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INTERCROPPING OF GRASSES OR LEGUME SPECIES IN MAIZE CROP IN THE CERRADO

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Abstract – In grain crop production systems, the cultivation of maize intercropped with grasses or legumes, with soil management, can provide sustainability without reducing maize yield in the low altitude Cerrado. Thus, this study aimed to evaluate the effects of sowing maize intercropped with grasses or legume species, in two soil management systems, on the agronomic characteristics and yield of maize, in the first crop season in physically limited soil in the Cerrado. The experiment was developed in the agricultural years of 2015/16, 2016/17 and 2017/18, in the municipality of Selvíria, in the state of Mato Grosso do Sul, in typical dystrophic Red Latosol, with clay texture. The randomized block experimental design was used, in a 2x5 factorial scheme, consisting of soil management systems (no-tillage and minimum tillage) and maize intercropped or not (sole maize; maize + *Urochloa ruziziensis*; maize + *U. brizantha*; maize + *Crotalaria spectabilis;* and maize + *Cajanus cajan*). The intercropping of maize with legumes or grasses sown simultaneously in the interrow spacing, when implemented and conducted properly, did not affect the average maize yield. Regardless of soil management and maize intercropping systems, the high soil density and penetration resistance, observed in the experimental area, were not impediments to satisfactory maize grain yield.

Keywords: *Zea mays* L., *Cajanus cajan, Crotalaria spectabilis*, compacted soil, *Urochloa* sp.

CONSÓRCIO DE GRAMÍNEAS OU LEGUMINOSAS NA CULTURA DO MILHO NO CERRADO

Resumo - Em sistemas de produção de culturas de grãos, o cultivo do milho consorciado com gramíneas ou leguminosas, juntamente com o manejo do solo, pode conferir sustentabilidade sem reduzir a produtividade do cereal no Cerrado de baixa altitude. Assim, objetivou-se avaliar os efeitos da semeadura do milho consorciado com gramíneas ou leguminosas, em dois manejos de solo, nas características agronômicas e produtividade do milho, na primeira safra em solo limitado fisicamente no Cerrado. O experimento foi desenvolvido nos anos agrícolas de 2015/16, 2016/17 e 2017/18, no município de Selvíria-MS, em LATOSSOLO VERMELHO Distrófico típico argiloso. O delineamento experimental foi em blocos casualizados, em esquema fatorial 2x5, sendo manejos de solo (sistema plantio direto e cultivo mínimo) e milho consorciado ou não (milho exclusivo; milho + *Urochloa ruziziensis*; milho + *U. brizantha*; milho + *Crotalaria spectabilis* e milho + *Cajanus cajan*). O consórcio do milho com leguminosas ou gramíneas, semeadas nas entrelinhas e simultaneamente, quando implantadas e conduzidas de forma adequada, não afetou a produtividade média do cereal. Independente do manejo do solo e dos consórcios do milho, a alta densidade do solo e resistência à penetração observadas na área experimental não foram impeditivos para uma produtividade satisfatória de grãos de milho.

Palavras-chave: *Zea mays* L., *Cajanus cajan, Crotalaria spectabilis*, solo compactado, *Urochloa* sp.

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The cultivation of maize in Brazil has been going through technological changes, which resulted in significant gains in productivity. The area dedicated to maize cultivation in Brazil basically has not changed in the last seven years and the production records are largely due to the increase of productivity, especially in the Cerrado region. In this sense, it becomes increasingly important to have more research being conducted with the purpose to improve the management of technologies focused on the increase of maize crop yield, with emphasis on the intercropping of maize and grass or legume species.

Intercropping is a technique involving the cultivation of two or more plant species simultaneously, aiming at grain production, ground cover crop and green manure for the subsequent crop, forage for animal feeding, either as silage or hay, and even pasture renovation, with undeniable benefits for sustainability and consolidation of production in the no-tillage system (NTS) in Cerrado areas (Ceccon, 2013). Among the plant species used in association with maize, the grasses stand out, belonging to the *Poaceae* family, and among them, the species from the *Urochloa* genus, due to their deep and vigorous root system, high tolerance to water deficit, capacity to absorb nutrients in deeper soil layers (Barducci et al., 2009) and to develop under unfavorable environmental conditions such as in compacted soils. Chioderoli et al. (2010) verified higher grain yield in the intercropping of maize and *U. ruziziensis* in comparison with the intercropping with *U. brizantha*. However, all treatments produced sufficient amount of straw for maintenance of NTS stability in the Cerrado region, pointing out that, although there are particularities between the species, both are indicated for this cultivation method.

In addition to grasses, species that belong to the *Fabaceae* family also stand out in the association with maize (Kappes et al., 2013), being characterized by lower C/N ratio, when compared with the *Poaceae* species, and N_2-fixing capacity, being capable of increasing soil nitrogen availability and absorption by the plant, which results in increase of maize yield (Kappes, 2011). Heinrichs et al. (2005), when studying intercropping of maize with a variety of crops, such as dwarf pigeon pea and *C. spectabilis*, planted in maize interrow spacing of 0.90 m, verified that, in the first crop year, the intercropping system did not affect maize yield, while in the second year, the best intercropping was with jack bean. However, when comparing maize in sole crop or in association with *C. spectabilis* or dwarf pigeon pea, there was no difference between them.

With the advent of NTS, many soils used for agriculture, in grain production and/or integration with livestock farming, started to present compaction problems (Mazurana et al., 2011). Soil compaction increases the soil penetration resistance and reduces its air and water permeability, which may cause the root concentration in the surface layer, with negative impacts on the soil volume explored by the roots and absorption of water and nutrients by the

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plants (Secco et al., 2009).

One of the options to mitigate soil compaction would be the scarification of soil under NTS, which has been proposed as a viable alternative to minimize the physical limitations to plant growth and soil degradation (Klein et al., 2008). Therefore, the use of scarifiers (minimum tillage), in addition to breaking up the compacted soil surface layer, provides higher infiltration of water into the soil, root growth, soil exploration by the roots, and also maintains the soil surface covered with plant residues (Debiasi et al., 2013). According to Secco et al. (2009), soil scarification increased maize grain yield in dystrophic Red Latosol in relation to the three states of soil compaction (higher compaction state: PR = 2.1-2.8 MPa and D_S = 1.55 Mg m^{-3}).

Therefore, the intercropping system, together with a proper soil management, has great importance for the establishment and development of maize crop, generating profitability to the producer. In view of the above, this study had the aim to evaluate the effects of sowing maize intercropped with grasses or legume species, in two soil management systems, on the agronomic characteristics and yield of maize in the first crop season, in physically limited soil in the Cerrado.

Material and Methods

The research was developed in three crop seasons (2015/16, 2016/17 and 2017/18), in an experimental area that belongs to the Teaching, Research and Extension Farm – Plant Production Department of the School of Engineering of Ilha Solteira - UNESP, located in the municipality of Selvíria, state of Mato Grosso do Sul (20°20'S and 51°24'W), with altitude of 335 meters and average annual rainfall of 1,330 mm. The soil in the area is classified as typical dystrophic Red Latosol, with clay texture (Santos et al., 2013). Climate data during conduction of the experiment are presented in Figure 1.

Before the experiment was implemented, the chemical characterization of the soil was performed for the 0.0 - 0.20 m layer, in the experimental area (Raij et al., 2001), with the followings results: pH ($CaCl_2$) = 5.8; MO = 20 g dm^{-3}; $P_{(resin)}$ = 21 mg dm^{-3}; K = 2.2 $mmol_c$ dm^{-3}; Ca = 36 $mmol_c$ dm^{-3}; Mg = 19 $mmol_c$ dm^{-3}; 28 $mmol_c$ dm^{-3} of H+Al; Al = 0.0 $mmol_c$ dm^{-3}; $S\text{-}SO_4$ = 5 mg dm^{-3}; CTC = 85.2 $mmol_c$ dm^{-3}; and V = 67.0 %. Characterization of soil physical properties was also carried out (Table 1), with the use of an impact penetrometer (Stolf, 1991) for physical evaluation of soil penetration resistance. In those same points, the volumetric ring method was used to assess density, macroporosity, microporosity, and total porosity (Teixeira et al., 2017).

The randomized block experimental design was used, in a 2 x 5 factorial scheme, consisting in the combination of two soil management systems (no tillage and minimum tillage/scarification) and maize crops (sole maize; maize + *Urochloa ruziziensis*; maize + *U. brizantha* cv. Marandu; maize + *Crotalaria spectabilis* Roth; and maize + *Cajanus cajan* cv. IAPAR 43), totaling 10 treatments, with four replications each. During

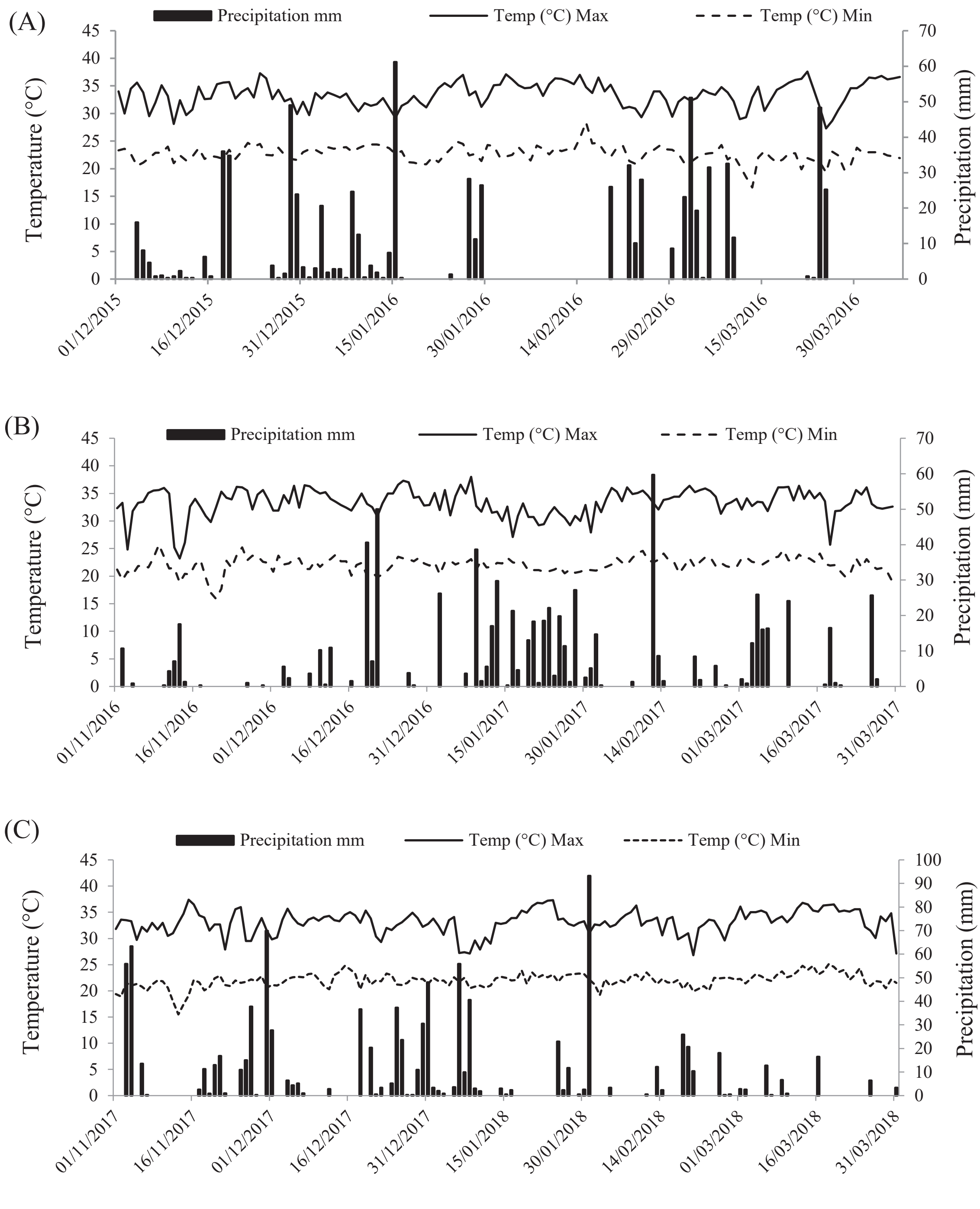

Figure 1. Daily precipitation values and minimum and maximum air temperatures during conduction of the experiments. (A) 2015/16 crop season, (B) 2016/17 crop season, (C) 2017/18 crop season. Selvíria-MS, 2019.

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Table 1. Characterization of soil physical properties. Selvíria-MS, 2015 [(1)].

Layer	D_S	MA	MI	TP	SPR
	Mg m^{-3}	--------------------	m^3 m^{-3}	------------------	MPa
0.0 – 0.10 m	1.59	0.06	0.31	0.37	2.41
0.10 – 0.20 m	1.60	0.05	0.31	0.36	2.66

[(1)] D_S = density of soil; MA = macroporosity; MI = microporosity; TP = total porosity; SPR = soil penetration resistance.

the experiment period of three years, the plots were composed of 8 maize rows, spaced 0.90 m apart, with the intercropping species planted in maize interrow spacing, equidistant 0.45 m from the cereal, being all rows 5 m long, with an area of 36 m^2 per plot.

The experiment was implemented in center pivot area, under no-tillage system for approximately 20 years, where scarification was carried out in part of the area, only in the first year, to receive minimum tillage. For that, a Jumbo Matic scarifier was used, equipped with 5 rods, with average working depth of 0.40 m., followed by an operation with light duty disc harrow (32 x 20”). During the experiment period of three years, the BRS 1501 millet (25 kg ha^{-1} of seeds) was sown in the month of September, with no fertilization applied, in both no-tillage and minimum tillage areas as ground cover crop. Around 60 days after sowing (flowering), the desiccation of the area was carried out with application of glyphosate-based herbicides (1440 g a.i. ha^{-1}) and 2.4-D amine (670 g a.i. ha^{-1}). Fifteen days after that, the disintegration of cover crop residues was performed with the use of a mechanical disintegrator (Triton), before the sowing of maize and intercropping species.

In the first agricultural year, the DeKalb hybrid DKB350_PRO was sown, which is a three-way cross hybrid, VT Pro® transgenic, early maturing, with 860 degrees-days. In the second and third years, the Dow AgroSciences hybrid 2B710PW was sown, being a single-cross hybrid, PowerCore™ transgenic, early maturing, with 850 degrees-days. The seeds of both maize hybrids were treated with fludioxonil (0.025 g a.i./kg seed) + metalaxyl-M (0.02 g a.i./kg seed) + thiabendazole (0.15 g a.i./kg seed) + deltamethrin (0.002 g a.i./kg seed) + pirimiphos-methyl (0.008 g a.i./kg seed). In the three crop years, additional treatment was provided for the hybrids and for the intercropping plant seeds, with the application of pyraclostrobin (0.05 g a.i./kg seed) + thiophanate-methyl (0.45 g a.i./kg seed) + fipronil (0.50 g a.i./kg seed).

In the first crop year, the sowing of maize and intercropping plants was performed on the 12th of December 2015; in the second year, on the 29th of November 2016; and in the third year,

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on the 16th of November 2017. Maize seedling emergence happened 5 days after sowing in the three crop years. In both management systems, maize sowing was carried out mechanically with the use of no-till planter, with 0.90 m interrow spacing, and distribution of 6.2 seeds per meter, targeting at a final population around 60,000 plants ha^{-1}. In regard to the opening of furrows for deposition of fertilizer, care was taken to always use a double-disk opener in order preserve the scarification effect. The planter row units were kept at 0.45 m spacing to prepare the furrows to receive the intercropping plant seeds. These seeds were manually sown at a 3-cm depth, with no fertilization applied, and with the use of hand-operated seeders on the same day and after maize sowing. For the sowing of intercropping plants, the following were used: 20 seeds per meter of *Cajanus cajan* cv. IAPAR 43 (25 kg ha^{-1} of seeds); 30 seeds per meter of *C. spectabilis* (12 kg ha^{-1} of seeds); around 12 kg ha^{-1} of seeds (CV=36%) for *U. brizantha*; and around 7 kg ha^{-1} of seeds (CV=70%) for *U. ruziziensis*.

As to the mineral fertilization applied at maize sowing, 300 kg ha^{-1} of the fertilizer NPK 04-20-20 were used in the first year. In the second and third years, 300 kg ha^{-1} of the fertilizer NPK 08-28-16 were used, being these amounts calculated according to the chemical characteristics of the soil and recommendations from Cantarella et al. (1997). Top-dressing nitrogen fertilization was carried out in the maize crop on the 19th, 23rd and 17th day after maize emergence in the first, second and third year, respectively, with the use of 90 kg ha^{-1} of N (ammonium nitrate). Whenever possible, supplementary water was supplied through the center-pivot irrigation system, with average irrigation depth of 12 mm h^{-1}. The R_1 stage (female flowering) of maize occurred at the 44th day in the first year and at the 48th day in the second and third years, after crop emergence.

Harvesting was done manually, at the 110th day in the first year, 116th day in the second year, and 120th day in the third year, after crop emergence. Harvesting was done in the two 5-meter central rows of each plot with useful area of 9.0 m^2, for agronomic evaluations of maize.

The following evaluations were performed: a) plant height - measurement of the distance from soil surface up to the tip of the male inflorescence (tassel), in five random plants per plot; b) first ear insertion height, measured in the same plants, from soil surface up to the ear base; c) stem diameter - measurement of the diameter at the second internode as from the plant base, in five plants; d) ear length measured in five ears; e) ear diameter measured at the middle length of five ears; f) kernels per ear - number of rows multiplied by the number of kernels per row of the five ears collected in the previous assessment; g) 100-grain weight - based on the average weighing of four subsamples of a hundred kernels per plot, with adjustment to 13% (base moisture); h) grain yield, measured after harvesting of useful plot areas, the ears were threshed and, after weighing, the values were converted to 13% (wet basis); and i) average yield of maize crop in the three years.

Data from each of the crop seasons analyzed were submitted to the F-test of analysis of variance, with the use of the statistical analysis program SISVAR. Since a significant result was determined by the F-test ($p \leq 0.01$ and $p \leq 0.05$), means were compared through Tukey's test ($p \leq 0.05$) for soil management and maize intercropping systems.

Results and Discussion

In regard to maize plant height (Table 2), significant difference was found for soil management systems in the 2016/17 crop season, with higher plant heights in minimum tillage areas. Intercropping did not influence etiolation of maize, since both the plant height and ear insertion height in intercropping systems did not differ from the sole maize crop. Gitti et al. (2012) have also not verified differences in heights of maize plants and ear insertion when in association with *C. juncea* and *C. spectabilis*, in the maize interrow spacing of 0.90 m, and they concluded that, during the vegetative stages until the V_t stage (tasseling), the competition between maize and *Crotalaria* plants was not so high as to reduce the longitudinal development of maize.

With regard to ear insertion height (Table 2), only in the 2015/16 crop season, the plants presented higher height in the no-tillage system in relation to minimum tillage. Oliveira et al. (2010) verified that the BRS 1035 maize in association with dwarf pigeon pea and *C. spectabilis*, when 90 kg ha^{-1} of N are supplied to the system, presented lower insertion height in relation to sole maize in Santo Antônio de Goiás-GO, and in Ipameri-GO no difference was found for the same treatments, even with *U. brizantha.*

In the unfolding of significant interaction for plant height (Table 3), higher height was verified when maize, in association with crotalaria, was sowed in no-tillage system, while higher height was observed in minimum tillage system in the intercropping of maize with dwarf pigeon pea in relation to the intercropping with crotalaria or *U. ruziziensis*. This possibly occurred due to the fact of the dwarf pigeon pea to present a higher height when compared with the other species used in the intercropping systems, thus influencing the maize competition for light, especially leading to maize plant etiolation.

Mean values for stem diameter and ear length are presented in Table 4, where it can be noted that the soil management systems have not influenced those characteristics. The intercropping systems did not affect the stem diameter of maize plant. Also, bedridden plants were not found in the area, which is an advantage in respect to the use of intercropping. According to Kappes & Zancanaro (2015), the stem diameter is the morphological characteristic that has been mostly associated with the percentage of lodging or breakage of maize crop plants. In an experiment in Itiquira-MT, they obtained larger stem diameter in maize associated with *C. spectabilis* if compared to sole maize (0.90 m) or maize intercropped with *U. ruziziensis*. Furthermore, these authors stated that the stem

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Table 2. Mean values for maize plant height and ear insertion height as a function of soil management and maize intercropped in three agricultural years. Selvíria-MS, 2019 [(1)].

Treatments		Plant height (m)			Ear insertion height (m)		
		---- Year ----					
		15/16	16/17	17/18	15/16	16/17	17/18
Soil Management (M)							
No tillage		2.65	2.61b	2.47	1.26a	1.20	1.13
Minimum tillage		2.60	2.66a	2.46	1.19b	1.21	1.14
SMD		0.03	0.03	0.03	0.03	0.02	0.03
Intercropping (I)							
Maize		2.64	2.62	2.47	1.23	1.21	1.13
Maize + ruziziensis		2.59	2.66	2.46	1.20	1.21	1.14
Maize + brizantha		2.63	2.61	2.45	1.24	1.20	1.13
Maize + crotalaria		2.59	2.65	2.46	1.20	1.24	1.12
Maize + pigeon pea		2.66	2.64	2.48	1.26	1.19	1.14
SMD		0.07	0.08	0.07	0.07	0.05	0.08
F value	M	10.07^{**}	10.77^{**}	0.98^{ns}	16.44^{**}	1.39^{ns}	0.18^{ns}
	I	2.56^{ns}	0.99^{ns}	0.53^{ns}	1.87^{ns}	2.08^{ns}	0.19^{ns}
	M x I	3.42^{*}	1.06^{ns}	2.23^{ns}	0.69^{ns}	1.47^{ns}	0.15^{ns}
CV(%)		1.99	2.08	2.01	4.12	3.09	4.84

[(1)] ns - not significant; ** and * - significant at 1% and 5% probability by F-test, respectively. Means followed by different letters differ according to Tukey's test at 5% probability. CV - coefficient of variation. SMD - significant mean difference.

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Table 3. Unfolding of significant interaction between soil management and maize intercropped for maize plant height (m) in the 2015/16 crop season. Selvíria-MS, 2019 [(1)].

Soil management	Intercropping				
	Maize	Maize + ruziziensis	Maize + brizantha	Maize + crotalaria	Maize + pigeon pea
No tillage	2.66	2.62	2.66	2.67 a	2.64
Minimum tillage	2.62 AB	2.56 B	2.60 AB	2.52 bB	2.68 A

[(1)] Means followed by the same lowercase letter in the columns and uppercase letter in the rows do not differ from one another according to Tukey's test at 5% probability.

diameter is very important for obtainment of high yield because plants with larger diameters present higher capacity to store photoassimilates that will contribute to grain filling. Ear length in the 2016/17 crop season was influenced by the sole maize crop, resulting in larger ears when compared to the association with *U. ruziziensis.*

Ear diameter and number of kernels per ear were not influenced by the soil management systems (Table 5). In the 2017/18 crop season, larger ear diameter was found in sole maize crops or maize intercropped with crotalaria in relation to the association with *U. brizantha*. However, this larger diameter added to longer ears did not result in a higher amount of kernels, since no significant difference was observed concerning this characteristic in any of the years when intercropping was carried out. Pariz et al. (2009) have also not obtained significant responses as to the number of kernels per ear in sole maize crops, with 0.90 spacing, or in maize intercropped, simultaneously in the interrow spacing, with *U. ruziziensis* and *U. brizantha* cv. marandu.

As to the number of kernels per ear, in the 2015/16 crop season, there was significant interaction between the studied factors. Upon verification of the unfolding of the interaction (Table 6) between management and each intercropping system, it was noted that, when sole maize was cultivated in the minimum tillage system and in association with dwarf pigeon pea in the no tillage system, the result was a larger number of kernels per ear. As to the intercroppings within each management system, larger number of kernels was obtained, in the no tillage system, with maize in association with dwarf pigeon pea or *U. ruziziensis*, and in minimum tillage, the larger amount of kernels was obtained with sole maize or maize in association with *U. ruziziensis*.

Table 4. Mean values for maize plant stem diameter and ear length as a function of soil management and maize intercropped in three agricultural years. Selvíria-MS, 2019 [(1)].

Treatments		Stem diameter (mm)			Ear length(mm)		
		Year					
		15/16	16/17	17/18	15/16	16/17	17/18
Soil Management (M)							
No tillage		22.87	21.64	21.05	184.2	150.7	163.8
Minimum tillage		22.53	21.49	21.57	185.4	150.9	164.9
SMD		0.84	0.76	0.57	4.50	4.20	4.70
Intercropping (I)							
Maize		23.38	22.03	21.70	190.0	156.4a	164.0
Maize + ruziziensis		22.74	21.28	21.28	187.2	146.8b	161.6
Maize + brizantha		22.53	21.73	21.09	185.7	149.1ab	164.0
Maize + crotalaria		22.41	22.03	21.25	180.0	153.4ab	166.5
Maize + pigeon pea		22.43	20.75	21.23	181.0	148.2ab	165.6
SMD		1.89	1.71	1.30	10.20	9.50	10.60
F value	M	0.67^{ns}	0.17^{ns}	3.42^{ns}	0.29^{ns}	0.01^{ns}	0.23^{ns}
	I	0.78^{ns}	1.76^{ns}	0.54^{ns}	2.92^{ns}	2.97^{*}	0.52^{ns}
	M x I	1.01^{ns}	0.78^{ns}	0.53^{ns}	0.34^{ns}	0.41^{ns}	1.13^{ns}
CV(%)		5.70	5.43	4.19	3.78	4.34	4.42

[(1)] ^{ns} - not significant; * - significant at 5% probability by F-test. Means followed by different letters differ according to Tukey's test at 5% probability. CV - coefficient of variation. SMD – significant mean difference.

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Table 5. Mean values for maize ear diameter and number of kernels per ear as a function of soil management and maize intercropped in three agricultural years. Selvíria-MS, 2019 [(1)].

Treatments		Ear diameter (mm)			Kernels per ear		
		---Year---					
		15/16	16/17	17/18	15/16	16/17	17/18
Soil Management (M)							
No tillage		49.44	49.16	53.70	487	568	574
Minimum tillage		49.84	49.37	54.15	483	587	578
SMD		0.75	1.15	0.80	18	27	19
Intercropping (I)							
Maize		49.66	49.48	54.62a	497	586	589
Maize + ruziziensis		49.50	49.58	53.12ab	504	571	565
Maize + brizantha		49.05	49.06	52.75b	465	576	568
Maize + crotalaria		49.97	48.75	54.87a	474	569	575
Maize + pigeon pea		50.03	49.47	54.25ab	485	589	582
SMD		1.70	2.60	1.80	41	62	43
F value	M	1.20^{ns}	0.13^{ns}	1.32^{ns}	0.17^{ns}	2.00^{ns}	0.15^{ns}
	I	0.92^{ns}	0.31^{ns}	4.61^{**}	2.62^{ns}	0.36^{ns}	0.87^{ns}
	M x I	1.44^{ns}	1.43^{ns}	1.04^{ns}	2.75^{*}	0.22^{ns}	1.71^{ns}
CV(%)		2.35	3.62	2.29	5.80	7.36	5.19

[(1)] ^{ns} - not significant; ** and * - significant at 1% and 5% probability by F-test, respectively. Means followed by different letters differ according to Tukey's test at 5% probability. CV - coefficient of variation. SMD – significant mean difference.

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Table 6. Unfolding of significant interaction between soil management and maize intercropped for the number of kernels per ear in the 2015/16 crop season. Selvíria-MS, 2019 [(1)].

Soil management	**Intercropping**				
	Maize	Maize + ruziziensis	Maize + brizantha	Maize + crotalaria	Maize + pigeon pea
No tillage	475 bB	511 aA	460 aB	479 aB	508 aA
Minimum tillage	519 aA	496 aA	469 aB	469 aB	462 bB

[(1)] Means followed by the same lowercase letter in the columns and uppercase letter in the rows do not differ from one another according to Tukey's test at 5% probability.

With regard to the 100-grain weight (Table 7), it was observed that this variable was not influenced by the soil management systems and that, in the 2016/17 crop season, maize in association with dwarf pigeon pea produced heavier grains in relation to the intercropping with *U. brizantha*. According to Kappes & Zancanaro (2015), the 100-grain weight is a characteristic that can be influenced by the genotype, the availability of nutrients and the weather conditions during grain filling stages. These researchers obtained, in the second maize crop (*safrinha*), larger masses for maize in sole crop and in association with *C. spectabilis* if compared to the intercropping with *U. ruziziensis*.

With respect to grain yield (Table 7), in the 2015/16 crop season, higher productivity was obtained in the no tillage system, while in the 2017/18 crop season, the highest productivity was obtained in the minimum tillage. Still in the 2017/18 crop season, it was noted that the intercropping of maize and *U. ruziziensis* resulted in lower productivity in comparison with maize in sole crops or in association with legume species. This result is associated with a higher interspecific competition for available resources, light and nutrients. Considering the average of the three crop years, the maize yield was not influenced by the soil management and intercropping systems. These results are similar to those found by Gitti et al. (2012), who concluded that the intercropping of maize (0.90 m) with *C. spectabilis* can be done simultaneously, in the interrow spacing, without impacting 100-grain weight and productivity or interfering in harvesting operation. Likewise, Kappes & Zancanaro (2015) have also not detected significant difference as to maize yield in the first crop season when they compared sole maize crop (0.90 m) to maize in association with *C. spectabilis* or *U. ruziziensis* in the interrow spacing. However, the highest yields were achieved when using the 0.45 m spacing of maize

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and with the distribution of *C. spectabilis* in the sowing row or through broadcast seeding and of *U. ruziziensis* in the sowing row.

Pariz et al. (2009) verified that the intercropping of maize and *U. ruziziensis* resulted in higher maize grain yield, if compared with the

Table 7. Mean values for 100-grain weight, average yield and 3-year average yield as a function of soil management and maize intercropped in three agricultural years. Selvíria-MS, 2019 [(1)].

Treatments		100-grain weight (g)			Yield (kg ha^{-1})		Average Y (kg ha^{-1})
		------ Year ------					
		15/16	16/17	17/18	15/16	16/17	17/18	3 years
Soil Management (M)								
No tillage		30.35	27.92	28.97	7,246 a	9,416	7,698b	8,120
Minimum tillage		29.98	27.99	28.48	6,098 b	9,565	8,136a	7,933
SMD		0.75	0.54	0.72	704	593	362	319
Intercropping (I)								
Maize		30.64	28.13ab	28.30	6,553	9,441	8,216a	8,070
Maize + ruziziensis		30.37	28.04ab	28.45	6,855	9,190	7,074b	7,706
Maize + brizantha		29.55	27.05b	29.20	6,510	9,263	7,694ab	7,822
Maize + crotalaria		30.13	27.89ab	28.56	6,828	9,442	8,261a	8,177
Maize + pigeon pea		30.13	28.67a	29.13	6,614	10,119	8,342a	8,359
SMD		1.70	1.22	1.63	1,585	1,335	815	718
F value	M	0.97 ^{ns}	0.06 ^{ns}	1.90 ^{ns}	11.18**	0.26 ^{ns}	6.15*	1.44 ^{ns}
	I	0.95 ^{ns}	3.90*	1.07 ^{ns}	0.17 ^{ns}	1.29 ^{ns}	7.37**	2.30 ^{ns}
	M x I	0.99 ^{ns}	1.17 ^{ns}	1.10 ^{ns}	1.38 ^{ns}	1.23 ^{ns}	1.16 ^{ns}	1.54 ^{ns}
CV(%)		3.87	2.99	3.90	16.26	9.63	7.05	6.13

[(1)] ^{ns} - not significant; ** and * - significant at 1% and 5% probability by F-test, respectively. Means followed by different letters differ according to Tukey's test at 5% probability. CV - coefficient of variation. SMD – significant mean difference.

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simultaneous sowing of maize and *U. brizantha* cv. marandu, and that both the intercropping systems did not differ from the sole maize crop. However, in that study, the higher productivity was obtained in the intercropping with *Panicum maximum* cv. Tanzania. Chioderoli et al. (2012) observed that the intercropping of maize with *U. ruziziensis* and *U. brizantha* cv. marandu did not impact maize yield and 100-grain weight. They concluded that the association of maize with *Urochloas* produced no change in maize yield, but increased the input of dry mass in the no-till production system.

According to Crusciol & Soratto (2010), in years with occurrence of water deficit, yield losses are almost always registered in areas where there is some sort of soil disturbance when compared to NTS. In this work, in the 2015/16 crop season, after tasseling of maize, the area went through a 20-day period of water deficit, which may have caused lower maize yield in the minimum tillage area. Debiasi et al. (2010) verified that, in Red Argisol, scarification significantly reduced maize yield in relation to continuous no-till system, due to the extremely lower values of soil density and high values of macroporosity in the scarified area, which reduced water availability.

Another reason for this lower productivity in the first year of maize intercropping in minimum tillage area, according to Debiasi (2008), is associated with the center-pivot irrigation system that minimizes the negative effects of soil compaction in NTS. With respect to the average yield of the three crop years, the fact that there was no significant difference between the soil management systems, according to Drescher et al. (2016), would be due to the fact that changes in the variables that indicate soil structural state such as density, total porosity and macroporosity, after mechanical scarification, have a duration inferior to one agricultural crop season.

Hence, the success of the intercropping of maize and legume species or grasses, in addition to being intrinsic to the selection of the plant species and to the implementation method, is directly associated with the edaphoclimatic conditions and the crop location/environment, since, in the present study, the difference between the intercropping systems was verified only in the third crop year, in the intercropping of maize and *U. ruzizensis*, which resulted in lower productivity. However, in the study carried out by Oliveira et al. (2010) in Santo Antônio do Goiás-GO, a reduction of 12% was identified in grain yield of maize associated with *C. spectabilis*, in comparison with the sole maize crop, with application of the same topdressing nitrogen dose. In Ipameri-GO, no significant difference was observed concerning productivity and they concluded that the intercropping with dwarf pigeon pea or *C. spectabilis*, when 90 kg of N ha^{-1} are supplied to maize, can be considered viable, since there was no decrease of grain yield. These authors also state that the intercropping with *U. brizantha* does not interfere in maize grain yield, as long as the maize demand of nitrogen is supplied by mineral fertilizer.

Conclusions

The intercropping of maize with grasses (*U. ruziziensis* and *U. brizantha*) or legume species (*Crotalaria spectabilis* and *Cajanus cajan*), sowed simultaneously in the interrow spacing, does not affect the average maize yield, considering the 0.90 m interrow spacing.

Minimum tillage/scarification did not influence the average grain yield of maize cultivated with the use of center-pivot irrigation system.

Regardless of the soil management and maize intercropping systems, the high soil density and penetration resistance, observed in the experimental area, were not impediments to satisfactory maize grain yield.

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