory effect of this herbicide in the growth of signalgrass (brachiaria), together with a better cultivation control (Jakelaitis et al., 2005) by reducing the spacing on inter-rows of maize. According to Borghi & Crusciol (2007), in intercropping conditions it is possible that competition for nutrients is minimized by adopting practices that promote weed cultivation control.

Similar to what was observed for phosphorus, it was found, for potassium (K) content, a triple interaction of the factors assessed. The application of Nicosulfuron gave higher values in K content of maize in the spacing of 1.00 m, while in the spacing of 0.50 m there was no statistical difference between herbicide application and the control (Table 4).

Maize, unlike other species of the family of grasses (poaceae, also called gramineae or true grasses), has low ability to compensate empty spaces, for it rarely yields and presents limited capacity of leaf expansion. In this case, the best distribution of the plants in the area resulting from the reduction in the spacing between the seeding rows may aid in the culture control of the Brachiaria by early shading of the inter-row, reducing the accumulation of forage biomass (Jakelaitis et al., 2005).

The foliar content of K in maize was linearly reduced with increasing plant density of signalgrass (brachiaria), regardless of spacing and herbicide application (Figure 4). The relative reduction in the content of nutrients due to the interference promoted by weeds was

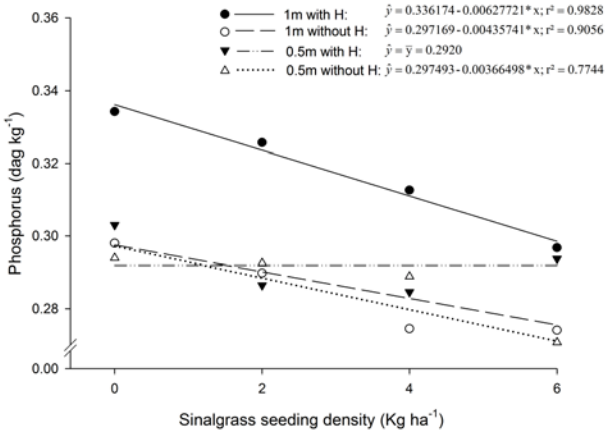

Figure 3 **-** Phosphorus content in maize leaves grown in intercropping, according to the seeding density of *Urochloa brizantha.*

also reported by Ronchi et al. (2003) for coffee beans. Gimenes et al. (2008) have reported that higher densities of *Urochloa decumbens*, *Urochloa brizantha* and *Urochloa ruziziensis* have enabled large farm soil exploration in surface and volume and thus have intensified the competitive effects on maize.

The increase in forage density has reduced the values of yield for maize grains (Figure 5), corroborating studies by Cobuci et al. (2001) and Jakelaitis et al. (2008). The reduction in the yield of maize, intercropped with a higher density of forage seeding regarding sole maize in the presence of an underdose of Nicosulfuron, was approximately 5%, while in the absence of the herbicide the drop in yield has exceeded 15%. This can be explained by the selectivity of maize to Nicosulfuron and by the high efficiency of this herbicide to reduce the growth of *Urochloa brizantha* when applied even in an underdose (Petter et al., 2011).

Table 4 - Average potassium content in dag kg^{-1} in maize plants grown in two planting spacing and in the presence (Pres) and absence (Abs) of Nicosulfuron herbicide (Herb)

Herb	Seeding density of *Urochloa brizantha* (kg ha^{-1})							
	0		2		4		6	
	Spacing (m)							
	1.00	0.50	1.00	0.50	1.00	0.50	1.00	0.50
Pres	1.80 Aa	1.78 Aa	1.76 Aa	1.55 Ba	1.59 Aa	1.64 Aa	1.53 Aa	1.53 Aa
Abs	1.66 Aa	1.84 Aa	1.29 Ba	1.82 Aa	1.33 Bb	1.56 Aa	1.07 Bb	1.59 Aa

Means followed by the same lowercase letters in the row and uppercase letters in the column do not differ by Tukey test at 5% probability.

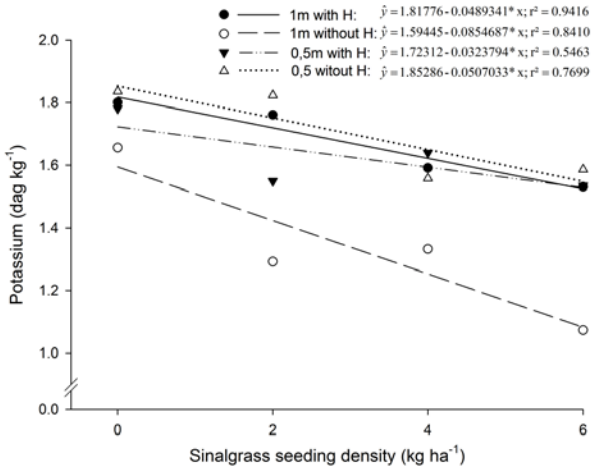

Figure 4 - Potassium content in maize leaves grown in intercropping, according to the seeding density of *Urochloa brizantha*.

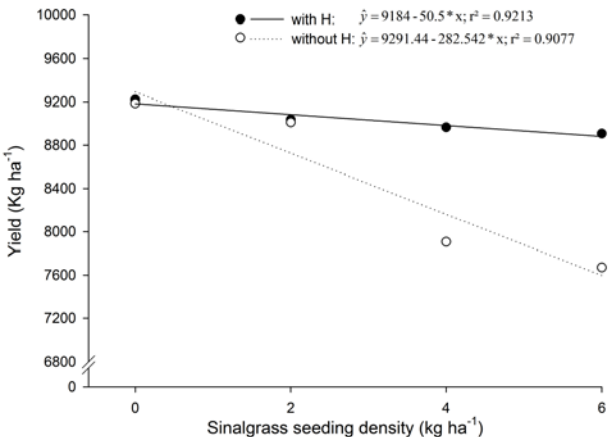

Figure 5 - Average yield of maize grains depending on planting density of *Urochloa brizantha* and application of a underdose (8 g ha^{-1}) of Nicosulfuron.

Jakelaitis et al. (2006b) have found that when maize is established before the forage, there are no losses in grain yield. The rapid establishment of maize in relation to signalgrass (brachiaria) favors its mastery on the forage due to competition mainly for light. However, according to these authors, the highest densities of *Urochloa brizantha* can reduce crop yield, and the management is recommended to avoid significant crop losses. Cobucci (2001) has reported the need, in some situations of intercropping, for the use of Nicosulfuron in underdoses to reduce the growth of forage and thereby ensure good crop yield. The results of this study also indicate the need of Nicosulfuron use when the population of *Urochloa brizantha* is high in the early development of maize (Table 5).

It was noted, in Table 6, that the increase in *Urochloa brizantha* seeding density has not provided higher dry matter values for the spacing of 0.50 m on inter-rows of maize and in the presence of Nicosulfuron. It was also found that regardless of the spacing used, herbicide application contributed to a lower dry matter yield of signalgrass (brachiaria).

Lower values of dry matter for the highest densities of seeding of *Urochloa brizantha* (4 and 6 kg ha^{-1} of seeds) were obtained in intercrops with narrower rows of maize and the application of Nicosulfuron at 1/5 of the recommended dose. This confirms the positive effect of reducing the spacing between rows of maize and the application of the herbicide underdose in reducing the initial growth rate of forage and the competitive potential of this one with intercropped maize.

It was concluded that in order to achieve economic success in this intercropping system, special attention is necessary to the spacing of maize plants and the forage seeding density and that the application of an underdose of Nicosulfuron is an important

Table 5 - Average of grain dry matter in kg of maize plants grown in two planting spacings intercropped with four densities of *Urochloa brizantha* in the presence and absence of Nicosulfuron

Nicosulfuron (8 g ha^{-1})	Seeding density of *Urochloa brizantha* (kg ha^{-1})			
	0	2	4	6
Presence	2305.00 A	2259.37 A	2241.25 A	2226.87 A
Absence	2272.50 A	2195.00 A	1976.67 B	1945.83 B

Means followed by the same letters do not differ by Tukey test at 5% probability.

Table 6 - Dry matter (g m^{-2}) of the different seeding densities of *Urochloa brizantha* intercropped with maize in two spacings, with and without application of a underdose of Nicosulfuron

Nicosulfuron (8 g ha^{-1})	Seeding density of *Urochloa brizantha* (kg ha^{-1})					
	2		4		6	
	Spacing (m)					
	1.00	0.50	1.00	0.50	1.00	0.50
Presence	11.33 Aa	9.78 Aa	21.98 Aa	14.31 Ab	24.58 Aa	10.66 Ab
Absence	19.51 Ba	14.71 Bb	23.27 Ab	37.56 Ba	26.60 Ab	60.13 Ba

Means followed by the same lowercase letters in the row and uppercase letters in the column do not differ by Tukey test at 5% probability.

alternative to minimize the competitive effects of the highest densities of *Urochloa brizantha* with maize.

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