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Milho segunda safra consorciado com forragens e correção do solo: produtividade e distribuição das raízes das forrageiras

Maize second-crop intercropped with forages and soil correction depths: grain yield and forages root distribution

Segundo cultivo de maíz consorciado con forraje y corrección del suelo: rendimiento de granos y distribución de las raíces de forraje

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Resumo

A correção dos solos é uma prática obrigatória que visa diminuir os efeitos nocivos da acidez, promover melhor desenvolvimento das plantas garantindo o potencial produtivo agrícola. Neste sentido, o trabalho teve como objetivo avaliar a produtividade do milho em monocultivo e/ou consorciado e estudar o comportamento das raízes de Urochloa spp em função de diferentes combinações de correção química do solo sob condição de sequeiro. O experimento foi conduzido no município de Selvíria, MS, Brasil em LATOSSOLO VERMELHO distrófico. O delineamento do experimento foi em blocos casualizados com parcelas subdivididas e três repetições. Os tratamentos de correção foram dispostos nas parcelas (controle, gesso, calcário (0 - 0,2 m); calcário e gesso (0 - 0,2 m); calcário (0 - 0,4 m); calcário e gesso (0 - 0,4 m)), e as subparcelas foram ocupadas milho solteiro, milho consorciado com U. ruziziensis ou consorciado com híbrido Mulato II (Convert HD 364). Os consórcios produziram quantidades suficientes de palha para iniciar e/ou manter o sistema de plantio direto na região do Cerrado e a presença das forrageiras na cultura do milho não influenciou o rendimento de grãos. O híbrido Mulato II possui maior diâmetro radicular, sendo mais indicado para solos compactados, embora a U. ruziziensis tenha obtido os maiores comprimentos radiculares.

Palavras-chave: *Urochloa* spp; *Zea mays*; Acidez do solo; Palhada; Sistemas produtivos.

Abstract

Correction of soils is a required practice that aims to reduce the harmful effects of soil acidity, promote better development of the plants and ensure the productive potential of agriculture. In this sense, the objective of this work was to evaluate the maize yield in monoculture and / or intercropped and to study the development of Urochloa spp roots according to different combinations of chemical correction of the soil in rainfed conditions. The experiment was developed in an experimental area, Selvíria, MS, Brazil in dystrophic Oxisol. The experimental design used was the randomized blocks with subplots, with three replications. The soil correction treatments were arranged in the plots (control, gypsum, lime (0 - 0.2 m); lime and gypsum (0 - 0.2 m); lime (0 - 0.4 m); lime and gypsum (0 - 0.4 m)), and the subplots were occupied with maize, maize intercropped with U. ruziziensis or with Mulato II hybrid (Convert HD 364) The two intercrop with forages produced sufficient amounts of straw to start and/or maintain no-tillage system in the Cerrado region and the presence of forage in maize crop did not influence grain yield. The Mulato II hybrid had a larger root diameter, being more indicated for compacted soils, however longest root lengths were obtained by U. ruziziensis.

Keywords: Urochloa spp; Zea mays; Soil acidity; Straw; Cropping systems.

Resumen

La corrección de los suelos es una práctica necesaria que tiene por objeto reducir los efectos nocivos de la acidez del suelo, promover un mejor desarrollo de las plantas y asegurar el potencial productivo de la agricultura. En este sentido, el objetivo de este trabajo fue evaluar el rendimiento del maíz en monocultivo y/o intercalado y estudiar el desarrollo de las raíces de Urochloa spp. según diferentes combinaciones de corrección química del suelo en condiciones de secano. El experimento se desarrolló en un área experimental, Selvíria, MS, Brasil en Ferrasol. El diseño del experimento se hizo en bloques aleatorios con parcelas subdivididas y tres repeticiones. Los tratamientos de corrección del suelo se dispusieron en las parcelas (control, yeso, cal (0 - 0,2 m); cal y yeso (0 - 0,2 m); cal (0 - 0,4 m); cal y yeso (0 - 0,4 m)), y las subparcelas se ocuparon con maíz, maíz intercalado con U. ruziziensis o con el híbrido Mulato II (Convert HD 364). Los dos cultivos intercalados con forrajes producían cantidades suficientes de paja para iniciar y/o mantener el sistema de siembra directa en la región de la sabana y la presencia de forraje en el cultivo de maíz no influyó en el rendimiento del grano. El híbrido Mulato II tenía un diámetro de raíz más grande, siendo más indicado para suelos compactados, sin embargo las longitudes de raíz más largas fueron obtenidas por U. ruziziensis.

Palabras clave: *Urochloa* spp*; Zea mays*; Acidez del suelo; paja; Sistemas productivos.

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1. Introduction

Soil correction for agricultural production in areas with high level weather is a mandatory practice to reduce the harmful effects of acidity, and to promote better development of plants ensuring the agricultural production potential of these regions. Among the factors of acidity, aluminum (Al3+) toxicity and calcium (Ca2+) deficiency have been reported as the most relevant root growth restrictions (Natale et al., 2012).

Liming, a practice used to neutralize soil acidity, is able to increase nutrient availability, reduce the content of toxic elements, and increase base saturation (BS%), thus improving the root environment, restoring the productive capacity of agricultural soils (Caires et al., 2005; Natale et al., 2007; Raij, 2011). However, the action of lime has limited effects on soil surface due to its low mobility, solubility and products obtained from the reaction (Rampim et al., 2011). Improvement of soil conditions below surface layers can be a factor of increase and/or stability of crop yields. Therefore, the supply of Ca2+ and Magnesium (Mg2+) and the reduction of the Al3+ free form in the subsoil layers play an important role in increasing crop yields in areas affected by acidity and dry periods in Cerrado regions (Costa et al., 2018).

In this context, the application of gypsum has been recommended as an alternative to decrease Al3+ activity and increase base saturation (BS%) in subsurface layers, thus allowing greater root development and, consequently, greater exploration of the soil by the roots (Soratto and Crusciol, 2008; Silva et al., 2015). Lime associated with gypsum provides an increase in the dry matter of the crops and, consequently, of straw left on the soil surface (Costa et al., 2018). The protection of the soil from the presence of plant residues is important for its physical quality, acting both in the protection of the surface and in the contribution of dry matter from shoots and roots (Souza et al., 2014).

Grain crops intercropped with tropical forage grasses, such as those of the genus Urochloa, which has a high C:N ratio, enables the longevity of the soil cover (Jakelaitis et al., 2005; Rosolem and Pivetta, 2017). This type of system contributes to an increase in the area and time of covered soil, being the Urochloa spp able to produce mass during and after maize harvest (Ceccon et al. 2011), protecting the soil between crop seasons. The root system of forages can reach great depths, contributing significantly to the cycling of nutrients that are in this zone and generally are not explored by maize roots (Ceccon et al., 2013).

Thus, soil improvement through the use of correctives, cover plants intercropped with the culture of economic importance as well as the development of forage crops in the face of

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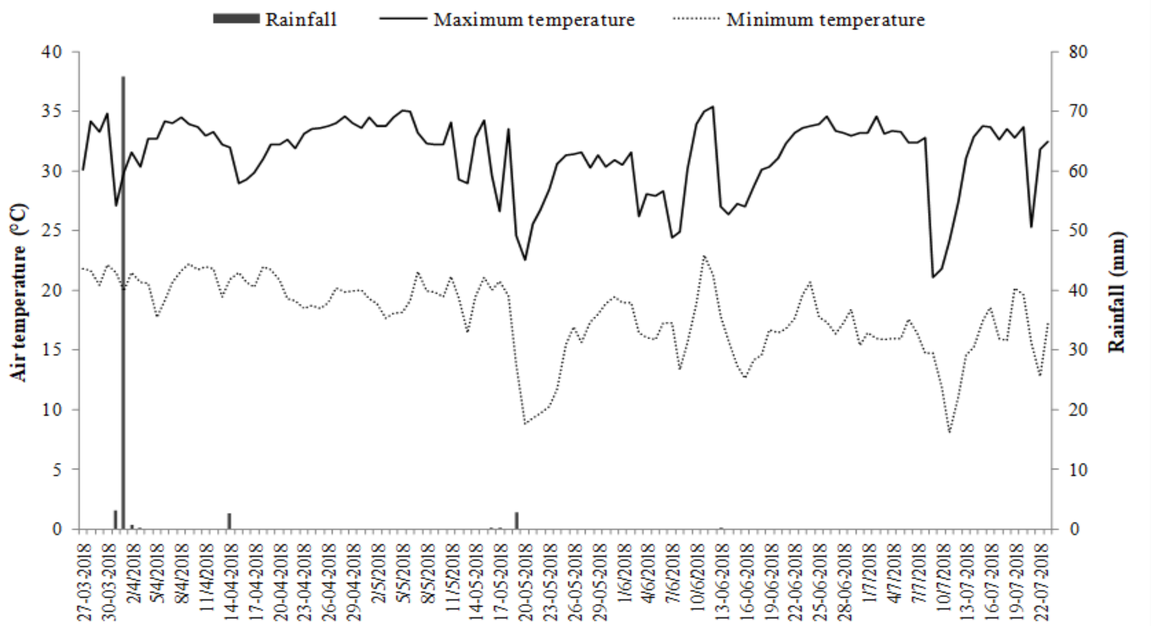
the treatments have extreme importance, since they constitute an important component in the system in respect to nutrient cycling and improvements in the environment. Thisway, the objective was to evaluate the maize yield in monoculture and/or intercropped and to study the development of Urochloa spp roots according to different combinations of soil chemical correction under dry conditions.

2. Material and Methods

A research is made to bring new knowledge for society as stated by Pereira et al (2018). The experimental was a field research, of quantitative nature, carried out in an experimental area located in Selvíria country, Mato Grosso do Sul State, Brazil, situated 20º20′ South latitude and 51º24’ West longitude of Greenwich, with an altitude of 335 m, approximately.

The climate type of this region is Aw, defined as tropical wet with a rainy season in the summer and dry in the winter, with temperature and annual average precipitation of 25 ºC and 1,313 mm (average of the last 15 years). The climatic data relating to the period of conduction of the experiment are shown in Figure 1.

Figure 1. Maximum and minimum daily temperature and rainfall referring to the period of the experiment conduction. Selviria, MS, Brazil, 2018.



Source: Author.

According to the current nomenclature, the soil of the experimental area is classified as a clayey dystrophic Oxisol (Santos et al. 2018). The soil was prepared in a conventional way by means of plowing and gradations, and the previous crop was soybean (Glycine max (L.) Merrill) in the last three agricultural years. Therefore, in order to characterize it before the sowing of production systems (February 2018), a survey of soil fertility in total area was carried out according to the methodology proposed by Raij et al. (2001), on the layers of 0 - 0.20 m and 0.20 - 0.40 m (Table 1).

Table 1. Chemical characterization of the soil in the experimental area.

Depht	P_{resin}	SOM	pH	K	Ca	Mg	H+Al	CEC	BS
(m)	(mg dm^{-3})	(g dm^{-3})	($CaCl_2$)	($mmol_c$ dm^{-3})					(%)
0 – 0.20	19	21	5.2	2,4	18	13	31	64,4	52
0.20 – 0.40	11	17	5.2	1,7	16	10	28	55,7	50

P: phosphorus; SOM: soil organic matter; CaCl2: calcium chloride; K, potassium; Ca, calcium; Mg, magnesium; H + Al, total acidity (hydrogen + aluminium); CEC, cation exchange capacity, BS, base saturation. Source: Author

The experimental design used was the randomized blocks with subplots, with three replications. The soil correction treatments were arranged in the plots (control (C), gypsum (G), lime (L) (0 - 0.2 m); lime and gypsum (L+G) (0 - 0.2 m); lime (L) (0 - 0.4 m); lime and gypsum (L+G) (0 - 0.4 m)), and for the subplots were occupied with single maize, maize intercropped with Urochloa ruziziensis or intercropped with Urochloa hybrid Mulato II (CONVERT HD 364), which was obtained by crossing the U. ruziziensis, U. decumbens cv. Basilisk and U. brizantha cv. Marandu. The plots were 10.5 m wide and 7.0 m long. In this regard, each subplot was 3.5 m wide by 7.0 m long.

The lime rate used was proportional to the soil layer to be corrected, seeking to increase the BS to 70%. The gypsum dose used was calculated according to the methodology proposed by Souza et al. (2006), considering the soil as clay. The dose of 2,200 kg ha-1 of gypsum was applied independently of the limes dose. Soil management consisted of operations such as scarification, plowing and grading common to all treatments.

The application of lime and gypsum in the area was performed on March, 2018 and after, operations were to incorporate them in the different layers, according to the treatments mentioned above. A sampling of lime and gypsum was carried out prior to calculations, where the water content in these inputs was determined for the correct application of the quantity, considering both inputs with 0% of water content. The physical and chemical characteristics of the inputs used are RPTN: 85%, Ca: 30%, Mg: 7.2% for lime, and Ca: 22%

and S: 17% for gypsum.

Maize sowing was carried out on March, 2018. The single cross hybrid 2B710 PRO was used, at a row spacing of 0.45 m, with an expected population of 65,000 plants per hectare (3.25 seeds m−1) considering a germination of 90%. Sowing fertilization was based on the analysis of soil previously removed from the experimental area, consisting of 250 kg ha−1 of formulation N-P2O5-K2O 08-28-16.

The sowing of forages used in intercropped occurred simultaneously to maize, with the use of the third sowing box specifically for this purpose. Thus, broadcast seeding was applied and incorporated by the movement of the soil in the sowing line, carried out by the planter. Seeds were used at the rate of 10 kg ha−1 (crop value of 60%).

At maize phenological stage V4 (Ritchie et al., 1993), the nitrogen top dressing (100 kg ha−1 of the urea was carried out. The fertilization was carried out manually and after fertilizer application, a single irrigation was performed, applying water depth to approximately 10 mm, to reduce losses by volatilization. Phytosanitary management was performed according to the crop needs.

Maize was harvested on July, 2018, and were determined grain yield, where the ears of the plants in the useful area of each subplot (two rows of 3.0 m)harvested manually and then mechanically trimmed, with the grains obtained weighed on a scale, and the humidity corrected to 13% (wet basis) with the values expressed in kg ha-1.

Root system samples of the forage grasses were taken in the maize inter-row, avoiding clumps, along the profile in each subplot of the intercropped at 70 days after maize harvest. A galvanized-steel probe with a 42.58 mm diameter cutting tip was used for root samples on depths of 0–0.10, 0.10–0.20, 0.20–0.30, 0.30-0.40 0.40-0.50 and 0.50–0.60 m. All root structures were carefully separated from the soil and other residues by washing under a flow of swirling water over a 0.5 mm mesh sieve, according to Oussible et al. (1992). The root samples were immersed in a 70% ethyl alcohol solution in plastic pots with lids and stored under refrigeration at 28ºC until evaluation.

To evaluate the root length density (km m–3) and diameter (mm), all root samples were digitalized with an optical scanner (Scanjet 4C/T; HP, Palo Alto, CA, USA) at high resolution (600 dpi) and then analyzed by the software program WinRhizo® version 3.8-b (Regent Instruments, Quebec). The root-length distribution was calculated by the ratio between root-length density data in each layer and total root length, with the result multiplied by 100.

At seventy days after the maize harvest, the green matter was also sampled from the forage plants of the intercropped. For that, a square metallic with an area of 0.25 m2 and a cleaver were used for sampling in the subplots, where the plants were cut close to the soil. Following these assessments, the samples were dried in a forced-air oven at 65 °C for 72 h to measure dry matter, expressed in kg ha-1.

The results were submitted to the analysis of individual variance ANOVA by F test (p <0,01 or p> 0,05), and when a significant difference was verified, the averages were compared by the LSD test ($p \leq 0.05$).

3. Results and Discussion

The root length of both *Urochloa* species was influenced by chemical soil correction along the profile, with isolated significance of the factors and significant interactions between forages and soil correction (Table 2).

Table 2. F values and averages for root length of forages along the profile as a function of soil correction. Selvíria, MS, Brazil, 2018.

TREATMENTS	Root Leght (km m^{-3})					
	0-0.10 m	**0.10-0.20 m**	**0.20-0.30 m**	**0.30-0.40 m**	**0.40-0.50 m**	**0.50-0.60 m**
SOIL CORRECTION (SC)						
Control	11.98	8.95	5.87	3.46	3.03	2.25
Gypsum	18.86	13.22	4.94	2.73	2.25	1.04
Lime (0-0.20)	23.26	8.39	5.67	3.86	2.77	2.92
Lime + Gypsum (0-0.20)	29.88	15.45	6.50	4.49	2.07	2.10
Lime (0-0.40)	20.57	10.24	5.87	3.02	3.15	4.04
Lime + Gypsum (0-0.40)	14.29	11.17	5.39	4.12	1.74	2.01
LSD	4.64	1.79	1.12	0.73	1.69	0.71
CROP SYSTEM (CS)						
Maize + Mulato II hybrid	15.94	6.83	3.62	1.85	1.67 b	1.98
Maize + *U. ruziziensis*	23.68	15.64	7.79	5.38	3.33 a	2.81
LSD	2.30	4.78	0.79	0.42	0.40	0.57
	F Test					
***p value* (SC)**	0.0008**	0.0005**	0.1369	0.0068**	0.3608 ^{ns}	0.0007**
***p value* (CS)**	0.0002**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	0.0117*
***p value* (SC x CS)**	0.0003**	0.0058**	0.0061**	0.0019**	0.0853 ^{ns}	0.0287*
Overall average	19.80	11.23	5.70	3.61	2.50	2.39
CV. sub-plot (%)	11.63	17.39	13.89	11.52	16.07	23.75

ns, * and ** is, respectively, not significant, significant at ($P \leq 0.05$) and ($P \leq 0.01$) probability by F test Averages followed by the same letters in the column do not differ by LSD's test at the 5% significance level. Source: Author.

By doing a direct comparison of the species used in the intercropped, without taking into account the chemical correction of the soil, it is possible to affirm that, in general, *U.*

ruziziensis stood out in the length of root in the sampled layers when compared to Mulato II hybrid, having a more aggressive root system along the profile.

It was observed interaction between soil correction and forage plants at different depths evaluated, except in the 0.40 - 0.50 m layer where there was only difference between the forage grassesused, with emphasis on *U. ruziziensis*, which was superior to the Mulato II hybrid, presenting 3.33 km m^{-3} of root in the sampled layer (Table 2).

The longest lengths of *U. ruziziensis* roots in the layers of 0 - 0.10 m and 0.10 - 0.20 m were obtained when the lime application occurred at the same time as the gypsum up to 0.20 m with an average of 46.78 and 24.97 km m^{-3} of roots in the respective layers (Table 3).

Table 3. Unfolding of the significant interaction between soil correction and crop system for root length (km m^{-3}) of forages in 0 – 0.1 m and 0.1 – 0.2 m layers. Selvíria, MS, Brazil, 2018.

SOIL CORRECTION	CROP SYSTEM			
	Maize+ *U. ruziziensis*	Maize + Mulato II	Maize + *U. ruziziensis*	Maize + Mulato II
	0 – 0.10 m		0.1 – 0.20 m	
Control	11.88 dA	12.08 cdA	12.98 cdA	4.93 bB
Gypsum	21.10 bcA	16.63 bcA	19.36 bA	7.08 abB
Lime (0-0.20)	24.83 bA	21.69 abA	11.31 dA	5.46 bB
Lime + Gypsum (0-0.20)	46.78 aA	12.98 cdB	24.97 aA	5.94 bB
Lime (0-0,4)	18.90 cA	22.25 aA	10.17 dA	10.30 aA
Lime + Gypsum (0-0.40)	18.59 cA	9.99 dB	15.05 cA	7.29 abB

Averages followed by the same lowercase letter in the columns and capital letter in the line do not differ by LSD’s test at the 5% significance level. Source: Author.

The Mulato II hybrid in the 0- 0.10 m layer presented longer root length when liming was performed to correct the 0 - 0.40 m layer, however it did not differ from the correction with lime up to 0.20 m.

The longer root length of the hybrid in the second soil layer was obtained with application of lime up to 0.40 m, a result similar to the previous layer, differing from Control, L (0-0.20) and L + G (0-0.20) (Table 3).

In the 0.20 - 0.30 m and 0.30 - 0.40 m layers, the development of *U. ruziziensis* before the correction treatments showed the same tendency as the previous layers. The best results were obtained through liming and gypsum, where treatment L + G (0-0.20) was the most efficient in the 0.20 - 0.30 m (10.87 km m^{-3}) layer and in the 0.30 - 0.40 m layer, the treatment of gypsum with lime aiming at correction up to 0.20 and 0.40 m were superior to the other treatments presenting, respectively, 7.31 and 6.69 km m^{-3} in length (Table 4).

Table 4. Unfolding of the significant interaction between soil correction and crop system for root length (km m^{-3}) of forages in 0.2 – 0.3 m and 0.3 – 0.4 m layers. Selvíria, MS, Brazil, 2018.

SOIL CORRECTION	CROP SYSTEM			
	Maize+ *U. ruziziensis*	Maize + Mulato II	Maize + *U. ruziziensis*	Maize + Mulato II
	0.20 – 0.30 m		0.30 – 0.40 m	
Control	7.57 bcA	4.17 abcB	5.15 bA	1.77 bB
Gypsum	6.55 cA	3.32 bcdB	4.07 cA	1.39 bB
Lime (0-0.20)	6.88 bcA	4.45 abB	4.33 bcA	3.40 aA
Lime + Gypsum (0-0.20)	10.87 aA	2.13 dB	7.31 aA	1.68 bB
Lime (0-0,4)	6.72 bcA	5.06 aA	4.73 bcA	1.31 bB
Lime + Gypsum (0-0.40)	8.18 bA	2.61 cdB	6.69 aA	1.55 bB

Averages followed by the same lowercase letter in the columns and capital letter in the line do not differ by LSD's test at the 5% significance level. Source: Author.

In the case of the Mulatto II hybrid, its longer roots in the 0.20 - 0.30 m layer were found in the treatment L (0-0.40), however this did not differ from L (0-0.20) and Control. In the 0.30 - 0.40 m layer, Mulato II forage presented a higher value when lime was applied aiming to correct the profile up to 0.20 m (Table 4)In the 0.50 - 0.60 m layer, the Mulato II hybrid had better root system development when liming was performed up to 0.40 m. *U. ruziziensis*, in turn, had better responses to three treatments in this layer, being these L (0-0.40), L (0-0.20) and L + G (0-0.20) which presented 4.12, 3.93 and 3.35 km m^{-3} , respectively (Table 5).

Table 5. Unfolding of the significant interaction between soil correction and crop system for root length (km m^{-3}) of forages in 0.5 – 0.6 m layer. Selvíria, MS, Brazil, 2018.

SOIL CORRECTION	CROP SYSTEM	
	Maize + *U. ruziziensis*	Maize + Mulato II
	0.50 – 0.60 m	
Control	2.80 bA	1.70 bcA
Gypsum	1.27 cA	0.81 cA
Lime (0-0.20)	3.93 aA	1.90 bcB
Lime + Gypsum (0-0.20)	3.35 abA	0.86 cB
Lime (0-0,4)	4.12 aA	3.97 aA
Lime + Gypsum (0-0.40)	1.39 cA	2.63 bA

Averages followed by the same lowercase letter in the columns and capital letter in the line do not differ by LSD's test at the 5% significance level. Source: Author.

In all layers of the soil profile it was possible to observe that Ca^{2+}, supplied through lime and/or gypsum, is a nutrient with a preponderant role in the root growth of forages, based on the data presented. This macronutrient is important in preserving the absorption capacity of the roots by maintaining the integrity of the plasmatic membrane, increasing the accumulation of nutrients by the plant (Malavolta, 2006).

Fernandes (2006) attributed to Ca^{2+}, when in low soil contents, the possibility of root growth paralysis due to the action of this nutrient in the growth points of the roots. Therefore, the application of lime and gypsum in areas of Cerrado is of extreme importance, since the soils of this biome have high acidity and low concentrations of sulphur and calcium under natural conditions (Amaral et al., 2017).

Forage plants of the genus *Urochloa* are mostly known as tolerant to acid soils (Paulino and Teixeira, 2009), however the degree of tolerance varies among them, because in addition to the genetic characteristics of the plants, the soil has different proportions of acidity factors, either active acidity due to the presence of H^{+} or chemical, by the presence of aluminum in the Al^{3+} form.

The Mulato II hybrid is well adapted to acid soils of low fertility and high toxic aluminium content (Argel et al., 2007), common in tropical conditions.

Although it is not a demanding forage, the cultivar responded to soil correction by presenting higher root length values when lime was added.

On the other hand, *U. ruziziensis* in relation to the other species of the genus *Urochloa* is the most demanding in terms of soil fertility (Alvim et al., 2002), corroborating with the results obtained in this work, where there was a better performance of the species when the gypsum associated to the limestone was applied in the different layers.

Table 6 shows that the roots diameter was larger for the Mulato II hybrid, except for the roots evaluated in the 0.50 to 0.60 m layer. Considering that the treatments with soil correction did not influence the roots diameter, it is admitted that this difference observed between the forages is an intrinsic factor of the species.

Although it presented a shorter root length, the Mulato II hybrid presented a larger root diameter with an average of 0.42 to 0.65 mm while *U. ruziziensis* did not exceed 0.47 mm.

U. ruziziensis has smaller diameter roots, which varied from 0.37 to 0.47 mm in the layers, and can be recommended for use in soils with already existing root canals and fissures because they are thinner (Müller et al., 2001). The Mulato II hybrid has as characteristic roots with larger diameters and these are more indicated when the soil is with high level of compaction and deficient in macropores where the roots need to deform the soil more than to explore fissures, because these present greater resistance to bending, according to Henderson (1989).

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Table 6. F values and averages for root diameter of forages along the profile as a function of soil correction. Selvíria, MS, Brazil, 2018.

TREATMENTS	Root Diameter (mm)					
	0-0.10 m	**0.10-0.20 m**	**0.20-0.30 m**	**0.30-0.40 m**	**0.40-0.50 m**	**0.50-0.60 m**
SOIL CORRECTION (SC)						
Control	0.53	0.59	0.44	0.63	0.43	0.44
Gypsum	0.55	0.46	0.45	0.50	0.45	0.36
Lime (0-0.20)	0.53	0.55	0.44	0.46	0.34	0.42
Lime + Gypsum (0-0.20)	0.60	0.47	0.50	0.43	0.34	0.40
Lime (0-0.40)	0.48	0.54	0.53	0.58	0.39	0.45
Lime + Gypsum (0-0.40)	0.61	0.63	0.36	0.35	0.42	0.32
LSD	0.19	0.22	0.11	0.07	0.13	0.09
CROP SYSTEM (CS)						
Maize + Mulato II hybrid	0.63 a	0.65 a	0.52 a	0.56 a	0.42 a	0.42
Maize + *U. ruziziensis*	0.47 b	0.44 b	0.39 b	0.42 b	0.37 b	0.38
LSD	0.04	0.08	0.12	0.08	0.04	0.07
	F test					
***p value*(SC)**	0.6184 ^{ns}	0.4836 ^{ns}	0.0957 ^{ns}	0.0541 ^{ns}	0.3400 ^{ns}	0.0747 ^{ns}
***p value* (CS)**	0.0002**	0.0008**	0.0360*	0.0085**	0.0173*	0.2238 ^{ns}
***p value* (SC x CS)**	0.0568 ^{ns}	0.1397 ^{ns}	0.6753 ^{ns}	0.4477 ^{ns}	0.0577 ^{ns}	0.4753 ^{ns}
Overall average	0.55	0.54	0.45	0.49	0.40	0.40
CV. sub-plot (%)	8.54	15.08	23.54	17.35	10.67	19.39

ns, * and ** is, respectively, not significant, significant at ($P \leq 0.05$) and ($P \leq 0.01$) probability by F test. Averages followed by the same letters in the column do not differ by LSD's test at the 5% significance level. Source: Author.

Evaluating the distribution of the root system of both species (Table 7), in the 0 – 0.10 m layer, there is a higher concentration of the Mulato II hybrid roots, independent of the soil correction treatment. In the 0.10 - 0.20 m layer, there is a higher concentration of *U. ruziziensis* roots when compared to the hybrid. In the layers below 0.20 m, the distribution was uniform for both species.

The root activity along the profile allows to create a bioporosity in the soil promoting improvements in the physical and physical-water qualities of the soil in depth, due to the large contribution of dry root mass.

Table 7. Distribution of the root system (%) of forages along the profile as a function of soil correction. Selvíria, MS, Brazil, 2018.

Depht (m)	C		G		L (0-0.2)		L+G (0-0.2)		L (0-0.4)		L+G (0-0.4)	
	R	**M**	**R**	**M**	**R**	**M**	**R**	**M**	**R**	**M**	**R**	**M**
	Distribution of the root system (%)											
0-0.1	26.9	44.9	38.2	53.8	45.4	55.6	48.6	52.7	38.4	50.0	34.8	41.5
0.1-0.2	29.4	18.3	35.1	22.9	20.7	14.0	25.9	24.1	20.6	23.1	28.2	30.3
0.2-0.3	17.1	15.5	11.9	10.7	12.6	11.4	11.3	8.7	13.6	11.3	15.3	10.8
0.3-0.4	11.6	6.6	7.4	4.5	7.9	8.7	7.6	6.8	9.6	3.0	12.5	6.4
0.4-0.5	8.7	8.3	5.1	5.4	6.2	5.5	3.2	4.3	9.4	3.8	4.2	5.2
0.5-0.6	6.3	6.3	2.3	2.6	7.2	4.9	3.5	3.5	8.4	8.9	4.9	5.8

C: Control; G: Gypsum; L (0-0.2): Liming up to 0.2 m layer; L+G (0-0.2): Liming and gypsum up to 0.2 m layer; L (0-0.4): Liming up to 0.4 m layer; L+G (0-0.4): Liming and gypsum up to 0.4 m layer; R: *U. ruziziensis*; M: Mulato II hybrid.
Source: Author.

A well distributed root system along the profile promotes beneficial changes that promote structuring, water infiltration, reducing mechanical resistance to penetration, since, when they decompose, these roots create ducts in the soil and increase organic material in the system (Mendonça et al., 2013; Chioderoli et al., 2012).

Such improvements can provide a more propitious environment for crops in succession by decreasing the risk of losses due to dry periods, frequent in Cerrado regions (Richetti, 2013).

The lime applied up to 0.4 m was the treatment that promoted the largest amount of roots in the 0.50 - 0.60 m layer (Table 7). The importance of Ca^{2+} in the subsurface layers is due to its function in root growth, for its performance in cell division and for being immobile in the plant (Hawkesford et al., 2012) and also for the significant and almost exclusive absorbance by root coping (Taiz et al. 2017).

The plant population of maize was not influenced by the crop system, single or intercropped, as well as it was not influenced by the chemical correction treatments of the soil (Table 8). Silva et al. (2015) reports that the lack of interference of grasses, possibly, can be explained by the slow initial growth of forages, when compared to maize.

Table 8. F values and averages for plant population, grain yield and dry matter of cover crops in different crop systems as a function of soil correction. Selvíria, MS, Brazil, 2018.

TREATMENTS	Plant Population (plants ha^{-1})	Grain Yield ($Mg\ ha^{-1}$)	Dry Matter of Cover Crops ($Mg\ ha^{-1}$)
SOIL CORRECTION (SC)			
Control	58436	2.64	5.03
Gypsum	60905	2.99	5.58
Lime (0-0.20)	59259	2.51	6.08
Lime + Gypsum (0-0.20)	62551	3.06	5.34
Lime (0-0.40)	58436	3.32	5.78
Lime + Gypsum (0-0.40)	60082	2.50	5.41
LSD	7227	0.40	0.61
CROP SYSTEM (CS)			
Maize	61728	2.88	1.61
Maize + Mulato II hybrid	58436	2.84	7.39
Maize + *U. ruziziensis*	59670	2.79	7.61
LSD	4358	0.19	0.65
		Teste F	
***p value*(SC)**	0.7804 ns	0.0053**	0.0419*
***p value* (CS)**	0.3071 ns	0.5717 ns	<0.0001**
***p value* (SC x CS)**	0.8433 ns	<0.0001**	0.0008**
Overall average	59945	2.83	5.53
CV. sub-plot (%)	10.56	9.81	17.04

ns, * and ** is, respectively, not significant, significant at ($P \leq 0.05$) and ($P \leq 0.01$) probability by F test
Averages followed by the same letters in the column do not differ by LSD's test at the 5% significance level.
Source: Author.

The interaction between treatments was significant for the maize grain yield (Table 8). The overall average yield of 2.8 t ha^{-1}observed in this study, is below the national average (4.7 Mg ha^{-1}) and the state average (3.8 Mg ha^{-1}), referring to the second crop of maize, according to the CONAB (2018). The late sowing of the experiment, which was carried out onlate March, therefore left the period recommended by the agricultural zoning, which defines that the cultivation of maize in dry condition must be sowed until first half of March (Conab, 2018).

High temperatures combined with low rainfall, which occurred in critical periods of the crop (Figure 1) as in floral differentiation, around phenological stage V_4 and V_5 where the yield potential of maize crop is defined (Ritchie et al., 1993), flowering and fruiting compromised yields levels. Therefore, lower grain production was observed in relation to the national average for second crop.

As for the unfolding, the cultivation modalities differed according to the correction treatment they received (Table 9).

Table 9. Unfolding of the significant interaction between soil correction and crop system for grain yield (Mg ha^{-1}) of maize in dry condition. Selvíria, MS, Brazil, 2018.

SOIL CORRECTION	CROP SYSTEM		
	Maize	**Maize + *U. ruziziensis***	**Maize + Mulato II hybrid**
Control	3.10 bA	2.59 bcB	2.22 cB
Gypsum	2.28 cdB	3.54 aA	3.14 abA
Lime (0-0.20)	2.11 dB	2.32 cB	3.08 abA
Lime + Gypsum (0-0.20)	2.89 bB	2.72 bcB	3.56 aA
Lime (0-0,4)	4.14 aA	3.09 abB	2.69 bcB
Lime + Gypsum (0-0.40)	2.75 bcA	2.41 cA	2.33 cA

Averages followed by the same lower case letter in the columns and capital letter in the line do not differ by LSD's test at the 5% significance level. Source: Author.

It is important to mention that the soil where the experiment was installed presented good initial fertility, which made the control treatment, which did not receive a correction, to present grain yield results similar to treatments with addition of lime and/or gypsum.

Due to low solubility, the presence and contact time of water with lime and gypsum have fundamental importance for their reaction in the soil. Therefore, the short time between the correctives application and the sowing of maize, allied to the low rainfall during the crop cycle, may have influenced the response of lime and gypsum on grain yields (Barros et al., 2009).

Single maize had a better performance when the correction with lime was effected up to 0.4 m, with an average grain yield of 4.14 Mg ha^{-1} being this higher than the state average and the nearest to the national average for the season. When cultivated with the *U. ruziziensis* species, maize presented higher productivity in the treatment where gypsum or lime correction was performed up to 0.4 m, with 3.54 and 3.09 Mg ha^{-1} of grains, respectively. The higher maize yield intercropped with the Mulato II hybrid (3.56 Mg ha^{-1}), was obtained when liming was carried out simultaneously with gypsum up to a 0.2 m layer, however it did not differ from the G and L (0-0.2) treatments (Table 9).

Dry matter of plants (Table 8), provided by *U. ruziziensis* and Mulato II hybrid intercropped with maize, it can be affirmed that the values obtained are in accordance with the appropriate values of dry matter that provide a good rate of soil cover, defined by Kluthcouski and Aidar (2003) and Cruz et al. (2017). These authors consider that the minimum amount of dry matter on the soil is on average 5 to 6 Mg ha^{-1}.

Although *U. ruziziensis* was superior to the Mulato II hybrid in root length along the soil profile (Tables 3, 4 and 5), both forages were similar in the production of dry matter of plants, except for the treatment of applying lime simultaneously to gypsum up to 0.40 m, in which *U. ruziziensis* produced a higher value of dry matter (Table 10).

Table 10. Unfolding of the significant interaction between soil correction and crop system for dry matter of cover crops (Mg ha^{-1}). Selvíria, MS, Brazil, 2018.

SOIL CORRECTION	CROP SYSTEM		
	Maize+ spontaneous plants	**Maize + *U. ruziziensis***	**Maize + Mulato II hybrid**
Control	1.33 aB	6.68 cA	7.08 bA
Gypsum	2.71 aB	6.77 cA	7.77 abA
Lime (0-0.20)	1.92 aB	7.38 bcA	8.85 aA
Lime + Gypsum (0-0.20)	1.39 aB	6.71 cA	7.92 abA
Lime (0-0,4)	0.97 aB	8.66 abA	7.70 abA
Lime + Gypsum (0-0.40)	1.79 aC	9.42 aA	5.01 cB

Averages followed by the same lower case letter in the columns and capital letter in the line do not differ by LSD’s test at the 5% significance level. Source: Author.

The dry matter produced by maize intercropped with *Urochloa* forage plants are the most appropriate for soil cover, because in addition to providing soil protection for a longer period of time they also promote nutrient recycling (Calonego et al., 2012).

The dry matter of spontaneous plants collected in the maize between rows, in single maize, did not exceed 3 Mg ha^{-1}. While, in the intercrops, the forages produced 5 to 9 Mg ha^{-1} of dry matter, changing depending on the species and soil correction (Table 10).

The *U. ruziziensis* was responsible for the highest dry matter productivity, producing up to 9.4 Mg ha^{-1} when liming was performed simultaneously gypsum up to 0.4m. However, this result did not differ from the treatment with application of lime in the same soil layer (8.6 Mg ha^{-1}). The lime applied up to 0.2 m provided the highest dry matter production of the Mulato II hybrid, 8.8 Mg ha^{-1} followed by 7.9, 7.8 and 7.7 Mg ha^{-1}, obtained by L + G (0-0.2), G and L (0-0.4) treatments, respectively.

The maize second crop intercropped with forage species represents a good alternative for maintaining maize as an economic crop, without presenting significant reductions in grain yield and by increasing the amount of residues on the soil surface.

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4. Final Considerations

This article provides unpublished information on the morphological characteristics of roots of different species of Urochloa and and dry matter of maize intercropped with this species. These results help to generate technical information to help producers choose the most appropriate cropping system.

The Mulato II hybrid had a larger root diameter, being more indicated for compacted soils, however longest root lengths were obtained by *U. ruziziensis.*

The two maize intercrop with *Urochloa* species produced sufficient amounts of straw to start and/or maintain no-tillage system in the Cerrado region. The presence of forage in maize crop did not influence grain yield.

The liming aiming the correction up to 0.4m allows greater grain yield when the corn is grown single. When in intercrop, the application of gypsum provides the best grain yield in the maize crop.

Future field research involving new maize hybrids and different forage species is important taking into account the different conditions found throughout the country.

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