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SOIL HYDRO-PHYSICAL CHARACTERISTICS AFTER MAIZE CULTIVATION INTERCROPPED WITH *Urochloa brizantha* CULTIVARS

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ABSTRACT:

The intercropping of maize with forage plants is a farming technique aimed at producing grains and grazing, with beneficial results for the sustainability of production. Most of the research carried out with maize (*Zea mays*) intercropped with palisadegrass (*Urochloa brizantha*) has evaluated the agronomic performance of the crops. Therefore, there is a lack of research on the effects of this technique on the soil hydro-physical characteristics. For this reason, the objective of this study was to evaluate the effects of the cultivation of maize intercropped with *U. brizantha* on the soil hydro-physical characteristics. The study was conducted in an experimental area at Faculdade Católica of Tocantins, in Palmas/Tocantins, Brazil; using a randomized complete block design, in a 4x2 factorial scheme, with three repetitions. The study comprised four types of intercropping: i) maize with *U. brizantha* cv. Marandu sown by broadcast; ii) maize with *U. brizantha* cv. Marandu sown between the maize rows; (iii) maize with *U. brizantha* cv. Piatã sown by broadcast; iv) maize with *U. brizantha* cv. Piatã sown between the maize rows; and two implantation periods: v) simultaneous sowing; vi) sowing 20 days after the maize. The hydro-physical properties evaluated were soil density, total soil porosity and soil water holding capacity. There was a significant interaction between the type of intercrop and the sowing time in the soil density and total soil porosity, but no significant differences in soil water holding capacity. Results show that the intercropping of maize with *U. brizantha* sown simultaneously improves the physical properties of the soil such as density and porosity, in comparison to the *U. brizantha* implantation 20 days after sowing maize. The intercrop of i) maize with *U. brizantha* cv. Marandu sown between the maize row and ii) maize with *U. brizantha* cv. Piatã sown by broadcast between the maize row (in simultaneous sowing) improved the soil physical attributes.

Keywords: *Urochloa brizantha*; Forage Plants; Integrated Crop-Livestock; Broadcasting.

CARACTERÍSTICAS FÍSICO-HÍDRICAS DO SOLO APÓS CULTIVO DE MILHO CONSORCIADO COM CULTIVARES DE *Urochloa brizantha*

RESUMO:

O consórcio de milho com plantas forrageiras é uma técnica de cultivo com objetivo de produzir grãos e pastagem, com resultados benéficos para a sustentabilidade da produção**.** A maioria das pesquisas feitas com consórcio de milho (*Zea mays*) e *Urochloa brizantha* avaliam o desempenho agronômico das culturas, sendo escassos na literatura trabalhos que analisem seus efeitos nas características físicas do solo. Neste sentido, o objetivo deste trabalho foi avaliar os efeitos nas características físico-hídricas do solo após o cultivo de milho consorciado com cultivares de *U. brizantha*. O experimento foi implantado na cidade de Palmas, TO com delineamento experimental de blocos casualizados, em esquema fatorial 4x2, com três repetições, em que os quatro tipos de consórcio foram: i) milho com *U. brizantha* cv. Marandu semeada a lanço; ii) milho com *U. brizantha* cv. Marandu semeada nas entrelinhas do milho; iii) milho com *U. brizantha* cv. Piatã semeada a lanço; iv) milho com *U. brizantha* cv. Piatã semeada nas entre-

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linhas do milho; e duas épocas de implantação de *U. brizantha*: v) semeadura simultânea; vi) 20 dias após a semeadura do milho. As propriedades físico-hídricas avaliadas foram densidade do solo, porosidade total e capacidade de armazenamento de água no solo. Foi observada interação significativa entre o tipo de consórcio e época de semeadura tais como, densidade do solo e porosidade total do solo, mas não foram observadas diferenças significativas para a capacidade de armazenamento de água do solo. Nas condições desta pesquisa, o consórcio de milho com *U. brizantha* semeados simultaneamente melhora os atributos físicos como densidade e porosidade do solo em relação à implantação da *U. brizantha* 20 dias após a semeadura do milho. O consórcio de milho com *U. brizantha* cv. Marandu semeada na linha e milho com *U. brizantha* cv. Piatã semeada na linha e a lanço, em semeadura simultânea, melhoram os atributos físicos do solo.

Palavras-chaves: *Urochloa brizantha*; Plantas Forrageiras; Integração Lavoura-Pecuária; Semeadura a lanço.

INTRODUCTION

The intensification of land-use in agriculture without any sustainable management techniques have led to the degradation of soils through pollution, leaching, pulverization, and erosion (Lima et al, 2014). Moreover, it has also led to the loss of organic matter and soil compaction (Hamza and Anderson, 2005).

The soil hydro-physical characteristics are directly related to the available water holding capacity, water infiltration, and to the processes of erosion. Soil density is related to its degree of compaction, a factor that influences directly on soil porosity. Thus, erosion is exacerbated by the insufficiency of pores caused by compaction that reduces water infiltration in the soil and increases the surface-runoff. The micro and mesopores determine the soil water holding capacity. They are essential for supplying water and nutrients to the plants, helping them to resist stress during periods of drought throughout the development of the cultivated plants (Volk; Cogo; Streck, 2004).

The reversal of soil degradation can be achieved through the use of sustainable agricultural systems, such as no-till system (NTS) and integrated crop-livestock systems (ICLS) (Lemaire et al., 2014; Salton et al., 2014). Apart from increasing productivity, forage plants that promote soil coverage also help in the recovery of degraded areas and in the conservation of natural resources (Ferreira et al., 2010; Andrade et al., 2017).

Plant intercropping systems improve the soil hydro-physical properties. They reduce evaporation (increasing water availability to the plants), incorporate organic matter, and recycle nutrients (Hashemi et al., 2013, Salton et al. 2014). The intercropping of maize with forage plants is a cultivation technique aimed at producing grains and grazing. The results of this system are highly beneficial to the sustainability of production (Almeida et al., 2017b). This practice can be implemented in integrated crop-livestock system (ICLS) during the transition from agriculture to pasture, and in no--till systems (NTS) to produce straw to cover the soil until the next crop (Janusckiewicz et al., 2015; Almeida et al., 2017a). Some studies have confirmed these benefits with the intercropping systems of maize and *Urochloa brizantha* (=syn. *Brachiaria brizantha*). This is because the grass doesn`t compromise the grain yield (Borghi et al., 2013; Ceccon et al., 2013; Almeida et al., 2017a, c).

Most of the researches carried out on the intercropping of maize with palisadegrass have evaluated the agronomic performance of the crops. Nevertheless, there is still a scarce literature on the soil hydro-physical changes with this particular type of intercropping. Therefore, the objective of this study is to evaluate the effects on the soil hydro-physical, after the intercropping of maize with palisadegrass planted in succession, established in four types of implantation.

MATERIALS AND METHODS

The study was conducted in an experimental area at Faculdade Católica of Tocantins, in Palmas/Tocantins, Brazil: 10° 16' 55. 90 S and 48° 17' 31.76 O, and at an altitude of 236 m. The soil was classified as Haplic CAMBISOL (IUSS Working Group WRB, 2006), with 570 g kg^{-1} of sand, 200 g kg^{-1} of clay and 230 g kg^{-1} of silt. Table 1 shows the soil chemical properties before the experiment was set up. The climate was classified according to Köppen and Geiger, as Aw, typical from tropical regions, with high temperatures and rain, dry winter and hot, rainy summer. The average annual temperature is 26.7 °C, and the average annual rainfall is 1760 mm (Seplan, 2012).

Table 1.Results of the soil chemical analysis at 0-20 cm layer to the soil experimental area, before the implantation of the crop.

pH[1]	O.M.	P[2]	K	Ca	Mg	Al	H+Al	SB	CEC	V
	%	mg dm^{-3}	---------------------------$cmol_c$ dm^{-3}--------------------------							%
6.2	1.11	3.4	0.27	2.4	0.8	0.00	1.8	3.5	5.3	66

[1]: $CaCl_2$ 0.01 mol L^{-1}; [2]: Mehlich Extractant.

The study began after harvesting the maize cultivated in intercropping plots from a previous experiment. The experimental design consisted of a randomized complete block (RCB), in a 4x2 factorial scheme, with three repetitions. Factor one comprised four types of intercrops while factor two comprised two implantation periods of the palisadegrass, totalling eight treatments as described in Table 2. The experimental plots had 27 m², and consisted of five rows of maize by 6 m in length.

Table 2. Intercropping treatments of maize with palisadegrass cultivars.

Treatment	Factor 1- Intercropping	Factor 2- Sowing time of the palisadegrass
1	Maize with Marandu palisadegrass broadcast sown	Simultaneous sowing
2	Maize with Marandu palisadegrass sown between the maize row	Simultaneous sowing
3	Maize with Piatã palisadegrass sown by broadcast	Simultaneous sowing
4	Maize with Piatã palisadegrass sown between the maize row	Simultaneous sowing
5	Maize with Marandu palisadegrass sown by broad-cast	Sown 20 days after the maize
6	Maize with Marandu palisadegrass sown between the maize row	Sown 20 days after the maize
	Maize with Piatã palisadegrass sown by broadcast	Sown 20 days after the maize
8	Maize with Piatã palisadegrass sown between the maize row	Sown 20 days after the maize

The hybrid maize 'DKB 390 PRO3' was sown on 04/08/2016 with a spacing of 0.90 m and a final population of 60,000 plants ha^{-1}. The two cultivars Marandu and Piatã palisadegrass were sown at the seeding rate of 25 kg ha^{-1} (cultural value 50%), at 0.05 m of depth in the center between the maize rows, or sown by broadcast in the plots area. The maize crop was irrigated, and 315 kg ha^{-1} of the NPK 05-25-15 formulation was applied to the maize row, which yielded 16 kg ha^{-1} of N; 80 kg ha^{-1} of P_2O_5 and 48 kg ha^{-1} of K_2O; plus 70 kg ha^{-1} of N (urea) in topdressing at 20 days after sowing.

The maize harvest occurred on 09/11/2016, producing an average of 4,767 kg ha^{-1} of maize grains. When sown simultaneously to maize, the Marandu palisadegrass produced 2,220 kg ha^{-1} and 2,760 kg ha^{-1} of dry mass with the intercropping by broadcast seeding and between the maize rows, respectively. When the Marandu palisadegrass was sown 20 days after the maize (20 DAS), the production was 1,864 kg ha^{-1} and 2,562 kg ha^{-1} of dry mass with the intercropping by broadcast and between the maize rows, respectively. When sown simultaneously to maize, the Piatã palisadegrass produced 2,039 kg ha^{-1} and 2,730 kg ha^{-1} of dry mass in the intercropping by broadcast and between the rows, respectively; when the Piatã palisadegrass was sown 20 days after the maize (DAS), the production was 1,257 kg ha^{-1} and 1,542 kg ha^{-1} of dry mass in the intercropping by broadcast and between the maize rows, respectively.

The samples for the hydro-physical characterization of the soil were collected on 01/04/2017, 143 days after the maize-harvesting period in which the palisadegrasses were kept in the area (field). Twenty-four samples (one at each plot) from depths of 0.15 m and 0.2 m were taken.

The samples for soil density (Sd) consisted of undisturbed soil cores taken with a volumetric ring with sharp edges and an internal volume of 50 cm³. The samples were placed in a drying oven with air circulation at 105 ° C for 48 hours, then placed in the desiccator until cooling, and weighed on a precision scale. Equation 1 below was used to obtain soil density (Embrapa, 1997).

$$Sd = \frac{a}{b} \qquad (1)$$

Where SD = soil density (g cm^{-3}); a = sample dry mass at 105ºC (g); b = volume of the volumetric ring (cm^{3}).

Particle density (Pd) was evaluated by measuring the liquid volume displaced by a known mass of solid particles (Embrapa, 1997). The dry mass of the soil particles was determined by placing 20g of weighed soil in an aluminium tin (of known weight) into a drying oven with air circulation at 105º C for 12 hours. The samples were transferred to a 50 ml volumetric flask with ethyl alcohol, the solution was stirred until the extinction of air bubbles, and then the volume of alcohol displaced was annotated. Equation 2 below was used to obtain the particle density.

$$Pd = \frac{mp}{vd} \quad (2)$$

Where: Pd = particle density (g cm^{-3}); mp = dry soil mass (particle); vd = volume of the displaced liquid (cm^{-3}).

Equation 3 below was used to obtain the total soil porosity (TP).

$$TP = \left(\frac{Pd - Sd}{Pd}\right) \times 100 \quad (3)$$

Where: TP = Total soil porosity (%); Sd = Soil density in g cm^{-3} (equation 1); Pd = particles density in g cm^{-3} (equation 2).

The soil holding capacity (ϴ) was obtained by determining the soil field capacity, divided by the volume of water retained in the soil and then by the soil volume collected in the undisturbed sample. The samples were left in water for 24 h until saturation, and then left in a punctured tray for a further 24 hours until they stopped dripping. At this point, they were weighed to determine the soil mass in the field capacity and then the samples were dehydrated for 48 hours at 105ºC to determine the dry soil mass. The ϴ was calculated using equation 4 (Reichardt & Timm, 2012).

$$\Theta = \frac{pcc - pss}{v} \quad (4)$$

Where: ϴ = Water holding capacity in the soil (g.cm^{-3}); pcc = soil weight at field capacity (g); pss = dry soil weight (g); v= volume of the volumetric ring (cm^3).

Data from Sd, TP and ϴ were subjected to the analyses of variance and the means were compared using the Scott-Knott test by the statistical analysis software SISVAR version 5.6, at 5% probability.

RESULTS

No significant difference was found for the soil water holding capacity (ϴ) (Table 3). However, there was a significant interaction between intercrop type and sowing time ($P \leq 0.05$) for the soil density and total soil porosity.

Table 3. Variance analysis of soil density (SD), total soil porosity (TP) and soil water holding capacity (ϴ) in relation to the types of maize intercropping with palisadegrass at sowing time, simultaneously (0DAS), and 20 days after the maize (20 DAS)

		SD		TP		ϴ	
FV	**DF**	**MS**	**F**	**MS**	**F**	**MS**	**F**
Type of Intercropping	3	0.0156	1.657^{ns}	25.9964	1.581^{ns}	0.0013	0.633^{ns}
Sowing time	1	0.4401	46.642**	735.2694	44.706**	0.0053	2.431^{ns}
Type of Intercropping x Sowing Time	3	0.0484	5.131*	80.8783	4.918*	0.0017	0.781^{ns}
CV %		7.33		8.88		13.31	

VS- variation source; DF-degree of freedom ;MS- Mean square; F- F-test; CV- coefficient of variation. ^{ns} = no significant* = significant at 5%;** = significant at least 0.1%.

The soil density (Sd) was 23% lower when the palisadegrass was implanted simultaneously (O DAS) than when sown 20 days after the maize (20 DAS), with the exception of maize intercropping with Maranudu palisadegrass by broadcast (Table 4). In this case, Sd was 1.16 times higher when sown simultaneously (by broadcast) than the other types of intercropping. Concerning the palisadegrass sown 20 days after the maize (20 DAS), there was no difference in Sd between the intercropping systems (Table 4).

Table 4. Results of soil density (SD) (g.cm^{-3}) in relation to the types of maize intercropping with palisadegrass at sowing time, simultaneously (0 DAS) and 20 days after the maize (20 DAS).

Type of Intercrop		0 DAS	20 DAS
Maize- Marandu palisadegrass	Broadcasting	1.333 Aa	1.390 Aa
Maize- Marandu palisadegrass	On the Row	1.193 Bb	1.486 Aa
Maize- Piatã palisadegrass	Broadcasting	1.130 Bb	1.370 Aa
Maize- Piatã palisadegrass	On the Row	1.103 Bb	1.596 Aa

Means followed by the same upper case in the line and lower case in the column are no different by Scott-Knott at $p \leq 0.05$.

The soil total porosity (TP) was 1.35 times higher when the palisadegrass was sown simultaneously (0 DAS) than when sown 20 days after the maize, except for the maize intercropped with Marandu palisadegrass by broadcast seeding (Table 5). In the simultaneous sowing (0 DAS), the porosity was 15% lower in the intercropping with Marandu palisadegrass by broadcast seeding than the other types of intercrop. There was no difference in TP between the intercropping systems when the palisadegrass was sown 20 days after the maize (20 DAS) (Table 4).

Table 5. Results of total soil porosity (%) from the types of maize intercropping with palisadegrass, at sowing time, simultaneously (0 DAS) and 20 days after the maize (20 DAS)

Type of Intercrop		0 DAS	20 DAS
Maize- Marandu palisadegrass	Broadcasting	45.316 Ab	43.027 Aa
Maize- Marandu palisadegrass	On the Row	51.028 Aa	39.096 Ba
Maize- Piatã palisadegrass	Broadcasting	53.702 Aa	43.799 Ba
Maize- Piatã palisadegrass	On the Row	54.805 Aa	34.650 Ba

Means followed by the same upper case in the line and lower case in the column are no different by Scott-Knott at $p \leq 0.05$.

There were no differences in soil water holding capacity (ϴ) regarding the types of intercropping and the implantation periods of the palisadegrass (Figure 1). The ϴ was in average 0.35 g cm^{-3} in all treatments.

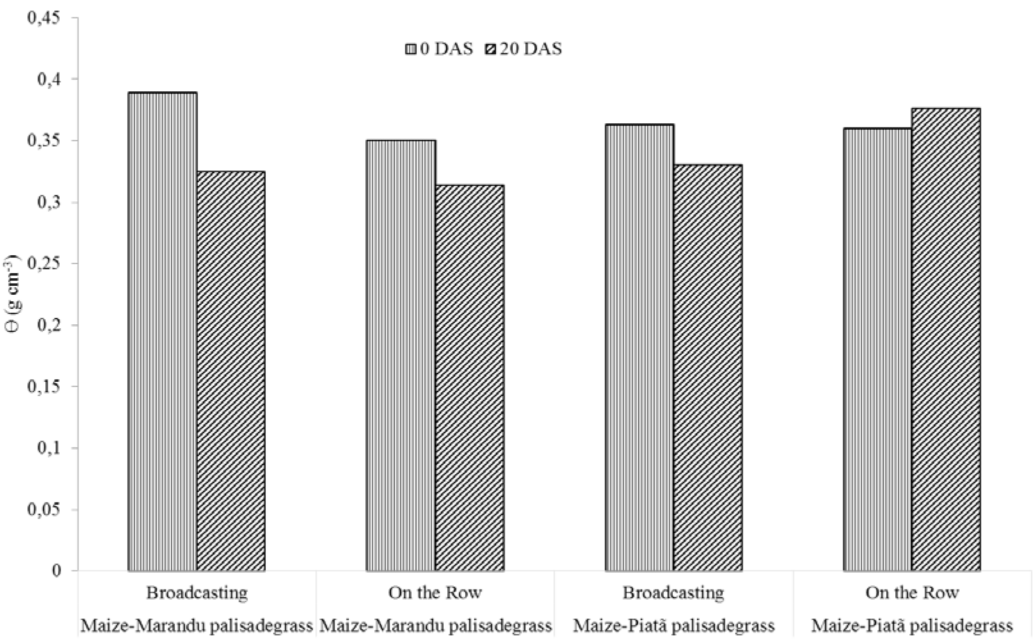

Figure 1. Soil water holding capacity (ϴ, g cm^{-3}) in different types of maize intercrop with palisadegrass, at sowing times, simultaneously to maize (0 DAS) and sowing 20 days after the maize (20 DAS).

DISCUSSION

Research shows that the shade promoted by maize onto the palisadegrass is the main success factor for this type of intercrop. In this situation, palisadegrass does not compete with maize for nitrogen (Almeida et al., 2017a, c) nor compromise its productivity (Borghi et al., 2013; Ceccon et al., 2013; Almeida et al., 2017a, c). With the simultaneous sowing of the plants, the palisadegrass has its initial growth with access to light up until the maize plants begin to shade. Whereas, when sown 20 days after the maize (20 DAS), palisadegrass are shaded as soon as it starts to emerge, which limits the growth during the interaction period with maize. Almeida et al. (2017b) found 10 to 14 times greater grass productivity in the simultaneous sowing of *Panicum* spp. cultivars. Borghi et al. (2013), also reported a 1.5 increase in the mass of palisadegrass, at 60 days after maize harvest in simultaneous sowing when compared to sowing after the maize. In the current study, the higher palisadegrass mass production occurred through the simultaneous sowing. The high mass production observed improved the physical quality of the soil such as reduction of soil density and increase of soil porosity.

The highest values of soil density were obtained with the implantation of palisadegrass 20 days after the maize. This type of intercrop produced 26% less grass mass than the simultaneous sowing. Thus, the simultaneous implantation had higher growth of grass roots, which provided a greater effect on the reduction of soil density, when compared to the treatments where the palisadegrass sown 20 days after the maize. Andrade et al. (2009) states that forage grasses contribute to the aggregation of the soil at the superficial layer. Salton et al. (2014), adds that systems with inclusion of pasture such as ICLS increase soil quality. Seidel et al. (2014) , also observed a higher palisadegrass root development, higher soil aggregation and total porosity, when sown simultaneously to maize in relation to sowing after the maize.

Soils with lower density usually have higher porosity, thus, the simultaneous implantation of the palisadegrass led to higher soil porosity than when sown 20 days after the maize (20 DAS), except for the maize intercropping with Marandu palisadegrass by broadcast seeding (Table 4 and 5). Freitas et al. (2005) reports that grass seeds need to be incorporated into the soil for a good establishment in the area. Under certain conditions, e.g. when there is a lack of correct seed incorporation, broadcast seeding results in a population of plants smaller than those from implantation on rows. This condition leads to a reduction in dry mass (Almeida et al., 2017b). Thus, the worst soil physical conditions can be observed with the maize intercropped with palisadegrass by broadcast seeding, in comparison to the maize incorporated between rows. This is evidenced by the observation of 23% lower biomass production with broadcast seeding treatments in comparison to the seeding incorporated between rows.

Despite the reported improvements in porosity and soil density, there was no alteration in the soil water holding capacity. The benefits promoted by forage grasses in sustainable agricultural systems are gradual and often barely perceptible in only one agricultural crop as it is the case of this study. Nevertheless, the results of this study show the importance of including palisadegrass intercropping to improve the soil physical fertility, which is important to increase the yield of subsequent crops (Andrade et al., 2017). The reduction of compaction, increase in porosity and increase in soil water holding capacity are essential for any production system. They are even more crucial in areas with high temperatures and intense rainfall during dry spell season. Such conditions increase water consumption, surface-runoff and hydro deficiency in crops, as it is seen at the agricultural areas of the state of Tocantins.

CONCLUSION

The intercropping of maize with palisadegrass sown simultaneously improves the density and porosity of the soil, when compared to the palisadegrass sown after the maize.

The soil physical properties were improved in the intercropping of maize with Marandu and Piatã palisadegrass, sown on the row and through simultaneous sowing. The intercropping with Piatã palisadegrass also improved the physical properties of the soil when sown by broadcasting and through simultaneous sowing.

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