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Grain yield of corn at different population densities and intercropped with forages

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no-tillage system
crop-livestock integration
crop rotation

ABSTRACT
The no-tillage system optimizes agricultural areas, maintaining the supply of straw and promoting crop rotation and soil conservation. The aim of the present study was to evaluate sowing quality and grain yield of corn intercropped with three forage species of the *Urochloa* genus associated with two corn population densities. The experiment was conducted at the São Paulo State University (UNESP), in Jaboticabal-SP, Brazil. The experimental design was randomized blocks in a 2 x 3 factorial scheme with four replicates. The treatments consisted of two corn densities (55,000 and 75,000 plants ha^{-1}) intercropped with three forages (*Urochloa brizantha*, *Urochloa decumbens* and *Urochloa ruziziensis*) sown between rows of corn in the V4 stage. The following corn variables were analysed: mean number of days for emergence, longitudinal distribution, grain yield, initial population and final population. There were differences between corn populations ($p < 0.1$) and the intercropping of corn with the species *U. brizantha* and *U. ruziziensis* promoted the best results, which permitted concluding that the cultivation of corn at the population density of 75,000 plants ha^{-1} intercropped *U. brizantha* and *U. ruziziensis* promoted better sowing quality and, consequently, higher grain yields.

Palavras-chave:
plantio direto
integração lavoura-pecuária
rotação de culturas

Produtividade de grãos de milho em diferentes densidades populacionais e consórcios com forrageiras

RESUMO
O sistema plantio direto aperfeiçoa as áreas agrícolas mantendo o aporte de palha, promovendo a rotação de culturas e a conservação dos solos. Objetivou-se, com o presente estudo, avaliar a qualidade do processo de semeadura e a produtividade de grãos de milho em função de três espécies forrageiras do gênero *Urochloa* associadas a duas densidades populacionais de plantas de milho. O experimento foi conduzido em área da UNESP/Jaboticabal, SP. O delineamento foi em blocos ao acaso, no esquema fatorial 2 x 3, com quatro repetições. Os tratamentos foram constituídos por duas densidades de plantas de milho (55.000 e 75.000 plantas ha^{-1}) consorciado com três espécies forrageiras (*Urochloa brizantha, Urochloa decumbens e Urochloa ruziziensis*) semeadas na entrelinha no estádio V4 do milho. Foram analisados, na cultura do milho, os números médios de dias de emergência, a distribuição longitudinal, a produtividade de grãos e a população inicial e final de plantas. Houve diferença entre as populações de plantas de milho ($P \leq 0,1$) em que o consórcio de milho com as espécies *U. brizantha* e *U. ruziziensis* proporcionou melhores resultados permitindo concluir que o cultivo milho na densidade populacional de 75.000 plantas ha^{-1} em consórcio com *U. brizantha* e *U. ruziziensis* promoveu uma qualidade melhor no processo de semeadura e, em contrapartida, maiores produtividades de grãos.

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Introduction

Pasture degradation is a concern that can be combated through conservational practices, such as crop-livestock integration. The cultivation of grain-producing plants with tropical forages, in no-tillage system, has significantly increased in regions characterized by dry winter (Borghi & Crusciol, 2007).

Corn produces a great amount of straw, an excellent option for crop rotation and, when intercropped with forages in the best spatial arrangement, it can further increase straw production without affecting grain yield (Chioderoli et al., 2010).

The intercropping of corn with forage crops, according to Garcia et al. (2012), can be used as an alternative for a sustainable management of the no-tillage system, which can be greatly satisfactory, especially for the intercropping of corn and *Urochloa ruziziensis,* simultaneously sown.

According to Silva et al. (2011), *Urochloa* is among the most recommended genera of forage species for crop-livestock integration, for having tolerance to water stress, competitive potential against weeds without hampering the main crop and persistence of straw in the soil, an essential attribute for the maintenance of the no-tillage system.

The forages *U. ruziziensis* and *U. decumbens* are more favorable to straw production, due to good development during the entire dry period and for being easily dried (Machado & Assis, 2010). According to Pacheco et al. (2011), *Urochloa* species show high potential for phytomass production during the offseason. Forage grasses, in general, have high C/N ratio, which makes it difficult the action of decomposing microorganisms and increases their persistence on the soil, thus resulting in a great potential for straw formation in no-tillage systems (Silva et al., 2011).

Urochloa can be sown simultaneously with corn, mixed with the fertilizer, which is the most practical method from the operational perspective, since the period and the distribution of *Urochloa* seeds do not alter straw production for no-tillage systems or even corn development (Chioderoli et al., 2012).

Pereira Filho et al. (2008) reported an important aspect of the corn crop, which is the planting density. Sowing population is one of the causes responsible for low corn yield in Brazil. Yield potential is related to variables like sowing density, spacing between rows, water availability, nutrients, weed management and climatic variations.

According to Freitas et al. (2013), corn production when intercropped with *Urochloa ruziziensis* is not altered; however, the dry matter production of the forage crop decreases as corn planting density increases. Higher planting densities in corn production, up to 80,000 plants ha^{-1}, cause reduction in the number of ears and kernels per ear row, but promote higher yields. Thus, the density of 80,000 plants ha^{-1} is recommended for regions or periods in which there is no water restriction (Souza et al., 2013).

The spatial arrangement of corn plants in the area can benefit the development of the grain-producing grass, as well as the form of intercropping. According to Pariz et al. (2011), the intercropping of *Urochloa* with broadcast-sown corn promoted lower grain yield for corn and optimal dry matter production for the forage, more than 2500 kg ha^{-1}, except for *Urochloa brizantha*.

This study aimed to evaluate the quality of mechanized sowing and grain yield of corn, at two population densities, intercropped with three forage crops (*U. brizantha, U. decumbens* and *U. ruziziensis*).

Material and Methods

The experiment was carried out at the Teaching, Research and Production Farm of the São Paulo State University (UNESP), in Jaboticabal-SP, Brazil (21°14’ S; 48°17’ W; 595 m). The soil in the experimental area has mean declivity of 4% and is classified as A-moderate typic eutroferric Red Latosol, with clayey texture and gently undulating relief, according to the Brazilian Soil Classification System (EMBRAPA, 2006). According to Köppen’s classification, the climate in the region is Aw, i.e., tropical with dry period in the winter.

A 2 x 3 factorial scheme was adopted, in a randomized block design, with six treatments and four replicates. The treatments were: two population densities (55,000 and 75,000 plants ha^{-1}) of corn intercropped with three forage species (*U. brizantha*, *U. ruziziensis* and *U. decumbens*), sown in the V4 stage, thirty days after corn emergence, along with top-dressing fertilization, totaling 24 experimental plots.

Seeds of the early single hybrid DKB 390 were used aiming population densities of 55,000 and 75,000 plants ha^{-1}, with spacing of 0.90 m between rows and sowing densities of 4.9 and 6.75 seeds m^{-1}, respectively. Corn seeds were treated with the product Thiodicarb, using the dose of 600 g of the active ingredient (a.i.) for each 100 kg of seeds. For the intercropping, 14 kg ha^{-1} of each forage were used, with certified seeds and cultural value of 50%.

Corn was fertilized at sowing, with 300 kg ha^{-1} of a commercial NPK formulation (08-28-16), and in the V4 stage, with 120 kg ha^{-1} of potassium chloride and 300 kg ha^{-1} of urea, as top-dressing. The forage crops were sown between the rows of corn in the V4 stage and fertilized with 20 kg ha^{-1} of a commercial NPK formulation (08-28-16), which was used only as a vehicle for seed distribution. At sowing, the soil water content was equal to 0.20 g kg^{-1}.

Each plot occupied an area of 300 m^2 (25 x 12 m) and the evaluation area corresponded to three meters of the two central rows of each plot (5.4 m^2). Between the plots, longitudinally, 15 m were left for maneuvers and speed stabilization of the tractor-seeder-fertilizer set.

The mean number of days for corn seedlings emergence was evaluated through daily counts of emerged seedlings until the stabilization in the evaluation area of each plot, calculated according to Edmond & Drapala (1958) (Eq. 1).

$$NDE = \frac{G1N1 + G2N2 + \ldots + GnNn}{G1 + G2 + \ldots Gn} \quad (1)$$

where:

NDE - mean number of days for corn seedlings emergence;

N1 - mean number of days elapsed between sowing and the first seedlings count;

G1 - number of emerged seedlings in the first count;

N2 - number of days elapsed between sowing and the second count;

G2 - number of seedlings emerged between the first and the second counts;

Nn - number of days elapsed between sowing and the last count; and

Gn - number of seedlings emerged between the penultimate and the last counts.

The longitudinal distribution between corn seedlings in the sowing row was determined by measuring the distance between all the plants in the evaluation area of each plot, using a ruler graduated in millimeters.

The spacings between seedlings (Xi) were analyzed using the classification proposed by Kurachi et al. (1989), by determining the percentage of spacings corresponding to the classes: normal (Xref < Xi < 1.5 Xref), multiple (Xi < 0.5 Xref) and gap (Xi > 1.5 Xref), based on the reference spacing (Xref), according to the regulation of the seed drill. In order to express the regularity of the spacings between seedlings, the coefficients of variation of all the spacings were determined.

Initial population was considered as the number of seedlings in the last day of evaluation of the mean number of days for emergence, after stabilization. The variable final population was obtained in the same area of the count of mean number of days for emergence on the day of the harvest. The values were converted to plants ha^{-1}.

For the variable grain yield, corn ears were manually collected in the evaluation area of each plot when crop moisture was approximately 18%. Corn ears were threshed in a stationary machine, the mass of grains was determined and the moisture was corrected to 13%. The obtained values were transformed to kg ha^{-1}.

The results were subjected to analysis of variance by F test (P < 0.1) and, when significant, the means were compared by Tukey test at 0.1 probability level.

Results and Discussion

The number of days for corn seedlings emergence was significantly different between population densities, but showed mean values considered as acceptable for the crop (EMBRAPA, 1993). In the same area and with conventional soil tillage, Furlani et al. (2001) obtained mean value of 4.2 days for corn seedlings emergence. At the population density of 75,000 plants ha^{-1}, the period for the stabilization of corn seedlings emergence was longer, which can affect grain yield, but it was not the case. For the data of longitudinal distribution, there was a significant difference between population densities for normal, gap and double distributions, and the population of 75,000 plants ha^{-1} showed the best longitudinal distribution (Table 1). These results can be explained by the action of the seed-metering mechanism, because, as the peripheral velocity of the disk increases, there is a continuous filling of the cells and, probably, lower contact with the conducting tube, significantly reducing seed ricocheting off the soil, which allows higher number of acceptable spacings and lower number of gaps and multiple spacings.

According to Table 2, for the initial population, there was significant interaction for yield (p < 0.1) by Tukey test. These results disagree with those reported by Mello et al. (2007), who observed no significant difference in corn populations as a function of sowing modalities, studying corn intercropped with forages at two spacings and different sowing modalities.

Initial and final populations were higher for all the forage crops at the corn population density of 75,000 plants ha^{-1} (Table 3). At this density, *U. brizantha* and *U. ruziziensis* showed the highest values of final population. Thus, even with the competition between corn and the forage crops and between corn at the highest population density, in the same spacing (0.9 m), there is no damage on plant population per hectare, showing the viability of the intercropping of corn with forages of the *Urochloa* genus even at higher population densities. Similar results were observed by Chioderoli et al. (2012) in the intercropping of corn with *Urochloa ruziziensis* and *Urochloa brizantha* in different cropping systems. The intercropping

Table 2. Mean values of initial population, final population and yield of corn intercropped with forage crops

Treatments		Initial Population (plants ha^{-1})	Final Population (plants ha^{-1})	Yield (kg ha^{-1})
Population density (P) (plants ha^{-1})	55,000	52,546	51,281	6,206
	75,000	75,309	70,062	7,249
Urochloa (U)	*U. brizantha*	63,426	61,111	6,988
	U decumbens	62,384	58,796	6,279
	U. ruziziensis	65,972	62,106	6,914
F value	P	378.70*	202.01*	18.80*
	U	3.32*	2.20*	3.50^{NS}
	PxU	8.75*	8.83*	4.51*
Coefficient of variation (%)		4.48	5.33	8.76

Means followed by different letters in each column differ by Tukey test at 0.1 probability level; ^{NS} Not significant; * Significant by F test at 0.1 probability level

Table 1. Mean values of days for emergence and longitudinal distribution of corn seedlings intercropped with forage crops

Treatments		Days of emergence	Longitudinal distribution (%) Normal	Gap	Double
Population density (P) (plants ha^{-1})	55,000	4.0 b	60 b	20 a	20 a
	75,000	5.9 a	74 a	13 b	13 b
Urochloa (U)	*U. brizantha*	4.8	68	18	14
	U decumbens	5.1	70	14	16
	U. ruziziensis	5.1	63	18	19
F value	P	52.34*	11.91*	9.67*	3.78*
	U	0.63^{NS}	1.16^{NS}	1.32^{NS}	0.77^{NS}
	PxU	1.20^{NS}	0.50^{NS}	0.48^{NS}	0.43^{NS}
Coefficient of variation (%)		13.07	15.4	35.58	53.19

Means followed by different letters in each column differ by Tukey test at 0.1 probability level; Absence of letters indicates equal values; ^{NS} Not significant; * Significant by F test at 0.1 probability level

Table 3. Follow-up analysis of initial population, final population and yield of corn intercropped with forage crops

		Urochloas		
		U. brizantha	*U. decumbens*	*U. ruziziensis*
Initial population				
Population density	55,000	50,926 Ab	54,398 Ab	52,315 Ab
(plants ha^{-1})	75,000	75,928 Aa	70,370 Ba	79,630 Aa
Final population				
Population density	55,000	49,074 Ab	53,241 Ab	51,528 Ab
(plants ha^{-1})	75,000	73,148 Aa	64,352 Ba	72,685 Aa
Yield				
Population density	55,000	6,317 Ab	6,255 Aa	6,044 Ab
(plants ha^{-1})	75,000	7,660 Aa	6,303 Ba	7,784 Aa

Means followed by different letters, lowercase in the columns and uppercase in the rows, differ by Tukey test at 0.1 probability level

of corn with the different forages did not influence its final population, because the forage crops were sown thirty days after corn emergence. The value that shows such difference between *U. decumbens* and the other species, at the population density of 75,000 plants ha^{-1}, may have been influenced by other environmental and operational factors not evaluated in the present study.

For the intercropping with forage crops, at the density of 75,000 plants ha^{-1}, higher values of corn grain yield (above 1,300 kg ha^{-1}) were observed for both U. brizantha and U. *ruziziensis* (Table 3), which is interesting because both are used in the crop-livestock integration. In addition, there are specific advantages: *U. ruziziensis* has easy drying and *U. brizantha* has rapid establishment, especially when sown late (Machado et al., 2011; Machado & Valle, 2011). These results do not agree with those reported by Pariz et al. (2011), who observed lower yield of corn intercropped with *U. ruziziensis* in comparison to other *Urochloa* species, due to the use of pelleted seeds of the other species, which promoted higher forage germination.

As to the population density, the highest corn yield was obtained for 75,000 plants ha^{-1}, despite being the highest density. This is consistent with Freitas et al. (2013), who claim that higher corn population densities, close to 80,000 plants ha^{-1}, promoted greater grain production. Similar results were observed by Souza et al. (2013), Farinelli et al. (2012) and Santos et al. (2011), who observed that higher corn densities promoted higher yields, corroborating Pereira Filho et al. (2008), who claim that sowing population is an important factor for the final production. According to Chioderoli et al. (2010), when the intercropping of corn with *Urochloa ruziziensis* has grain production as its main focus, it is recommended that *Urochloa* be sown in the period of top-dressing corn fertilization, as in the present study.

For the population density of 55,000 plants ha^{-1}, there was no interference of *Urochloa* species, showing mean grain yield of 6,200 kg ha^{-1}.

Conclusions

1. The quality of corn sowing, with the best values of longitudinal distribution, occurs at the population density of 75,000 plants ha^{-1}.

2. The population density of 75,000 plants ha^{-1} of corn intercropped with *U. brizantha* and *U. ruziziensis*, sown in the V4 stage, along with top-dressing fertilization, promotes higher grain yields.

Literature Cited

Borghi, E.; Crusciol, C. A. C. Produtividade de milho, espaçamento e modalidade de consorciação com *Uroclhoa brizantha* no sistema plantio direto. Pesquisa Agropecuária Brasileira, v.42, p.163-171, 2007. http://dx.doi.org/10.1590/S0100-204X2007000200004

Chioderoli, C. A.; Mello, L. M. M. de; Grigolli, P. J.; Silva, J. O. da R.; Cesarin, A. L. Consorciação de braquiárias com milho outonal em plantio direto sob pivô central. Engenharia Agrícola, v.30, p.1101-9, 2010. http://dx.doi.org/10.1590/S0100-69162010000600011

Chioderoli, C. A.; Mello, L. M. M. de; Holanda, H. V. de; Furlani, C. E. A.; Grigolli, P. J.; Silva, J. O. da R.; Cesarin, A. L. Consórcio de *Urochloas* com milho em sistema plantio direto. Ciência Rural, v.42, p.1804-1810, 2012. http://dx.doi.org/10.1590/S0103-84782012005000073

Edmond, J. B.; Drapala, W. L. The effects of temperature, sand and soil acetone on germination of okra seed. Proceedings of the American Society for Horticultural Science, v.71, p.428-434, 1958.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Recomendações técnicas para o cultivo do milho. Brasília: EMBRAPA, 1993. 204p.

EMBRAPA - Empresa Brasileira de Pesquisa Agropecuária. Sistema brasileiro de classificação de solos. Brasília: EMBRAPA, 2006. 412p.

Farinelli, R.; Penariol, F. G.; Fornasieri Filho, D. Características agronômicas e produtividade de cultivares de milho em diferentes espaçamentos entre linhas e densidades populacionais. Científica, v.40, p.21-27, 2012.

Freitas, R. J. de; Nascente, A. S.; Santos, F. L. de S. População de plantas de milho consorciado com *Urochloa ruziziensis*. Pesquisa Agropecuária Tropical, v.43, p.79-87, 2013. http://dx.doi.org/10.1590/S1983-40632013000100011

Furlani, C. E. A.; Lopes, A.; Rezende, L.; Silva, S. E.; Leite, M. Influência da compactação do solo na emergência das plântulas de milho (*Zeamays* L.) a diferentes profundidades de semeadura. Engenharia na Agricultura, v.9, p.147-53, 2001.

Garcia, C. M. P. de; Andreotti, M.; Tarsitano, M. A. A.; Teixeira Filho, M. C. M. T.; da Silva Lima, A. E.; Buzetti, S. Análise econômica da produtividade de grãos de milho consorciado com forrageiras dos gêneros Brachiaria e Panicum em sistema plantio direto. Revista Ceres, v.59, p.157-163, 2012. http://dx.doi.org/10.1590/S0034-737X2012000200002

Kurachi, S. A. H.; Costa, J. D. S.; Bernardi, J. A., Coelho, J. L. D.; Silveira, G. D. Avaliação tecnológica de semeadoras e/ou adubadoras: tratamento de dados de ensaios e regularidade de distribuição longitudinal de sementes. Bragantia, v.48, p.249-262, 1989. http://dx.doi.org/10.1590/S0006-87051989000200011

Machado, L. A. Z.; Assis, P. G. G. Produção de palha e forragem por espécies anuais e perenes em sucessão à soja. Pesquisa Agropecuária Brasileira, v.45, p.415-422, 2010. http://dx.doi.org/10.1590/S0100-204X2010000400010

Machado, L. A. Z.; Ceccon, G.; Adegas, F. S. Integração lavoura-pecuária-floresta. 2. Identificação e implantação de forrageiras na integração lavoura-pecuária. 1.ed. Dourados: Embrapa Agropecuária Oeste, 2011. 57p.

Machado, L. A. Z.; Valle, C. B. de. Desempenho agronômico de genótipos de capim braquiária em sucessão à soja. Pesquisa Agropecuária Brasileira, v.46, p.1454-1462, 2011. http://dx.doi.org/10.1590/S0100-204X2011001100006

Mello, A. J. R.; Furlani, C. E. A.; Silva, R. P.; Lopes, A.; Borsatto, E. A. Produtividade de híbridos de milho em função da velocidade de semeadura. Engenharia Agrícola, v.27, p.479-486. 2007. http://dx.doi.org/10.1590/S0100-69162007000300017

Pacheco, L. P.; Leandro, W. M.; Machado, P. D. A.; Assis, R. D.; Cobucci, T.; Madari, B. E.; Petter, F. A. Produção de fitomassa e acúmulo e liberação de nutrientes por plantas de cobertura na safrinha. Pesquisa Agropecuária Brasileira, v.46, p.17-25, 2011. http://dx.doi.org/10.1590/S0100-204X2011000100003

Pariz, C. M.; Andreotti, M.; Azenha, M. V.; Bergamas Chine, A. F.; Mello, L. D.; Lima, R. C. Produtividade de grãos de milho e massa seca de braquiárias em consórcio no sistema de integração lavoura-pecuária. Ciência Rural, v.41, p.875-882, 2011. http://dx.doi.org/10.1590/S0103-84782011000500023

Pereira Filho, I. A.; Alvarenga, R. C.; Cruz, J. C. Fatores que interferem no resultado do milho. Campo e Negócio, v.5, p.24-27, 2008.

Santos, R.; Pazini, C. J.; Oliveira, R. C. Produtividade de milho sob diferentes densidades populacionais. Revista em Agronegócios e Meio Ambiente, v.4, p.409-420, 2011.

Silva, V. J. da; Camargo, R. de; Wendling, B.; Pires S. C. Integração lavoura-pecuária sob sistema de plantio direto no cerrado brasileiro. Enciclopédia Biosfera, v.7, p.1-12, 2011.

Souza, R. S. de; Vidigal Filho, P. S.; Scapim, C. A.; Marques, O. J.; Queiroz, D. C.; Okumura, R. S.; Cortinove, V. B. Produtividade e qualidade do milho doce em diferentes populações de plantas. Ciências Agrárias, v.34, p.995-1010, 2013.