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Proceeding Paper

Cropping System and Nitrogen Supply Interfere in Sustainability of Maize Production in the Dry Season †

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Abstract: Diversification in cropping systems can increase production and reduce environmental impacts. Thus, we studied maize production as a function of the cropping system and the nitrogen rates applied as side-dressing. The experimental design involved randomized blocks with four replications in a split-plot scheme. The main plots were maize monoculture; maize intercropped with Congo grass (*Urochloa ruziziensis* cv. Comum); and maize intercropped with Aruana Guinea grass (*Megathyrsus maximus* cv. Aruana). The subplots were four nitrogen rates (0; 50; 100 and 150 kg ha^{-1}) applied as side-dressing. The maize and grasses row were fertilized with nitrogen. Maize intercropped with grasses needs an adequate nitrogen supply to be applied as side-dressing.

Keywords: Aruana Guinea grass; Congo grass; diversification practices; environmental impacts; intercropping system; sustainable agriculture

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1. Introduction

No-till farming is widely adopted in Brazilian farmlands, using soybean in the summer and maize (*Zea mays* L.) in the autumn–winter. However, the widespread adoption of this process has resulted in the greater uniformity of agricultural landscapes, making it less efficient and sustainable [1]. Thus, it is necessary to adopt new strategies to improve this system. Among the available strategies, the use of tropical grass intercropped with crop maize has shown environmental and economic advantages [2].

Among the species studied in the intercropping system, the genera of *Urochloa* and *Megathyrsus* have shown large amounts of dry biomass, which is critical for residue formation in no-till farming and animal feed in the dry season. In addition, these grasses have high C/N and lignin/total N ratios, reducing the decomposition rate and protecting the soil against erosion and solar radiation action for a longer time [3–5]. Maize and tropical grasses are nitrogen-demanding plants, and its low availability in the soil can result in variations in their production efficiency [6]. However, there is lack of information about the nitrogen supply when maize and tropical grasses are in the intercropping systems.

In this particular setting, the objective of this investigation was to assess the plant height, cob height, and grain yield of maize as a function of the cropping systems and nitrogen rates applied as side-dressing.

2. Materials and Methods

A field experiment was developed from August 2019 to September 2021 in southeastern Brazil, with soybean in summer and maize in autumn–winter. Here, we present the results of the last maize crop (March to September 2021). The soil is a red–yellow Argisol-Ultisol [7,8] of medium texture. The local climate is "Aw" type [9] (Figure 1). The soil attributes before the experiment are presented in Table 1. The soil was prepared before planting in 2019.

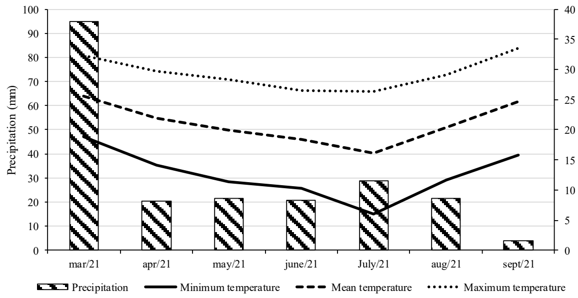

Figure 1. Temperatures and rainfall in the period.

Table 1. Soil attributes before the beginning of the experiment.

$pH_{(CaCl2)}$	O.M	$P_{(resin)}$	SO_4^{-2}	$K_{(resin)}$	$Ca_{(resin)}$	$Mg_{(resin)}$	H + Al	Al	CEC	SB
	g dm^{-3}	mg dm^{-3}		mmol$_c$ dm^{-3}					%	
4.7	30	4	9	1.5	10	7	47	3	66	28

$pH_{(CaCl2)}$ = pH determined in $CaCl_2$ method. O.M = organic matter determined in colorimetric method. $P_{(resin)}$ = phosphorus determined in resin method. SO_4^{-2} = sulfate determined in turbidimetric method. $K_{(resin)}$ = potassium determined in resin method. $Ca_{(resin)}$ = calcium determined in resin method. $Mg_{(resin)}$ = magnesium determined in resin method. H + Al = potential acidity determined in SMP buffer solution method. CEC = cation exchange capacity. BS = base saturation.

The treatments were administered in a split plot scheme in a randomized complete block design with four replications. The main plots were maize monoculture, maize intercropped with Aruana Guinea grass (*Megathyrsus maximum* cv. Aruana) and maize intercropped with Congo grass (*Urochloa ruziziensis* cv. Comum). The subplots had nitrogen rates of 0, 50, 100, and 150 kg ha^{-1} applied as side-dressing in rows of maize and tropical grasses when the maize plants had 5–6 fully expanded leaves. The plant height, cob height and grain yield of the maize at the time of its physiological maturity were evaluated.

A sowing-fertilizer machine for a no-tillage system, with a separate box for the differential distribution of large and small seeds, was used to plant maize and grasses in the same operation. The maize cultivar used was AG8061PRO2. The maize monoculture rows were spaced 0.90 m apart. In the intercropping system, the rows were spaced 0.45 m apart. Only maize rows were fertilized at planting with 30 kg ha^{-1} of N, 50 kg ha^{-1} of P_2O_5, and 40 kg ha^{-1} of K_2O [10].

The SAS GLM procedure was used for the analysis of variance. The main effects and interactions were studied. Tukey's test was used to compared mean, and regression analysis verified the effect of nitrogen rates.

3. Results

The plant height and cob height of the maize showed significance for the interaction between maize intercropped with Congo grass and nitrogen rates applied as side-dressing (Table 2). The lowest plant height (138.36 cm) in maize intercropped with Congo grass occurred at the nitrogen rate of 125.71 kg ha^{-1} (Figure 2a). Furthermore, maize intercropped with Congo grass showed a lower plant height at the nitrogen rate of 100 kg ha^{-1}, differing statistically from other cropping systems (Table 2). The cob height of the maize decreased as the nitrogen rates increased in maize intercropped with Congo grass (Figure 2b). Moreover, maize intercropped with Congo grass showed a lower cob height at the nitrogen rate of 100 kg ha^{-1}, not differing statistically from maize intercropped with Aruana Guinea grass (Table 2).

Table 2. Plant height, cob height and grain yield of maize at the time of its physiological maturity.

Cropping Systems	N Rates (kg ha^{-1})				Means	F Test for Regression	
	0	50	100	150		Linear	Quadratic
Plant height (cm)							
maize monoculture	171.50 a	158.00 a	182.00 a	151.00 a	165.63 a	0.6089	0.7665
maize + Aruana Guinea grass	168.75 a	151.50 a	160.75 a	176.00 a	164.25 a	0.6857	0.5881
maize + Congo grass	184.25 a	176.00 a	121.50 b	146.00 a	156.94 a	0.0168	0.0327
Means	174.83	161.83	154.75	157.67		0.1575	0.2556
CV%	10.35 **						
Cob Height (cm)							
maize monoculture	80.50 a	72.75 a	75.00 a	67.25 a	73.87	0.2689	0.9554
maize + Aruana Guinea grass	67.00 a	62.75 a	69.50 ab	81.25 a	70.12	0.2190	0.3193
maize + Congo grass	90.00 a	85.25 a	52.50 b	67.50 a	73.81	0.0380	0.0774
Means	79.17	73.58	65.67	72.00		0.2117	0.2406
CV%	12.63 **						
Grain yield (kg ha^{-1})							
maize monoculture	1933.06 a	1025.53 b	1562.09 a	602.42 b	1280.77 a	0.0190	0.0709
maize + Aruana Guinea grass	1106.02 a	1433.14 ab	1348.75 ab	1899.18 a	1446.77 a	0.0545	0.1532
maize + Congo grass	1341.82 a	1825.44 a	733.39 b	1138.45 ab	1259.78	0.2033	0.4551
Means	1460.30	1428.04	1214.74	1213.35		0.2231	0.4781
CV%	5.55 *						

Means followed by different lowercase letters in the columns differ from each other by Tukey's test at the 5% level. Coefficient of variation referring to data transformed to * log(X) and ** square root (X).

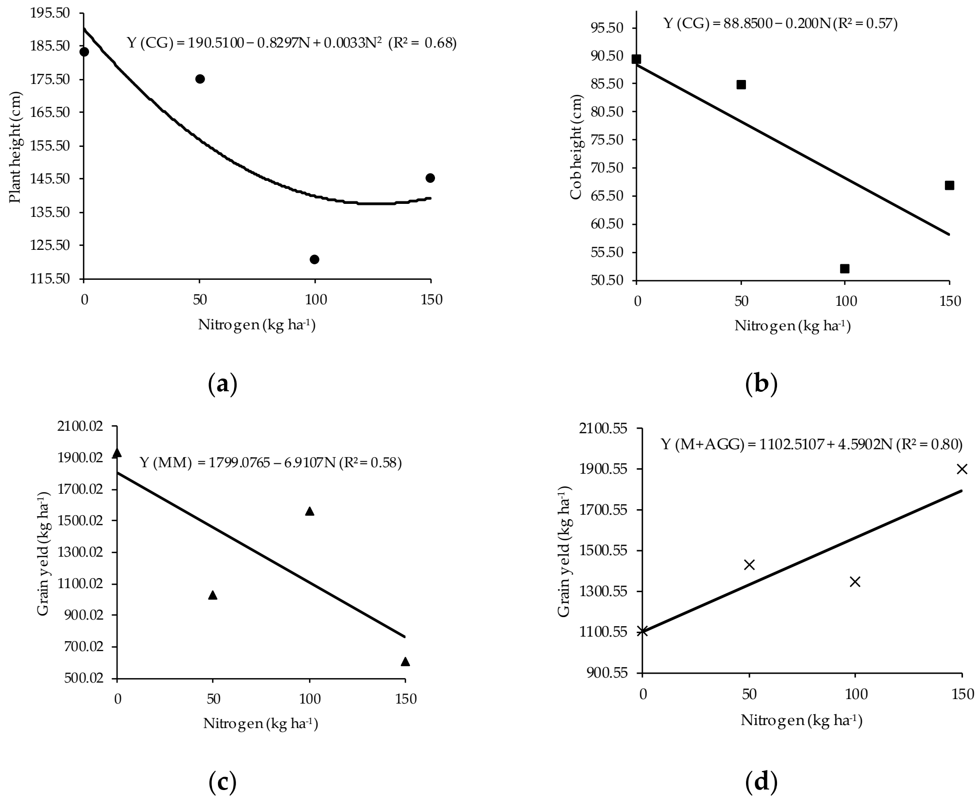

Figure 2. Plant height (**a**), cob height (**b**) and grain yield (**c**,**d**) of maize at the time of its physiological maturity as a function of the cropping system and nitrogen rates applied as side-dressing.

The grain yield of maize showed significance for the interaction between the maize monoculture and nitrogen rates applied as side-dressing and the maize intercropped with Aruana Guinea grass and nitrogen rates applied as side-dressing (Table 2). The grain yield of the maize monoculture decreased linearly as the nitrogen rates applied as side-dressing increased (Figure 2c). Meanwhile, in the maize intercropped with Aruana Guinea grass, the grain yield increased linearly as the nitrogen rates applied as side-dressing increased (Figure 2d). In addition, no difference was observed in the grain yield of maize between intercropping systems at the nitrogen rates of 50 to 150 kg ha^{-1}. Regardless of the cropping systems or nitrogen rates applied as side-dressing, the grain yield of maize was low. However, the climatic conditions in the period were unfavorable for the maize, with a total precipitation from planting to physiological maturity of 185.88 mm, a mean temperature of 17.79 °C, and frost during the grains fill of maize (Figure 1).

4. Discussion

The dynamics of the plant height and cob height showed that the adaptation of the maize intercropped with Congo grass depends on an adequate nitrogen supply (Figure 2a). The adaptation of maize height to the intercropping system is key to its agricultural performance, as it results in an increase in crop uniformity, a favorable split in carbon and nutrients between grain and non-grain biomass, and improvements in the efficient use of fertilizers, pesticides and water [11].

The maize showed a low grain yield, which can be associated with the conditions of low precipitation and temperature (Figures 1 and 2c,d). The impact of the climate variables on crop yield can be summarized as follows: rainfall is related to the crop yield, affecting the water balance; this is because, when the soil water limits the ability of crops to meet the atmospheric demand of evaporation, the stomata close, reducing water loss, but also photosynthesis. Meanwhile, extremely low or high temperatures damage the vegetative and reproductive structures of the plant [12]. In addition, the moisture conditions of the dry soil after the six fully expanded leaf stage, a period that corresponds to maize development after using nitrogen fertilization as side-dressing, may limit the maize root development, nitrogen uptake and biomass production above soil, thus reducing the number and mass of the maize grains [13].

The grain yield (Figure 2c,d) also illustrated the challenges associated with the application of nitrogen in maize intercropped with tropical grasses in the dry season. Drought conditions, during the late vegetative growth period and the onset of stigma-style, represent a critical period in which soil moisture or nutrient deficiency can reduce the maize grain yield potential [14].

5. Conclusions

Our results showed that, when maize is intercropped with Congo, the nitrogen supply interferes in the plant height and cob height. In conditions of a high nitrogen supply, a low cob height occurs. When maize is intercropped with Congo grass, a high nitrogen supply is necessary for a high grain yield. Maize intercropped with tropical grasses is more nitrogen-demanding than maize monoculture.

Supplementary Materials: The presentation materials can be downloaded at: https://www.mdpi.com/article/10.3390/IOCAG2023-15828/s1.

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