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Phosphate fertilization in a corn-Urochloa intercrop system[1]

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ABSTRACT

Corn intercropped with *Urochloa* contributes not only to increasing soil coverage but also to improving physical, biological, and chemical quality, especially in Cerrado soils that have low phosphorus availability. Therefore, the objective of this work was to evaluate the response of different doses of phosphorus (P) in production systems on the chemical attributes of the soil, and physiological, biometric, and productive parameters of corn. Thus, an experiment was conducted with a randomized block design in a split-plot scheme, with four replications. The plots consisted of two production systems: single corn and intercropped corn. The subplots consisted of three doses of phosphorus. Soil chemical attributes, gas exchange, chlorophyll content, biometric components, and corn productivity were evaluated. The physiological parameters were not affected by the systems and P doses. In the biometric components, there was a significant effect only for stalk diameter, where corn in the single system had a larger diameter in comparison to the intercropped one. There were effects for P contents in the system and dose factors, while for organic matter and carbon only in the dose factor. Production systems and phosphate fertilizer did not influence corn grain productivity.

Keywords: phosphorus doses; production systems; soil chemical attribute.

INTRODUCTION

Corn is a highly productive cereal due to its physiological characteristics, making it a highly profitable crop for producers. Concern about the means of production, the environment, and the high costs of agricultural activities are the factors that have led to research and the adoption of more economical and sustainable cultivation techniques by the producers.(1)

One option that has proven to be viable is the intercropping of grain-producing plants with tropical forages, as they provide a reduction in cost and greater production efficiency. These results can be achieved in a relatively short period, due to greater biomass production, which is reflected in greater nutrient cycling, reduced weed infestation, and greater efficiency in the use of fertilizers.(2-4)

Because corn is a species with rapid and vigorous initial growth, it facilitates intercropping with other plant species, whose interest in this technique has exponentially increased. Among the species used in this intercropping, *Urochloa* stands out for improving soil fertility, particularly in the superficial layers, through the recovery of nutrients in depth, due to its large production of aerial and root phytomass. Furthermore, in the intercropping of corn with *Urochloa*, the forage can have a dual purpose, serving as food for livestock farming, from the end of summer until the beginning of spring and, later, for the formation of straw in the no-tillage system.(5)

One of the most limiting factors in the formation and management of tropical pastures and corn production is the extremely low level of phosphorus (P) in the soil, due to natural poverty and the high capacity for fixing this in acidic soils.(6) According to Carvalho(7), *Urochloa* can absorb forms of phosphorus and potassium that other crops do not have access to, and after its decomposition, these nutrients are made available to the soil in forms that other crops can absorb. When compared to nitrogen and potassium, concerning the amounts, phosphorus is less required in corn crops.(8) However, it is an essential nutrient for grain production, with around 85% of the total absorbed by corn plants being exported to grains.(9)

Therefore, the use of phosphate fertilizers has become essential for increasing productivity, especially in soils in the *Cerrado* region that have a low concentration of this nutrient. In this sense, considering the high cost of phosphate fertilizers is raised the hypothesis that the intercropping of corn with *Urochloa* can increase the availability of phosphorus in the soil, thus allowing a more efficient use of these fertilizers. As a result, the objective of this work was to evaluate different doses of phosphate fertilizer in production systems on the chemical attributes of the soil, physiological and biometric parameters, and productivity of corn with *Urochloa ruziziensis*.

MATERIAL AND METHODS

The work was carried out on the School Farm of the Federal University of Jataí - Campus Jatobá, located in the municipality of Jataí, state of Goias (GO), within the geographic coordinates 17º53' S and 52º43' W, at an altitude of 670 meters. According to Koppen's classification, the climate in the region is Aw, tropical Savanna, with rain in the summer and dry winter. The average annual minimum and maximum temperature are 14.4ºC and 29.3ºC, respectively, with an average rainfall of 1,541 mm. The soil in the experimental area is classified as a dystroferric Red Latosol (LVdf) with a clayey texture.(10)

The chemical characteristics of the 0-20 cm layer before the experimental setting up are shown in Table 1.

The experimental design used was randomized blocks in a split-plot scheme with four replications. The plots consisted of two corn cultivation systems (single and intercropped with *Urochloa ruziziensis*) and the subplots with three doses of phosphorus [80, 60, and 40 kg ha^{-1} of P_2O_5, which corresponded to 100%, 75%, and 50 % of the recommended dose for crops by Sousa and Lobato (11), using monoammonium phosphate. Each plot consisted of 10 rows with 0,45 meters between rows and five meters long, totaling 22.5 m^2.

Corn was sown on March 4, 2022, using the AS1820 PRO3 hybrid, recommended for the region. Corn was sown at a depth of 3 cm and three seeds were used per meter

Table 1: Soil texture and chemical analyses in the experimental area before the 2020/2021 harvest of soybean crop. Jataí, state of Goiás (2020)

Ph ($CaCl_2$)	OM (g kg^{-1})	P_{resine}	K	Ca	Mg	V (%)	Sand	Silt	Clay
		(mg dm^{-3})		(cmol$_c$ dm^{-3})			(g kg^{-1})		
5.1	36	14.1	2.1	2.76	1.02	40.96	175	240	585

(single and intercropped) and *Urochloa* was sown on the same day between the corn rows at a density of 6 kg of seeds per hectare (VC = 90%). The opening of the furrows for depositing the *Urochloa* seeds was done manually using a hoe. Fertilization was carried out according to the results of the interpretation of the soil analysis collected before the installation of the experiment, taking into account the recommendations of Sousa & Lobato[11], 15 kg ha^{-1} of N, 80 kg ha^{-1} of P_2O_5 and 60 kg ha^{-1} of K_2O.

Phosphate fertilization was carried out by broadcasting at the time of sowing, with doses 80, 60 and 40 kg ha^{-1} of P_2O_5 in the plots defined for each of the treatments. During the experiment, complementary fertilization was carried out at the V3 phenological stage (15 days after planting) of 100 kg ha^{-1} of N in the form of urea NPBT plus 60 kg ha^{-1} of K_2O in the form of potassium chloride. The corn crop was harvested in July 2022.

The relative chlorophyll content was evaluated with a hand-held chlorophyll meter (AtLeaf, FT Green LLC Wilmington, USA). Measurements were made on three plants in each plot, namely in the middle third of the last fully developed leaf, representing the average of three evaluation points in that region of the leaf. It should be observed that the measurements were carried out in the useful area of all plots of the single and intercropped corn crop at stage V4.

Gas exchange assessments were also carried out in stage V4, with the aid of a portable conventional infrared gas analyzer (LCpro-SD; ADC BioScientific Ltd, UK). The net photosynthetic rate (A), transpiration rate (E), stomatal conductance rate (Gs), leaf temperature (T_{Leaf}), and internal CO_2 concentration (Ci) were evaluated in both production systems. Measurements were carried out in the morning from 8 a.m. to 10 a.m. on leaf +3, on three plants in the useful area of each plot, with fully expanded new leaves.

To evaluate the chemical attributes of the soil, samples were collected after harvesting the corn crop in both production systems. Also, from each plot, a composite sample was collected from the collection of four simple samples totaling 24 composite samples. The samples were collected using hoes and augers at depths of 0-10 and 10-20 cm.

The determinations of pH, CEC, exchangeable bases (Ca^{2+}, Mg^{2+}, and K^+), extractable P in Mehlich-1, exchangeable Al^{3+}, H+Al, and organic matter were based on the methodologies recommended by Embrapa.[10]

The evaluation of biometric components (plant height and stalk diameter) and was carried out on 10 plants in the useful area of each experimental unit in the period before harvest, 115 days after sowing. The plant height and stalk diameter were measured, as follows: from the base of the stem to the highest point of plant using a millimeter ruler; and at 0.3 m from the base of the stem using a digital caliper, respectively. The mass of 1000 grains were measured on a precision scale of two decimal places, and corrected to 13% humidity, as adapted from the RAS - Rules for Seed Analysis[12]; plant population and ears: count of plants in the useful area of the two central 4-meter lines in each plot; number of grains per ear: it was determined by the product of counting the number of rows per ear and the number of grains per row in five ears; grain yield: the ears contained within 4 m were manually harvested in the two central rows of each plot. After going through a type of threshing, the grains were weighed on a precision electronic scale. Afterwards, grain moisture was determined using a portable moisture meter, to correct productivity to 13% moisture (wet basis), then productivity was calculated in kg ha^{-1}.

The data obtained during the work were subjected to analysis of variance (F test), and the means when they showed differences at the level of 5% probability, were compared using the test of Tukey, using the statistical program Sisvar 4.2.[13]

RESULTS AND DISCUSSION

Physiological evaluations

Figure 1 presents the results regarding the measurement of exchange gases in corn cultivation. It can be observed that there was no significant interaction between systems and doses of P. Neither it was observed significant differences in the Evaluated variables: leaf temperature, internal CO_2 concentration, transpiration, stomatal conductance, and photosynthetic rate for the isolated factors. These results demonstrate that in the initial phase of development, an important period in defining the productive potential of corn, there was no competition for environmental resources between species, which may have been favored by climatic conditions, high temperature, and precipitation and also by the adequate levels of P in the soil (Table 1).

Stomatal density, size and aperture serve as crucial factors governing the rate of gas exchange, and P nutrition is closely linked to photosynthetic rates. Adequate P nutrition enhances plant resilience to abiotic stresses, preventing photosynthesis inhibition and improving the recovery of stomatal conductance and photosynthesis.[14,15]

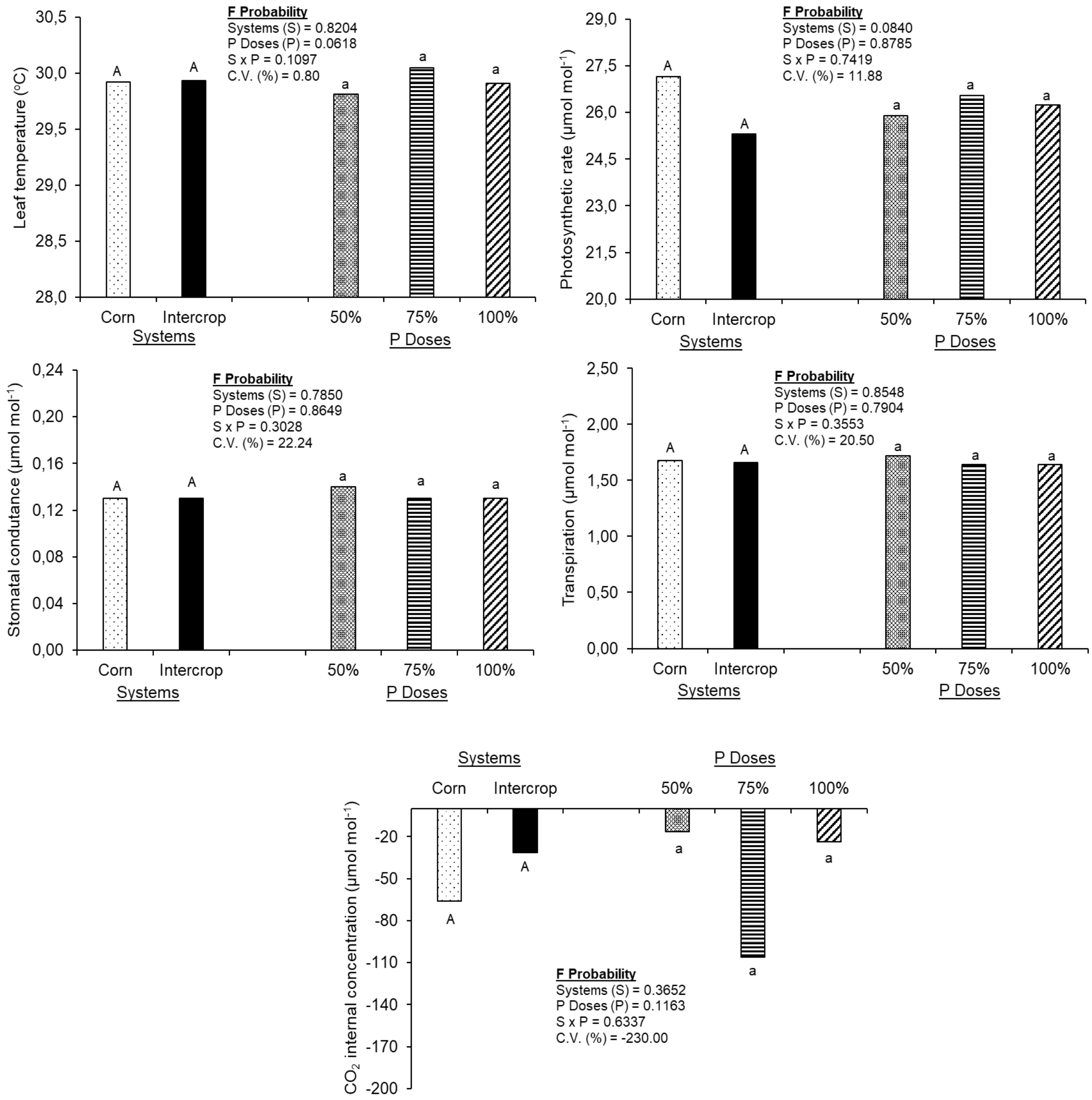

Figure 1: Probability values of the F test for leaf temperature values, photosynthetic rate, stomatal conductance, transpiration, CO_2 internal concentration in corn leaves in single and *Urochloa ruziziensis*-intercropping systems as a function of P doses. Jataí, GO, 2022. Different uppercase letters differ for systems and different lowercase letters differ for P doses.

Makino[16], evaluating the agronomic and physiological performance of corn in plant arrangements, with and without brachiaria, in summer and autumn-winter, also observer no effect of the cultivation systems on the physiological variables evaluated, except stomatal conductance.

The negative values for Ci in the leaves, in both evaluated systems, as well as for different doses of P, possibly demonstrate that the corn plants were carboxylating more than the amount of carbon dioxide that was available to them at the time of the evaluation. In other words, regardless of the type of system and P doses, the corn plants were working below their maximum photosynthetic capacity due to the lower concentration of CO_2 in the leaves. This same behavior was observed by Leite[17] when the author characterized the efficiency of popcorn lines in the use of water in terms of root and physiological attributes, which reported negative values for Ci. The same author highlighted that this procedure represented lower contents of internal CO_2, as well as lower water losses through the stomata.

Chlorophyll contents in corn plants

According to the results obtained for chlorophyll levels in the corn crop, it can be seen that there was no interaction between the system factors and the P doses. The levels of chlorophyll a/b and total chlorophyll (a + b) were not statistically affected in production systems in the initial stages of corn crop development (Figure 2).

This is because until the V4 stage of corn development, there was no competition with *Urochloa*. Whether there was competition for light, there would be a change in the relative proportion of chlorophyll b, due to the compensatory effect of the species and the lower amount of radiation available[16] as corn is part of the C4 group, which is deficient in photosystem II (PSII).

These results corroborate Jordão *et al.*[18] in which they evaluated the relative levels of chlorophylls in two production systems of single corn and intercropped with *Urochloa* under doses of nitrogen, where they observed that the management of single and intercropped corn does not influence the relative levels of chlorophylls in corn leaves. Similarly, Nunes[19] observed no difference in chlorophyll levels in two study areas evaluating two spacings in corn crops, single or in consortium with brachiaria, with and without co-inoculation. For P levels, the two chlorophylls evaluated were not statistically affected (Figure 2). The good availability of P may have been explained to the concentration of chlorophylls found in the photochemical stage of photosynthesis which, in turn, are necessary for the absorption, reduction, and assimilation of nitrogen, a component of the chlorophyll molecule.[20] It should be seen that from the V4 stage onwards, the plant begins an accelerated stem elongation, making it essential that P and other nutrients are readily available for absorption.[21]

Evaluation of the biometric components

Data relating to stem diameter and plant height as a function of corn intercropping and phosphate fertilization are contained in Figure 3. In the isolated factors, there was a significant difference in stem diameter in the production systems factor. Although it is seen in many works that phosphate fertilizer promotes an increase in biometric components in crops[22, 23], in the experiment conducted, the difference was not significant. The absence of forage interference on the height of corn plants was also reported in the work of Borghi et al.[24] This fact may be related to the rapid initial growth of corn compared to forage.[25]

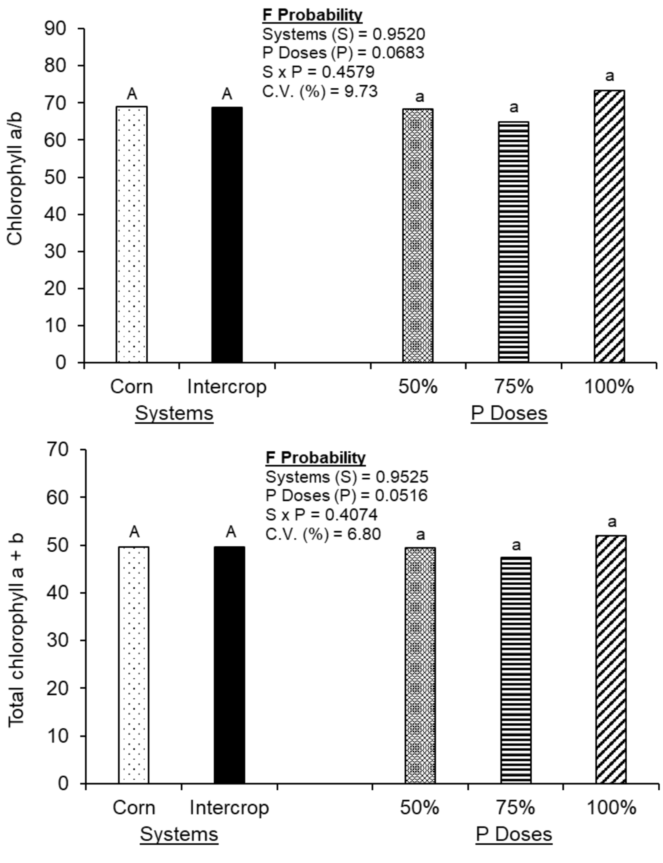

Figure 2: Probability values of the F test for chlorophyll a/b and total chlorophyll (a + b) contents in corn leaves at the V4 vegetative stage in single and *Urochloa ruziziensis*-intercropped systems as a function of P doses. Jataí, GO, 2022. Different uppercase letters differ for systems and different lowercase letters differ for P doses.

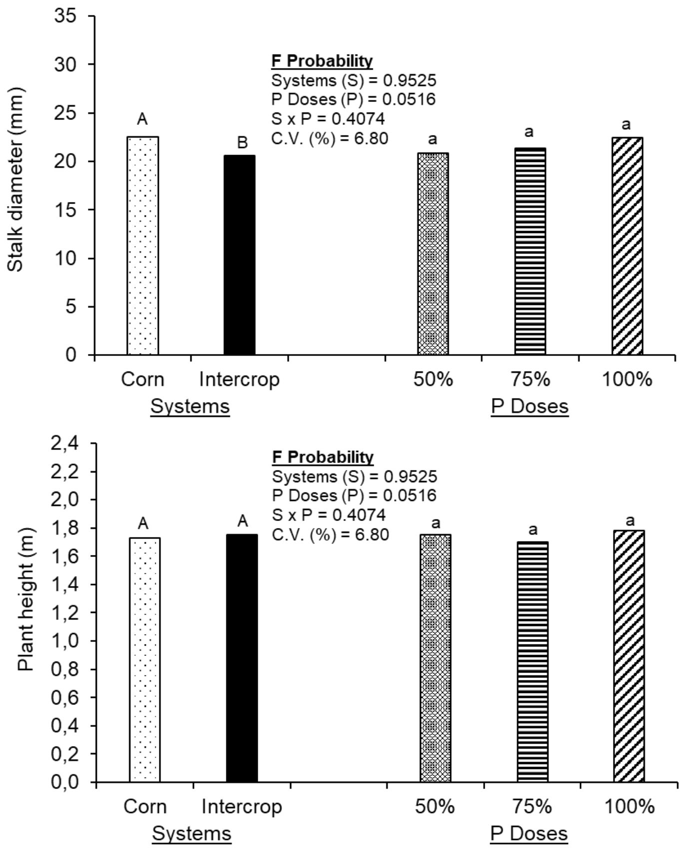

Figure 3: Probability values of the F test for stalk diameter (SD) and plant height (PH) of corn in single and *Urochloa ruziziensis*-intercropped systems as a function of P doses. Jataí, GO, 2022. Different uppercase letters differ for systems and different lowercase letters differ for P doses.

In the single corn system, a greater stalk diameter was observed in comparison to the intercropped system (Figure 3).

The reduction in stem diameter in the intercropped system is likely to be related to late interspecific competition between two species, in which *Urochloa* reduced the accumulation of reserves, both water and nutrients in the corn crop. The diameter of the stalk is an important variable, it functions as a reserve organ for the corn crop, especially in times of water stress. Some plants, as they have a larger nutrient reserve, end up using this resource to fill grains from the cob.[26] Pereira *et al.*[27] concluded that a smaller stem diameter reduces grain productivity and can function as a reserve organ for the crop concerning nutrients. The stem diameter is an important characteristic, as it reduces the risk of plant breakage and lodging, as the larger the stem diameter, the greater this accumulation of reserves.[28]

Components of corn yield and productivity

Data on plant population, number of grains per ear, mass of 1000 grains, and corn yield as a function of corn intercropping with *Urochloa* and phosphate fertilizer are contained in Figure 4. There was no significant interaction between systems and P doses. The analyses of the isolated factors showed that there was no significant difference in the components of corn production and productivity.

Regarding the types of systems, it was found that the forage plant did not harm the development of corn. Such results arise from the fact that *U. ruziziensis* presents a slow initial growth[29,30] and, normally, does not affect the growth of corn seedlings, which, on the contrary, have rapid initial growth. Corroborating the results of this work, Makino et al.[31] when evaluating the productivity and nutrient contents in populations of single off-season corn, intercropped with *Urochloa*, observed that, among the morphological variables evaluated, the height of plants and insertion of corncobs, and leaf area per plant were not affected by the treatments. In addition, they concluded that the cropping systems have not influenced the production components evaluated in corn, demonstrating that, despite affecting the contents of some leaf nutrients and morphological characteristics, the competition between *Urochloa* and corn plants in the intercropped system was not capable of compromising crop productivity. Coletti et al.[32] have found similar results when evaluating the performance of intercropped corn with forage plants sown by the time of corn topdressing.

Nunes[19] also found no effect of intercropping with Brachiaria, row spacing, and co-inoculation on corn productivity. The author did not observe any difference in crop productivity in the two evaluation areas; furthermore, the N and P contents of the grains did not vary between the treatments studied. Wenneck et al.[33] did not observe any statistical difference between the cultivation of corn intercropped with Brachiaria, in interspersed rows, and the cultivation of corn alone. However, both treatments were superior to the intercropping with Brachiaria between rows or in the same row as corn, which suggests, according to the authors, that the sowing position in the corn/Brachiaria intercrop may influence biomass production.

Components of corn yield and productivity were not affected by the P dose factor (Figure 4). This result may be related to the soil analysis of the area where the experiment is located, in which the average P content (14.1 mg dm^{-3}) in the soil is close to the levels considered adequate according to the recommendation of Sousa & Lobato[11] (Table 1). It should be observed that in the case of soils that have adequate phosphorus levels, fertilization is important, and over time there may be a depletion of these levels due to the export of crops in plots that received reduced fertilization.[34]

Soil chemical attributes -

The data obtained for soil chemical attributes showed that there was no significant interaction between system factors and P doses in the two Evaluated layers (Tables 2 and 3). The levels of cátion exchange capacity (CEC) and base saturation (V) in the soil were not significantly affected by production systems. For the factors analyzed separately, the systems only affected the P contents in the soil, in the 0-10 cm layer, while the P doses affected the levels of organic matter (OM), aluminum (Al), and P, all only in the 0-10 cm layer, and the level of carborn (C) in both layer (Table 2).

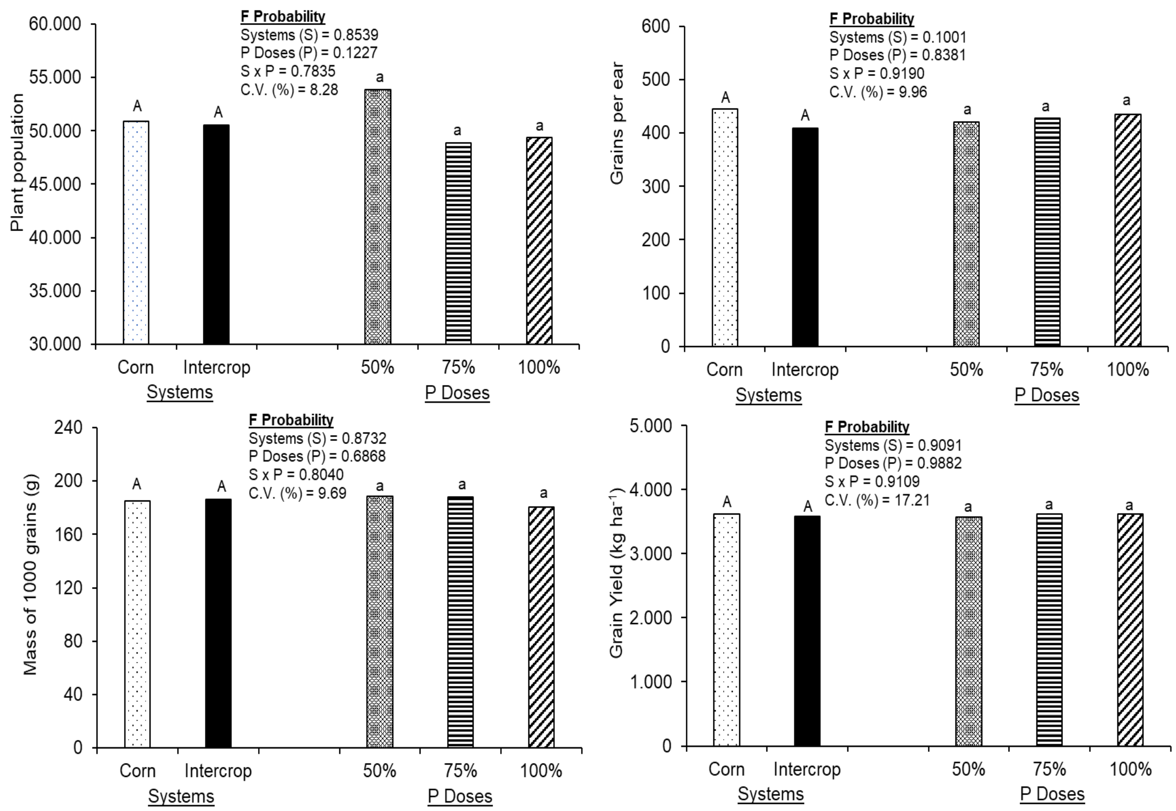

Figure 4: Probability values of the F test for plant population, number of grains per ear, mass of 1000 grains and grain yield of corn in single and *Urochloa ruziziensis*-intercropped systems as a function of P doses. Jataí, GO, 2022. Different uppercase letters differ for systems and different lowercase letters differ for P doses.

Table 2: Summary of the analyses of variance (F test) for the values of organic matter (O.M.), Carbon (C), pH in H2O, aluminum (Al), H+Al, cátion exchange capacity (CEC) and base saturation (V) contents in both soil layers according to the grown systems and P doses, Jataí, GO, 2022

	O.M.	C	pH (H_2O)	Al	H + Al	CEC	V
	(g kg^{-1})			(cmol$_c$ dm^{-3})			%
				0 – 10 cm layer			
Systems							
Single	42.2	24.4	4.95	0.10	5.31	12.2	56.0
Intercropping	43.1	25.0	5.01	0.15	5.75	11.7	50.4
Dose							
50 %	39.9 b	23.1 b	4.93	0.12 ab	5.47	11.8	52.7
75 %	42.2 ab	24.5 ab	4.87	0.17 a	5.93	11.9	49.4
100 %	45.9 a	26.6 a	5.10	0.08 b	5.20	12.3	57.4
F probability							
System (S)	0.37^{ns}	0.353^{ns}	0.42^{ns}	0.34^{ns}	0.19^{ns}	0.31^{ns}	0.24^{ns}
Dose (D)	0.03*	0.03*	0.97^{ns}	0.01*	0.07^{ns}	0.21^{ns}	0.07^{ns}
S x D	0.87^{ns}	0.86^{ns}	0.67^{ns}	0.34^{ns}	0.85^{ns}	0.97^{ns}	0.90^{ns}
C.V 2 (%)	9.46	9.046	3.91	38.71	10.53	5.02	11.65
				10 – 20 cm layer			
Systems							
Single	34.6	20.1	4.58	0.27	6.35	9.48	32.6
Intercropping	33.9	19.7	4.46	0.26	6.77	9.54	28.9
Dose							
50 %	34.1	19.5 b	4.51	0.26	6.63	9.65	30.8
75 %	33.6	19.7 ab	4.50	0.33	6.57	9.45	30.1
100 %	35.2	20.4 a	4.56	0.21	6.48	9.43	31.3
F probability							
System (S)	0.80^{ns}	0.35^{ns}	0.42^{ns}	0.93^{ns}	0.50^{ns}	0.76^{ns}	0.53^{ns}
Dose (D)	0.93^{ns}	0.03*	0.97^{ns}	0.08^{ns}	0.84^{ns}	0.59^{ns}	0.92^{ns}
S x D	0.35^{ns}	0.86^{ns}	0.67^{ns}	0.54^{ns}	0.18^{ns}	0.06^{ns}	0.90^{ns}
C.V 1 (%)	18.09	18.20	8.73	78.20	20.54	4.53	54.51
C.V 2 (%)	26.77	26.78	2.98	37.43	7.73	4.80	19.20

*and ns are, respectively, significant at 5%, and not significant by the F test. Means followed by the same letter in the column are not different from each other at the 5% probability level by the test of Tukey. C.V: Coefficient of variation.

As for the P doses, it was observed that the 100% dose differed statistically only from the 50% dose, in which it was found that the O.M. and C levels were higher in the 100% dose, followed by the 75% and 50% doses (Table 2). These results are justified by the greater contribution of plant biomass with increasing doses observed over time. There are many potential direct and indirect mechanisms which affect the sorption of P and OM on soil surfaces. Added OM crumbles, and its products can adsorb to the binding sites of the mineral surface, resulting in reduced P sorption and hence increased P concentration in soil solution and available P for plant uptake.[35-37] OM can increase the availability of phosphorus (P) in the soil through abiotic processes such as decomposition and mineralization of organic P in soil or ligand exchange.

Furthermore, the greater soil coverage consequently will reduce water losses, contributing to improvements in the physical, chemical, and biological properties of the soil. According to Costa et al.[38], chemical changes in the soil in intercropped systems result from the high accumulation of plant residues on the soil surface which, after decomposition, provide nutrients to the system and stimulate biological activity.

As for the absence of effects on the other variables analyzed for the P doses factor, it may be related to the average P contents (14.1 mg dm^{-3}) in the soil, as well as the high organic matter content of the soil before implementing the experiment (Table 1).

The results of evaluating macronutrient levels had no interaction between the factors' production systems and P doses. The levels of K, Ca, Mg, S, B, Cu, Fe, Mn and Zn in the soil were not significantly affected by production systems, except P, which was affected by the doses and system factors (Table 3).

It was found that P was affected by the production systems factor, where single corn was statistically different from the intercropped, obtaining a higher P content. The P plays a crucial role in the initial establishment of the crop, especially during the early stages of root system development.[15,39] Therefore, the reduction in P content in intercropped systems may be related to the growth of *U. ruziziensis*, which is characterized by a greater initial increase in the root system, which can favor the rapid fixation of the plant in the soil and consequently better accumulation of this nutrient by the roots.

These results reinforce the observations of Silveira et al.[40], who reported the less significant behavior of P in a corn intercrop system with *Urochloa*, which can be explained by the lower biomass of the forage when in intercropping, and by the harvest of grains produced by the corn plants, characterizing the export of nutrients from the area. The same authors point out that intercropped systems can change the nutrient content in the soil, given the differences in nutritional requirements, root depth, and amount of plant material that returns to the soil.

For the P dose factor, it was observed that the 100% dose differed statistically only from the 50% dose, in which the P levels in the soil were higher at the 100% dose, followed by the 75% and 50% doses. These results can be attributed to the effectiveness of phosphate fertilization which was carried out at planting. According to Malavolta [41], this is because P acts directly in the production of energy for the plant, helping in the processes of mineral absorption and protein synthesis.

It should be observed that the levels of K, Ca, Mg, S, CEC, and V were not significantly influenced by the production systems and P doses in the two layers evaluated. This result is of the adequate conditions of soil fertility in the experimental area before the installation of the experiment, which also presented high levels of organic matter (Table 1), as OM is an important contributor to negative soil loads, therefore increasing the adsorption of cations and, consequently, the sum of bases, base saturation and soil CEC.[42] Furthermore, organic matter in the topsoil also contributes to maintaining neutrality, by avoiding sudden changes in pH, due to its high buffering power.[41]

Some studies show that in the long term, there may be changes in chemical attributes in production systems due to the longer implementation time of these systems, where *Urochloa* needs a longer development time[42,43], which was different from this work. In addition to the time factor observed in *safrinha* corn, a less favorable climate factor can be seen, with low precipitation, limitations in solar radiation, and low temperature in the final phase of its cycle, as it is grown in the autumn-winter period, unlike corn grown in summer.

The outcome of the evaluation of the levels of boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) in the soil were not significantly affected by the factors production systems and P doses (Table 3). The Fe levels in the soil were not altered by the factors evaluated in the two layers. This result can be related to the characteristics of Cerrado soils[44], as generally, they have an acidic pH, high content of iron and aluminum oxides, and low nutrient availability.

It was also observed that the levels of B, Cu, Mn, and Zn were not influenced by the factors evaluated. Such results may be associated with greater addition of plant residues to the soil surface.

The availability of micronutrients depends on the stability, solubility and reactivity of the organometallic complex formed.[45,46] The stoichiometry of mixtures of metals with complexing agents and the pH also regulate the availability of micronutrients in the complexes and the ability of plants to promote the cleavage of the organometallic complex, with subsequent release and absorption of the complexed micronutrient.[47,48]

However, although fertilization with micronutrients was not carried out during the present experiment, in general, it was found that the micronutrient levels in the soil were not interfered with by either production systems or P doses, which could be explained by the ratio of the appropriate pH range and the appropriate organic matter contents (Table 1), since the greater presence of organic matter avoids nutritional imbalances, as the micronutrients are present in the soil in the form of complexes, instead of prevailing in the form of free ions in the soil solution readily available to crops.[49]

These results highlight the increase in soil cover, the maintenance of the physical, chemical, and biological quality of the soil, as well as better nutrient cycling and increment in the organic matter in these systems.

Table 3: Summary of the analyses of variance (F test) for the mean values of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) according to the growing systems and phosphorus doses, Jataí, GO, 2022

	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	($mg\ dm^{-3}$)		($cmolc\ dm^{-3}$)			($mg\ dm^{-3}$)				
					0 – 10 cm layer					
Systems										
Single	48.0 a	163.8	4.06	2.46	15.8	0.33	6.26	22.6	42.9	3.8
Intercropping	33.6 b	134.3	3.44	2.22	17.9	0.30	6.45	24.0	37.7	3.6
Dose										
50 %	24.6 b	134.7	3.67	2.31	18.8	0.32	6.46	23.2	40.1	3.6
75 %	40.2 ab	161.1	3.45	2.11	17.2	0.30	6.48	24.4	39.7	3.7
100 %	57.6 a	151.3	4.13	2.61	14.5	0.32	6.13	22.3	41.1	3.7
F probability										
System (S)	0.00*	0.190^{ns}	0.25^{ns}	0.37^{ns}	0.45^{ns}	0.18^{ns}	0.62^{ns}	0.54^{ns}	0.08^{ns}	0.33^{ns}
Dose (D)	0.01*	0.167^{ns}	009^{ns}	0.12^{ns}	0.46^{ns}	0.56^{ns}	0.40^{ns}	0.22^{ns}	0.88^{ns}	0.72^{ns}
S x D	0.52^{ns}	0.519^{ns}	0.93^{ns}	0.81^{ns}	0.14^{ns}	0.56^{ns}	0.69^{ns}	0.22^{ns}	0.84^{ns}	0.58^{ns}
C.V 2 (%)	45.68	17.52	15.66	18.94	24.46	16.64	8.69	10.08	13.48	11.25
					10 – 20 cm layer					
Averages	5.22	74.0	1.70	1.03	34.0	0.21	9.20	34.1	21.5	1.38
F probability										
Systems (S)	0.06^{ns}	0.45^{ns}	0.58^{ns}	0.70^{ns}	0.75^{ns}	0.22^{ns}	0.12^{ns}	0.45^{ns}	0.86^{ns}	0.58^{ns}
Dose (D)	0.78^{ns}	0.41^{ns}	0.97^{ns}	0.91^{ns}	0.72^{ns}	0.21^{ns}	0.34^{ns}	0.28^{ns}	0.97^{ns}	0.52^{ns}
S x D	0.48^{ns}	0.67^{ns}	0.83^{ns}	0.94^{ns}	0.52^{ns}	0.21^{ns}	0.59^{ns}	0.40^{ns}	0.29^{ns}	0.56^{ns}
C.V 1 (%)	13.37	27.13	67.11	53.38	57.95	18.39	5.31	15.40	15.42	21.67
C.V 2 (%)	32.00	21.84	24.36	24.17	32.69	12.40	6.26	7.42	18.69	30.96

*and ns are, respectively, significant at 5%, and not significant by the F test. Means followed by the same letter in the column are not different from each other at the 5% probability level by the test of Tukey. C.V: Coefficient of variation.

CONCLUSIONS

The production systems and P rates did not affect the physiological parameters evaluated in the V4 vegetative stage or corn productivity.

The hypothesis of the present study was not met, since P doses increase O.M., C and P in the 0-10 cm layer regardless of the production system.

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