

## Yield and economic analysis of corn and brachiaria intercropping in the northwestern Paraná

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### ABSTRACT

The maize and *Urochloa ruziziensis* intercropping have potential use for agricultural production systems, allowing the production of grains and biomass. The study aims to evaluate the yield and economic viability of corn and *U. ruziziensis* intercropping modalities in the northwestern region of Paraná. The experiment was conducted in Maringá-PR in a completely randomized design with five treatments (single corn; single *U. ruziziensis*; *U. ruziziensis* between the corn rows; corn with *U. ruziziensis* in the same row; corn rows interspersed with *U. ruziziensis* rows) and four replicates. Initial development, grain yield of corn, and the production of biomass of corn and *U. ruziziensis* were evaluated. The data were submitted to analysis of variance. The means were compared by the Tukey test at 5% probability. In the initial development of corn plants, there was no significant difference due to intercropping. *U. ruziziensis* in the intercropped system had a reduction in biomass production. Intercropping with corn rows interspersed with *U. ruziziensis* rows had grain yield higher than other intercropping modalities and similar to single corn cultivation

**Keywords:** Biomass, Grain production, No-Tillage System, *Zea mays*.

## Produtividade e análise econômica do cultivo consorciado de milho e braquiária no noroeste do Paraná

### RESUMO

A consorciação de milho e *Urochloa ruziziensis* apresenta potencial para os sistemas de produção agrícola, permitindo a produção de grãos e biomassa remanescente. O estudo tem como objetivo avaliar a produtividade e a viabilidade econômica das modalidades de consórcio de milho e *U. ruziziensis* na região noroeste do Paraná. O experimento foi conduzido em Maringá-PR, em delineamento inteiramente casualizado com cinco tratamentos (milho solteiro; *U. ruziziensis* solteira; milho com *U. ruziziensis* na entre linha; milho com *U. ruziziensis* na mesma linha; milho com *U. ruziziensis* em linhas intercaladas) e quatro repetições. Foi analisado o desenvolvimento inicial e produtividade de grãos do milho, e produção de biomassa de milho e *U. ruziziensis*. Os dados foram submetidos a análise de variância e as médias comparadas pelo teste *Tukey* com significância de 5%. No desenvolvimento inicial das plantas de milho não houve diferença significativa em função da consorciação. *U. ruziziensis* em sistema consorciado apresentou redução na produção de biomassa. O cultivo em linhas intercaladas apresentou produtividade de grãos superior as demais modalidades de consorciação e semelhante ao cultivo de milho solteiro.

**Palavras-chave:** Biomassa, Produção de grãos, Sistema Plantio Direto, *Zea mays*.

## 1. Introduction

The maize (*Zea mays*) and brachiaria (*Urochloa* sp.) intercropping is the aim of many studies, focusing on grain production and integrated agricultural production systems. The efficiency of intercropping can be obtained in a short time, related to biomass production, nutrients cycling, weed infestation, nitrogen fertilization efficiency, and inoculation of *Azospirillum brasilense* without reduction of yield potential of maize (Pacheco et al., 2016; Mechi et al., 2018; Veronezi et al., 2018; Arf et al., 2018; Oliveira et al., 2019).

Cultivating brachiaria (*Urochloa ruziziensis*) in intercropping systems allows biomass production to successor crops and is beneficial mainly in low soil fertility (Cordeiro et al., 2019; Oligini et al., 2019). The initial development of the forage is slower, allowing the establishment of an annual crop of economic interest without reducing yield potential (Kimecz et al., 2018).

Studies by Arf et al. (2018) show that maize production can be reduced in intercropping. The divergence between results about the effect of intercropping between corn and grasses, as *U. ruziziensis* are related to edaphoclimatic conditions, management, and cultivation practices. In addition, economic aspects must consider defining the efficiency of intercropping Garcia et al. (2012). Thus, regional studies show high importance, characterizing techniques that increase the efficiency of agricultural systems. The present study aimed to evaluate the yield and economic viability of the corn and *U. ruziziensis* intercropping

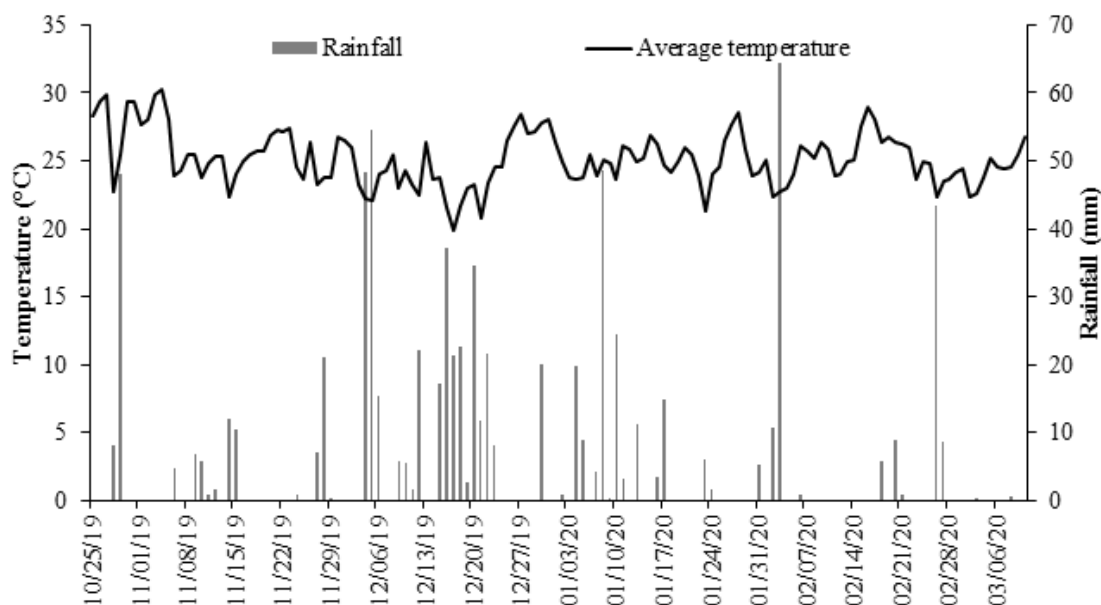
modalities in the northwestern region of Paraná.

## 2. Material and Methods

The study was carried out in the Irrigation Technical Center of the Department of Agronomy belonging to the State University of Maringá, in Maringá – PR - Brazil, at 23°25' S and 51°57' W, and altitude of 542 m. The region has annual precipitation between 1,400 and 1,600 mm, temperature between 21.1 and 22°C, evapotranspiration of 1,000 to 1,100 mm, and solar radiation of 14,5 to 15 MJ m<sup>-2</sup> day<sup>-1</sup> (Nitsche et al., 2019). During the crop cycle from 10/25/2019 to 03/09/2020, monthly variations of temperature and pluviometry were recorded (Figure 1).

A completely randomized design was adopted with five treatments (Table 1) and four replicates. The experimental plots had 20,25 m<sup>2</sup> of the total area and 11 m<sup>2</sup> of useful area. The corn hybrid Pioneer 3707 VYH was used. The seeds were treated with a product containing Pyraclostrobin, Methyl thiophanate, and fipronil (1 g a.i. kg<sup>-1</sup> of seeds) and inoculated with *Azospirillum brasilense*.

The predecessor cultivation of black oat (*Avena strigosa*) intercropped with oilseed radish (*Raphanus sativus* L.) produced 2,500 kg ha<sup>-1</sup> of dry matter of remaining straw in the experimental area. Corn was sown (10/25/2019) using a population density of 60,000 pl ha<sup>-1</sup> and 2.7 pl m<sup>-1</sup> (Table 1). Forage seeds were sown simultaneously with corn using 10 kg ha<sup>-1</sup> (cultural value of 50%), which are arranged in different positions relating to maize according to Table 1.



**Figure 1.** Meteorological data in the period from October 2019 to March 2020, Maringá-PR. Source: INMET (2020).

**Table 1.** Configuration of the cultivation system with corn, *U. ruziziensis*, and intercropping modalities.

Treatment	Cultivation system
1	Single corn <sup>(1)</sup>
2	Single <i>U. ruziziensis</i> <sup>(2)</sup>
3	Corn and <i>U. ruziziensis</i> intercropping (between rows) <sup>(1)</sup>
4	Corn and <i>U. ruziziensis</i> intercropping (same row) <sup>(1)</sup>
5	Corn and <i>U. ruziziensis</i> intercropping (interspersed rows) <sup>(3)</sup>

Spacing: <sup>(1)</sup> 0,45 cm between corn row; <sup>(2)</sup> 0,45 cm between brachiaria row; <sup>(3)</sup> 0,7 cm between corn rows.

The soil in the experimental area is classified as NITOSSOLO VERMELHO distroférrico, corresponding to a Ultisol in the Soil Taxonomy Classification (SANTOS et al., 2018), with clayey texture and pH (SMP method): 6.4; Al: 0 cmol<sub>c</sub> dm<sup>-3</sup>; Al + H: 3.66 cmol<sub>c</sub> dm<sup>-3</sup>; Ca: 4.1 cmol<sub>c</sub> dm<sup>-3</sup>; Mg: 2.56 cmol<sub>c</sub> dm<sup>-3</sup>; K: 0.37 cmol<sub>c</sub> dm<sup>-3</sup>; P (Mehlich-I): 3.47 mg dm<sup>-3</sup>; organic matter: 22.95 g dm<sup>-3</sup>, and soil cation exchange capacity: 10.69 cmol<sub>c</sub> dm<sup>-3</sup>. The fertilization at the sowing furrow was carried out with 300 kg ha<sup>-1</sup> of NPK formulation (10:20:20). The topdressing fertilization was carried out with 175 kg ha<sup>-1</sup> of urea (45% N), according to Pauletti and Motta (2017).

The initial corn development was analyzed in the different intercropping modalities, with the height determination in two evaluations in the vegetative stage. The biomass of corn and *U. ruziziensis* were evaluated with a square of 0.5 m x 0.5 m randomly launched in the useful area of plots. All plants into the square were collected, weighed in an analytical balance ( $\pm 0.001$  g), and kept in a forced air circulation oven at 105 °C until they reached constant weight, then the dry matter was obtained.

The harvest of corn in 2 m<sup>2</sup> per experimental parcel was carried out when the grains had 20% of water content on a wet basis (%wb), analyzing diameter, length, and the number of rows per spike. The grain mass was determined in analytical balance ( $\pm 0.001$  g), the grains water content at forced air circulation oven (105°C for 24 hours), and adjusted to 14% wb, estimating the grain yield (kg ha<sup>-1</sup>). The data were submitted to analysis of variance; the means were compared by the Tukey test at 5% probability, using the SISVAR software (Ferreira, 2019).

The production cost was calculated according to the CONAB methodology (2010). The price of agricultural machinery and equipment was based on the cost per hour of work, considering the management with sowing, nitrogen fertilization, and application of pesticides. General costs were calculated considering 2% of expenses with agricultural machinery and equipment. The cost of seeds, fertilizers, and pesticides was based on the purchase price. The cost of harvesting and transport was calculated according to the average cost (9.5% of production) practiced in the region by producers. The variable cost was calculated by the sum

of agricultural machinery and equipment costs, general costs, seeds, fertilizers, pesticides, harvesting, and transport.

Fixed costs were not considered. The variation of land capital and fees depending on the location of the cultivation was considered. The economic balance was calculated according to the financial return from yield and the variable costs of each management condition. Cost values were expressed in dollars, considering the US\$ 1.00 is equivalent to R\$ 5.422.

### 3. Results and Discussion

The analysis of the intercropping in different producing regions allows determining specific difficulties according to edaphoclimatic conditions and growing season, showing results with regional applicability. Significant differences were observed when considering the initial maize development concerning height, with higher plant height in the intercropping with *U. ruziziensis* sown between rows concerning the cultivation of single corn (Table 2).

According to Araújo et al. (2018), corn intercropping reduces production components associated with ear characteristics, like size, number of rows and grains, and grains mass. For variables related to spike traits, the results refer to the number of grains per row, and the diameter of spikes did not show differences among the treatments. However, the intercropping cultivation with interspersed rows produced spikes with a larger length, with significant values and higher than the spikes harvested in the maize and brachiaria intercropping in the same row (Table 2).

It suggests that the sowing position in the corn/brachiaria intercropping differs from features associated with soil cover, luminous interception and nutrients, and water demand, reflecting on the morphological development in both cultivations, consequently influencing the biomass production. In the experimental conditions, there was no significant difference in the corn biomass (Table 3), indicating that the competition for water and nutrients among the brachiaria plants in the row did not influence the performance and yield of the corn plants.

**Table 2.** Plant height at the vegetative stage, diameter and length of spikes, and the number of grain rows per spike of corn under different intercropping modalities with *U. ruziziensis*, Maringá-PR, 2019/2020 harvest.

Treatment	Plant height (cm)		Corn spike		
	36 DAS <sup>(1)</sup>	50 DAS <sup>(2)</sup>	Diameter (mm)	Length(cm)	Nº of rows
Single maize	57.20 ab	120.00 b	48.74 a	15.45 ab	16.27 a
Single <i>U. ruziziensis</i>	-	-	-	-	-
C+U (between rows)	62.03 a	159.25 a	48.80 a	15.66 ab	15.50 a
C+U (same row)	51.44 c	129.25 b	47.33 a	14.15 b	15.20 a
C+U (interspersed rows)	55.04 bc	147.50 ab	48.80 a	16.25 a	15.55 a
CV (%)	11.95	10.47	2.89	6.22	6.25

\*Means followed by the same letters in columns do not show differences between each other by the Tukey test ( $p < 0.05$ ); DAS - Days after sowing; (1) evaluation day 11/30/2019; (2) evaluation day 12/14/2019.

**Table 3.** Grains yield and production of biomass of corn (DM) and *U. ruziziensis* on intercropping modalities, Maringá-PR, 2019-2020 harvest.

Treatments	Grain yield (kg ha <sup>-1</sup> )	Biomass (kg ha <sup>-1</sup> )	
		Corn	Brachiaria
Single corn	10,099 a	23,143 a	-
Single <i>U. ruziziensis</i>	-	-	4,991 a
C+U (between rows)	9,157 b	19,869 a	527 c
C+U (same row)	9,492 b	20,104 a	1,097 b
C+U (interspersed rows)	9,852 a	21,919 a	930 b
CV (%)	5.57	9.44	8.7

\*Means followed by the same letter in the columns do not differ from each other by Tukey test ( $p < 0.05$ ).

The biomass production of *U. ruziziensis* was higher in the single cultivation than brachiaria in intercropping systems (Ribeiro et al., 2018). In the intercropping conditions, in interspersed rows and/or in the same row, the brachiaria biomass production was higher than the *U. ruziziensis* sowing between the corn rows (Table 3).

Developed studies in southwestern Paraná with intercropping of corn with different forage species did not show significant differences in the corn yield. The intercropping with *U. brizantha* and *U. ruziziensis* showed higher biomass production (Oligini et al., 2019). When assessing the intercropping of corn with *Brachiaria brizantha* cv. Marandu, they concluded that there was no interference in the maize yield. The corn showed a higher accumulation of nutrients in the remaining straw in the consortium system. (Arf et al., 2018).

Studying the corn intercropping with different species of forages (Santos et al., 2017) observed that

*Urochloa ruziziensis* did not affect the grain yield. According to Makino et al. (2019), the population arrangement of corn in the intercropping system shows a stronger influence on yield concerning the presence of brachiaria. Pereira et al. (2018) observed higher increments in the corn grain yield in the row spacing of 0.90 m concerning the 0.45 m.

Queiroz et al. (2016) obtained higher yield and biomass production of *U. ruziziensis* when the corn was sown with a row spacing of 0.9 m and the *U. ruziziensis* in the same rows, similar in this study. Araújo et al. (2018), when analyzing the spacing of corn sowing and concluded that the first ear insertion height was higher in the spacing of 0.5 m, without interfering in the yield components, while the largest dry matter production of *U. brizantha* was obtained in the spacing of 0.7 m. When analyzing the corn morphological components and brachiaria, there was variation in the economic margin between the intercropping modalities (Table 4).

**Table 4.** Economic analysis (US\$ ha<sup>-1</sup>) of intercropped and *Urochloa ruziziensis* cultivation, Maringá-PR, 2019/2020.

Productive variable/economic	Treatment				
	1	2	3	4	5
Machinery and equipment expenses	54.12	17,52	54.12	54.12	54.12
General expenses <sup>(1)</sup>	1.08	0.35	1.08	1.08	1.08
Seed	124.03	2.73	126.77	126.77	126.77
Fertilizer	82.34	33.47	82.34	82.34	82.34
Agrochemicals	67.37	16.28	67.37	67.37	67.37
Harvesting and transportation <sup>(2)</sup>	215.28	-	195.20	202.34	210,02
Total variable cost	544.22	70.35	526.88	534.02	541.7
Yield	168.32	-	152.62	158.20	164.20
Price per bag <sup>(3)</sup>	13.46	-	13.46	13.46	13.46
Economic return	2,265.58	-	2,054.26	2,129.37	2,210.13
Profit margin <sup>(4)</sup>	1,721.36	-70.35	1,527.38	1,595.35	1,668.43

<sup>(1)</sup> 2% of the cost of expenses with machinery and equipment; <sup>(2)</sup> 9.5% of production; <sup>(3)</sup> base price in the region of Maringá-PR (02/05/2021); <sup>(4)</sup> considering only variable costs.

Analyzing the economic scenario of crops and considering only variable costs, we checked that in the treatment 5 (maize/brachiaria *U. ruziziensis* in intercalated rows), the profit margin was 3.67% lower compared with the single cropping, diverging from the obtained by Garcia et al. (2012) that reported that the intercropping showed higher values than single cultivation of corn, indicating the economic importance of intercropping of cultivation for production system and greater profit for the producer. Still, without interfering in the corn yield, the intercropping with *U. ruziziensis* showed to be more economically viable to another forage species. In this study, the economic margin of brachiaria in the short term was lower, although the intercropping generated benefits in the harvest of the successor production system.

The corn intercropped with *U. ruziziensis*, as another species like *Crotalaria juncea* L., needs adequate management to minimize the effects of competition in the crop yield and consequently in the monetary return. Concerning the single cultivation of *U. ruziziensis*, biomass production generated a cost of US\$ 14,09 Mg<sup>-1</sup> DM.

Considering the productive and economic scenario, the utilization of the corn and *U. ruziziensis* intercropping in interspersed rows, row spacing of 0,45m, showed results closest to single cultivation of corn, and shows be a better option of intercropping to the cultivation conditions in the northwestern Parana.

#### 4. Conclusions

The biomass production of *U. ruziziensis* is reduced in intercropping with corn compared to the forage in the single cultivation system. Cultivation of corn intercropped with interspersed rows showed a similar

yield to the single cultivation system and higher than intercropping between rows or in the same row

#### Authors' Contribution

Gustavo Soares Wenneck contributed to writing, statistical analysis, interpretation of results, and economic data analysis. Reni Saath to the setup of the experiment, technical supervision, and revision. Larissa Leite de Araujo contributed to the collection of data in the field and the writing of the manuscript in the English language. Gustavo Lopes Pereira contributed to economic data analysis and writing of the manuscript in the English language. Giovanna Gabriela Ferreira de Oliveira contributed to crop management and collection of data. Nathália de Oliveira Sá contributed to crop management and collection of data. Camila de Souza Volpato contributed to crop management and the collection of data.

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