Embrapa
Portal de Periódicos da Embrapa
International Journal of
Maize&Sorghum
Formerly Revista Brasileira de Milho e Sorgo
ABMS
ISSN 3086-5433

MAIZE PERFORMANCE UNDER DIFFERENT INTERROW SPACINGS AND INTERCROPPING SYSTEMS WITH GRASS AND LEGUME DURING THE OFF SEASON

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ABSTRACT – The aim was to evaluate the agronomic performance of maize intercropped with *Urochloa ruziziensis* and *Crotalaria spectabilis* under different interrow spacings. The treatments were constituted by two maize interrow spacings (0.50 m and 0.90 m) and four maize cropping modalities (sole maize, maize + *Urochloa ruziziensis*, maize + *Crotalaria spectabilis*, and maize + *U. ruziziensis* + C. spectabilis). The reduced interrow spacing increases plant height (4%) and main ear insertion (7%) compared to 0.90 m interrow spacing, and consequently results in a smaller stem diameter (19%) in maize plants. Overall, maize yield was 32% higher at 0.50 m interrow spacing compared to 0.90 m. The maize + *U. ruziziensis* + *C. spectabilis* intercropping combined with 0.50 m interrow spacing showed a yield 5% lower than sole maize, mainly caused by the reduction of 100-grain weight.

Keywords: *Zea mays* L., *Urochloa ruziziensis* L., *Crotalaria spectabilis* L., no-tillage system

Among the grasses with high straw C/N ratios, several studies highlight brachiaria (*Urochloa* spp.), including *U. ruziziensis* and *U. brizantha*, which are used as sole crops or intercrops to increase dry mass supply and provide adequate soil cover without hampering maize grain yield (Mingotte et al., 2021a). Additionally, forage legume species were introduced into intercropping with maize to improve pasture nutritional quality and, at the same time, reduce the need for nitrogen fertilizers in the production system by favoring biological nitrogen fixation (BNF) (Cambaúva et al., 2019).

In this context, the association between maize and green manures (Cambaúva et al., 2019) has stood out in integrated systems. However, research studies have shown divergent results regarding the impact of intercropping with tropical forages in maize yield (Cambaúva et al., 2019; Mingotte et al., 2021b), highlighting the need for differentiated management with respect to the modalities of intercropping and fertilization (Cunha - Chiamolera et al., 2017; Cambaúva et al., 2019).

This study was conducted to evaluate the agronomic performance and straw formation of second-season maize at reduced spacing, intercropped with *Brachiaria ruziziensis* and *Crotalaria spectabilis*, under different modalities.

The experiment was conducted under field conditions, in the experimental area of the Citriculture Experimental Station of Bebedouro, São Paulo state, Brazil, located at 20º54’30” S and 48º30’57” W, at an average altitude of 595 meters. The climate is Aw (humid tropical with a rainy season in summer and a dry season in winter), according to Köppen’s classification, and with an average annual rainfall of 1,425 mm.

The soil of the experimental area was classified as Eutrophic Red Oxisol (Oxisol) with clayey texture. The chemical attributes in the 0-20 cm layer were: pH ($CaCl_2$) = 5.3; P(resin) = 22 mg dm^{-3}; organic matter = 22 g dm^{-3}; K+ = 2.2 $mmol_c$ dm^{-3}; Ca2+ = 22 $mmol_c$ dm^{-3}; Mg2+ = 9 $mmol_c$ dm^{-3}; H+Al = 22 $mmol_c$ dm^{-3}; CEC = 55.2 $mmol_c$ dm^{-3}; V = 60.0 %.

The experimental design was a randomized blocks split-plot design with four replicates. Treatments consisted of two interrow spacings (IRS) in maize (0.50 m and 0.90 m) and four cropping modalities - CM (sole maize, maize + *U. ruziziensis*, maize + *C. spectabilis*, and maize + *U. ruziziensis* + *C. spectabilis*).

Maize was mechanically sown under the desiccated millet using the single hybrid DKB 390 VTPRO2® at the estimated population density of 60,000 plants ha^{1}. The forage species were broadcast-sown simultaneously with maize sowing, following the technical recommendations regarding the points of crop value (CV) for each species. Fertilization at sowing for maize was based on soil chemical analyses and the recommendations of Cantarella et al. (1997), applying 20 kg ha^{-1} of N, 70 kg ha^{-1} of P_2O_5, and 40 kg ha^{-1} of K_2O, respectively. Top-dressing fertilization was performed in two steps: 80 kg of N ha^{-1} via 20-00-20 at V_4, and 80 kg of N ha^{-1} via urea at V_6, applied in a continuous strip on the soil surface.

After physiological maturity (R_6), maize agronomic performance was evaluated by determining plant height, main ear insertion height, stem diameter, number of rows per ear, number of grains per ear, 1000-grain weight, grain yield, and harvest index. Soil surface cover and the amount of straw or dry matter produced were determined after maize harvesting, as described by Laflen et al. (1981). The data were analyzed using ANOVA with the F test ($p<0.05$), and the means were compared using the Tukey test ($p<0.05$).

The interrow spacing of 0.5 m promoted higher main ear insertion height in sole maize and intercropped with *U. ruziziensis*, not differing from the 0.9 m spacing in the other intercropping modalities (Table 1). Stem diameter was lower in maize cultivated at reduced spacing (0.5 m) in all intercropping modalities. However, there was a positive effect of *C. spectabilis* on maize stem diameter, both in M+C and M+U+C at both spacings tested.

As for the number of grain rows per ear, there were no differences between treatments, indicating greater genetic than environmental dependence. However, the number of grains per ear was reduced by the intercropping systems at reduced spacing. Regarding the thousand-grain weight, sole maize showed superiority at each spacing, with a smaller reduction in 1000-grain weight at reduced spacing, particularly in the M+U and M+C intercropping modalities (Table 1).

Overall, maize grain yield was 32% higher when it was cultivated at reduced spacing, regardless of cropping modality (Table 2). The highest harvest index was observed in maize cultivated at reduced spacing, when comparing the intercropping modalities M+U and M+C. Separately, for the interrow spacing of 0.9 m, the M+U+C intercropping resulted in a high harvest index, not differing from that under reduced spacing.

Soil cover and the amount of straw produced were higher in situations where maize was intercropped with forage species compared to its cultivation as a sole crop (Table 2). The cultivation of sole maize and intercropped with *C. spectabilis* at reduced spacing (0.50 m) resulted in higher soil surface cover than at the conventional spacing (0.90 m). By contrast, the largest amounts of straw were obtained with the intercropping of maize + *U. ruziziensis* and maize + *U. ruziziensis* + *C. spectabilis*, both at a spacing of 0.90 m.

When considering only the interrow spacing of 0.5 m, grain yield was higher for M+U and M+C compared to M+U+C (Table 2). There was a reduction in maize grain yield with the intercropping M+U+C, in contrast to results reported by other studies (Cunha - Chiamolera et al., 2017; Cambaúva et al., 2019). Intercrop yield is affected by the distribution of solar radiation within the intercropping canopy, especially in systems that include both tall and short crops (Gao et al., 2010). Studies have highlighted the effects of plant density and population arrangement on

Table 1. Unfolding of significant interactions between maize interrows spacings and cropping modalities for the plant height and main ear insertion, stem diameter, number of rows per ear, and number of grains per ear, 1000-grain weight [(1)].

Treatments	Plant Height (cm)		Main ear insertion (cm)		Stem diameter (mm)	
	0.5m	0.9m	0.5m	0.9m	0.5m	0.9m
M	249 Aa	234 Ba	146 Aa	130 Bbc	21.15 Bba	24.49 Ab
M+U	235 Ab	227 Bb	147 Aa	124 Bc	19.16 Bb	26.26 Aab
M+C	248 Aa	239 Aa	141 Aab	140 Aa	21.54 Ba	27.33 Aa
M+U+C	240 Ab	239 Aa	133 Ab	136 Aab	22.38 Ba	25.81 Aab
Overall average	238.8		137.15		23.51	

Treatments	Rows per ear (n)		Grains per ear (n)		100-grain weight (g)	
	0.5m	0.9m	0.5m	0.9m	0.5m	0.9m
M	15.9Aa	16.4Aa	529.7Aa	484.6Aa	449.1Aa	445.5Aa
M+U	15.7Aa	16.3Aa	448.9Ab	487.0Aa	437.6Ab	426.1Bb
M+C	15.4Aa	15.7Aa	480.3Aab	518.2Aa	448.7Aa	423.9Ab
M+U+C	15.3Aa	15.7Aa	499.8Aab	453.7Aa	422.7Ac	420.5Bb
Overall average	15.8		487.8		434.3	

([1]) Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ, respectively, by the Tukey test (p<0.05). M (sole maize), M+U (maize + *U. ruziziensis*), M+C (maize + *C. spectabilis*), M+U+C (maize + *U. ruziziensis* + *C. spectabilis*).

Table 2. Unfolding of significant interactions between maize interrows spacings and cropping modalities for the grain yield, harvest index, soil surface cover, and amount of straw [(1)].

	Grain yield (kg ha^{-1})		Harvest index	
Treatments	0.5m	0.9m	0.5m	0.9m
M	9,635Aa	7,358Ba	0.42Ab	0.39Ab
M+U	9,406Aab	7,069Ba	0.46Aab	0.39Bb
M+C	9,674Aa	7,149Ba	0.48Aa	0.43Bab
M+U+C	9,114Ab	6,999Ba	0.46Aab	0.47Aa
Overall average	8,300		0.44	
	Soil surface cover (%)		Amount of straw (t ha^{-1})	
Treatments	0.5m	0.9m	0.5m	0.9m
M	80.00Ab	71.75Bc	7.0Ab	7.0Ab
M+U	100.00Aa	99.25Aa	7.7Bab	8.2Aa
M+C	98.75Aa	94.5Bb	7.8Aa	8.2Aa
M+U+C	99.75Aa	99.75Aa	7.4Bab	8.0Aa
Overall average	92.9		7.6	

(1) Means followed by the same letter, lowercase in the column and uppercase in the row, do not differ, respectively, by the Tukey test ($p<0.05$). M (sole maize), M+U (maize + *U. ruziziensis*), M+C (maize + *C. spectabilis*), M+U+C (maize + *U. ruziziensis* + *C. spectabilis*).

leaf area index and photosynthetic rate, affecting maize production components and yield (Chen et al., 2017), mainly in intercropping with tropical forages (Borghi et al., 2013; Mingotte et al., 2021b).

Regarding higher straw production from intercropping maize with forage species, other researchers (Borghi et al., 2013; Cambaúva et al., 2019) have reported similar results. Chioderoli et al. (2010) evaluated three intercropping modalities in the late off-season. In this study, the researchers found that all treatments produced sufficient straw to maintain and stabilize the no-tillage system (NTS). They demonstrated that sowing *U. ruziziensis* at the time of maize top-dressing fertilization resulted in superior grain yield and interesting straw formation.

Overall, maize grown at reduced interrow spacing (0.50 m) showed improved agronomic performance, with grain yield 32% higher than in 0.90 m spacing. Intercropping did not reduce maize grain yield and increased straw production

(13%) and soil cover (23%) compared with sole maize. Only the M+U+C intercropping combined with 0.50m interrow spacing reduced maize yield by 5% compared to sole maize. Intercropping maize with the cover crops *U. ruziziensis* and *C. spectabilis* at a 0.50 m interrow spacing represents a sustainable alternative for crop diversification, combining the ecosystem benefits of intercropping with the high yield of the cash crop during the off-season.

Acknowledgments

To Fundação Nacional de Desenvolvimento do Ensino Superior Particular (FUNADESP), for the financial support (Process number 4400143).

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