Organomineral fertilization effects on the agronomic performance of corn cultivars grown in monoculture and intercropped with *Urochloa ruziziensis*

Adubação organomineral no desempenho agronômico de cultivares de milho cultivadas em monocultura e consorciadas com *Urochloa ruziziensis*

Alan Mario Zuffo[1,*], Gabriel Coutinho de Sousa[1], Francisco Charles dos Santos Silva[1], Rafael Felippe Ratke[2], Augusto Matias de Oliveira[3], June Faria Scherrer Menezes[3], Tatiane Scilewski da Costa Zanatta[1], Jorge González Aguilera[4], Fábio Steiner[4] & Emilio Veitía Candó[5]

[1] State University of Maranhão (UEMA). Department of Agronomy, Balsas Campus, Balsas, MA, Brazil
[2] Department of Agronomy, Federal University of Mato Grosso do Sul, Chapadão do Sul Campus, Av. Engenheiro Douglas Ribeiro Pantaleão s/n Zona Rural, Chapadão do Sul 79560-000, Mato Grosso do Sul, Brazil
[3] University of Rio Verde (UniRV), Postgraduate Program in Plant Production, Rio Verde, Goiás, Brazil
[4] Department of Crop Science, State University of Mato Grosso do Sul, Cassilândia 79540-000, MS, Brazil
[5] Solar Energy Research Center, Santiago de Cuba 90400, Cuba

(*E-mail: alan_zuffo@hotmail.com)
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A B S T R A C T

Efficient management of phosphate fertilization with organomineral sources can increase the technical viability of integrated production systems. Therefore, this study aimed to evaluate the agronomic performance of corn (*Zea mays* L.) cultivars in monoculture and intercropped with *Urochloa ruziziensis* (Syn. *Brachiaria ruziziensis*) in response to phosphorus fertilizer sources. The experiment was conducted in a randomized block design in a split-subsplit-plot arrangement, with three replications. The main plot consisted of the two corn cropping systems (single and intercropped); the split-plot represented the two corn cultivars (FS 564 PWU and NK 555 VIP3); the split-split-plots consisted of the application of three phosphate sources [two organomineral fertilizers (OMF1 and OMF2) and one mineral fertilizer (single superphosphate – SSP)] and a non-fertilized treatment with phosphate (control). All phosphate fertilizers were applied at a dosage of 50 kg ha^{-1} of P_2O_5. During the physiological maturity phase, the production components of the corn ear and grain yield were evaluated. The data were subjected to principal component analysis, GGE biplot, and correlation. The corn–*U. ruziziensis* intercropping system increased yield stability and enhanced the response to phosphate fertilization. Organomineral sources showed efficacy equivalent to that of single superphosphate. The NK 555 VIP3 cultivar presented the greatest yield potential, whereas FS 564 PWU demonstrated greater phenotypic stability. The grain yield was positively correlated with the relative chlorophyll index (RCI) and primary ear components. The RCI was strongly correlated with the number of rows per ear, the number of grains per row, and the ear diameter. Organomineral fertilization associated with the intercropping system in responsive cultivars constitutes an efficient strategy to maximize corn yield and sustainability.

Keywords: Cropping system, Fertilizers, Phosphorus, *Zea mays* L.

R E S U M O

O manejo eficiente da adubação fosfatada com fontes organominerais pode aumentar a viabilidade técnica de sistemas integrados de produção. Portanto, este estudo teve como objetivo avaliar o desempenho agronômico de cultivares de milho (*Zea mays* L.) em monocultura e consorciado com *Urochloa ruziziensis* (Sin. *Brachiaria ruziziensis*) em resposta a aplicação de fontes de fertilizante fosfatado. O experimento foi conduzido em delineamento de blocos casualizados em esquema de parcelas sub-subdivididas, com três repetições. As parcelas principais consistiram de dois sistemas de cultivo do milho (monocultura e consorciado); as subparcelas consistiram de duas cultivares de milho (FS 564 PWU e

NK 555 VIP3); as sub-subparcelas consistiram da aplicação de três fontes de fosfato (dois fertilizantes organominerais e um fertilizante mineral (superfosfato simples) e um tratamento não fertilizado com fósforo. Todos os fertilizantes fosfatados foram aplicados na dosagem de 50 kg ha^{-1} de P_2O_5. Durante a fase de maturação fisiológica, os componentes morfológicos e fenométricos da espiga e a produtividade de grãos foram avaliados. Os dados foram submetidos à análise de componentes principais, biplot GGE e correlação. O sistema de consórcio milho-*U. ruziziensis* aumentou a estabilidade da produtividade e melhorou a resposta à fertilização. As fontes organominerais mostraram eficácia equivalente à do superfosfato simples. A cultivar NK 555 VIP3 apresentou o maior potencial de produtividade, enquanto a FS 564 PWU demonstrou maior estabilidade fenotípica. A produtividade apresentou correlação positiva com o índice de clorofila relativa (ICR) e com os componentes primários da espiga. O ICR apresentou forte correlação com o número de fileiras por espiga, o número de grãos por fileira e o diâmetro da espiga. A fertilização organomineral associada ao sistema de consórcio em cultivares responsivos constituem uma estratégia eficiente para maximizar a produtividade e a sustentabilidade do milho.

Palavras-chave: Sistema de cultivo, Fertilizantes, Fósforo, *Zea mays* L.

INTRODUCTION

Corn (*Zea mays* L.) is among the main agricultural crops in Brazil and worldwide and plays a fundamental role in food security, animal feed production, and as a raw material for industrial sectors (Jiao *et al*., 2022; Moritz *et al*., 2025). In tropical agricultural systems, the search for greater efficiency in the use of inputs and sustainability has driven the adoption of practices such as intercropping with forage crops. In Brazilian agriculture, the corn–*Urochloa ruziziensis* (Syn. *Brachiaria ruziziensis*) intercropping system is the most commonly used (Souza *et al.*, 2024).

Intercropping corn with forage crops represents an important innovation for sustainable agriculture in tropical regions and provides significant agronomic benefits, such as increased soil cover; increased productivity; nutrient cycling; increased organic matter; and improved soil physical, chemical, and biological soil properties (Liu *et al*., 2024; Nasar *et al*., 2024). However, this system can increase competition for resources, especially nutrients (Wu *et al*., 2023), requiring more efficient management strategies, particularly the use of fertilizers that promote greater availability and utilization of nutrients by plants (Khuong *et al*., 2026; Simão *et al*., 2026).

In this scenario, organomineral fertilizers have gained importance because they combine mineral sources with organic compounds, contributing to the gradual release of nutrients, a reduction in losses due to leaching, and an improvement in agronomic efficiency (Pereira *et al*., 2022; Xing *et al*., 2025; Aguilera *et al*., 2026). Furthermore, organomineral fertilizers use potentially polluting sources as raw materials, such as agricultural waste (Vieira *et al*., 2023; de Lima *et al*., 2026). In particular, phosphate fertilization is among the main limiting factors for corn productivity in highly weathered tropical soils, where phosphorus is not readily available because it is fixed in poorly soluble forms (Silva *et al*., 2024; Khuong *et al*., 2026).

Furthermore, the response to fertilization can vary depending on the genetic material used, with corn cultivars differing in nutrient use efficiency (Haegele *et al*., 2013; Hu *et al*., 2021; de Lima *et al*., 2026) and adaptation to intercropping systems. Therefore, understanding the interactions among cropping systems (monoculture and intercropping), cultivars, and organomineral fertilizers sources is necessary to optimize the agronomic performance of corn crops (Ye *et al*., 2026). Studies evaluating more efficient management practices, such as the use of organomineral fertilizers in intercropping systems, contribute to the development of sustainable agriculture, aligning with the global guidelines for responsible production, food security, and the conservation of natural resources proposed by the United Nations, especially within the framework of the Sustainable Development Goals.

Thus, the objective of this study was to evaluate the agronomic characteristics of corn cultivars grown in monoculture and intercropped with *Urochloa ruziziensis* in response to application of phosphorus fertilizer sources.

MATERIALS AND METHODS

Location and characterization of the experiment

The experiments were conducted under field conditions at Pequizeiro Farm, belonging to the Experimental Station of the company Accert Pesquisa e Consultoria Agronômica, located in the municipality of Balsas, Maranhão, Brazil (07°31′57″ S, 46°02′08″ W; mean altitude of 283 m), during the 2022/2023 and 2023/2024 agricultural seasons. The region's climate, according to the Köppen–Geiger classification, is hot and humid tropical (Aw) and characterized by a rainy summer and a dry winter (Peel *et al.*, 2007). The climatic conditions observed during the experimental period, as well as historical data from 1991 to 2020, are presented in Figure 1.

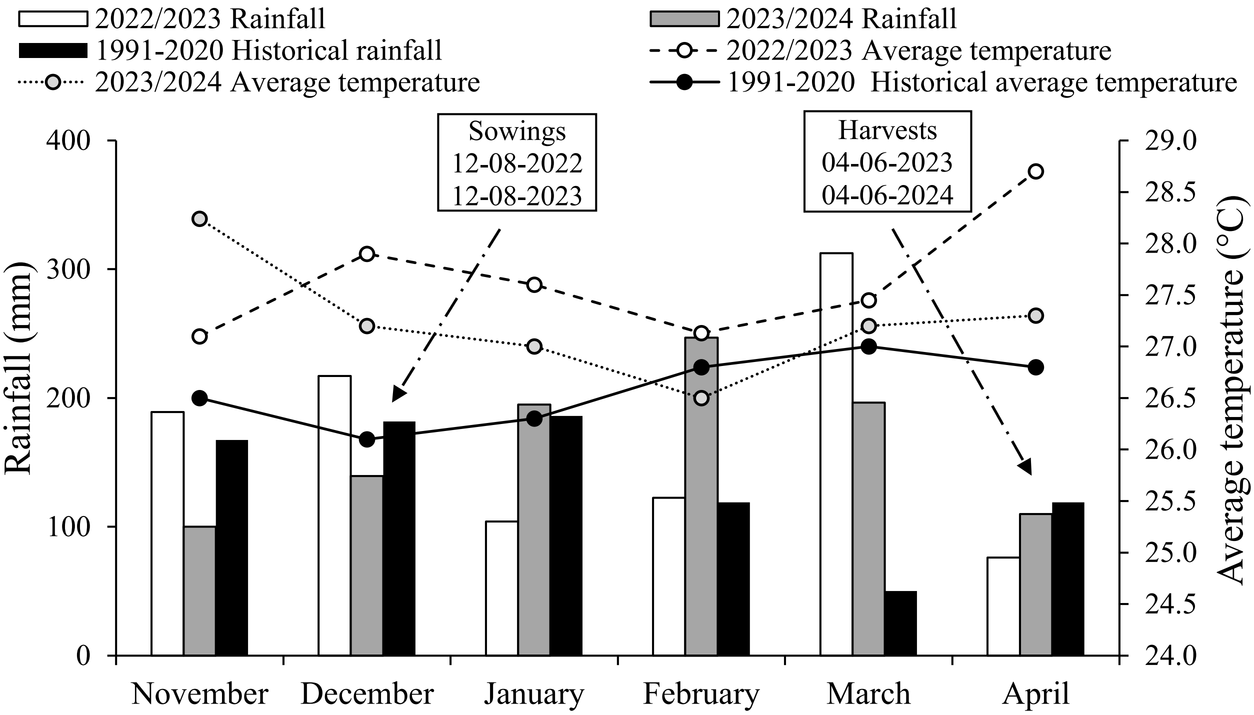

Figure 1 - Monthly accumulated rainfall and monthly mean air temperature during the experimental period in the 2022/2023 and 2023/2024 growing seasons, as well as the historical average (1991–2020), in Balsas, Maranhão State, Brazil. Source: National Institute of Meteorology (2024).

Table 1 - Main chemical properties of the soil from the experimental field

Agricultural season	Depth cm	pH	OM	$P_{Mehlich-1}$	H+Al	Al^{3+}	Ca^{2+}	Mg^{2+}	K^{+}	CEC	V
		H_2O	dag kg^{-1}	mg dm^{-3}		---------- cmol $_c$ dm $^{-3}$ ----------					%
2022/2023	0-20	6.00	1.29	54.95	1.20	0.01	2.15	0.71	0.35	4.41	72.78
2023/2024		5.92	1.57	45.71	1.58	0.01	3.39	1.04	0.15	6.16	74.34
2022/2023	20-40	4.65	0.23	20.72	1.80	0.54	0.95	0.30	0.18	3.23	44.26
2023/2024		5.03	1.07	30.24	1.76	0.37	1.81	0.49	0.29	4.35	59.58
		B	**Cu**	**Fe**	**Mn**	**Zn**	**S**	**TOC**	**Clay**	**Silt**	**Sand**
		---------- mg dm^{-3} ----------						dag kg $^{-1}$	---------- g kg $^{-1}$ ----------		
2022/2023	0-20	0.22	0.44	113.21	14.28	0.73	6.30	0.75	242.4	92.6	664.9
2023/2024		0.18	0.24	20.52	11.51	0.37	19.32	0.62	-	-	-
2022/2023	20-40	0.23	0.40	81.98	4.25	0.37	12.60	0.13	-	-	-
2023/2024		0.18	0.24	20.52	11.51	0.37	19.32	0.62			

Abbreviations: OM: organic matter. CEC: cation exchange capacity at pH 7.0. V: soil base saturation. TOC: total organic carbon.

The soil in the experimental area was classified as sandy-textured yellow latosol according to the Brazilian Soil Classification System (Santos *et al*., 2018). Before the experiments were conducted, soil samples were collected from the 0–20 and 20–40 cm depth layers, after which their chemical and physical properties were determined (Table 1).

EXPERIMENTAL DESIGN AND TREATMENTS

The experimental design used was a randomized block design, arranged in a split-split-plot scheme, with three replications. In the plots, the treatments consisted of two corn cropping systems (corn grown alone (monoculture) and corn intercropped with *Urochloa ruziziensis*), in the split-plots, two corn cultivars were sown (Cultivar 1: FS 564 PWU; Cultivar 2: NK 555 VIP3); and, in the split-split-plots,, three phosphate fertilizers sources were applied [two manufactured organomineral fertilizers (ORF1 - bovine manure + reactive natural phosphate, with 11.43% P_2O_5 and ORF 2 - bovine manure + natural phosphate + single superphosphate, with 12.26% P_2O_5), and one mineral fertilizer (single superphosphate with 18% P_2O_5)] and a non-fertilized treatment with phosphate (control). All phosphate fertilizers were applied at a dosage of 50 kg ha^{-1} of P_2O_5. The doses of phosphate fertilizers used in the experiments, as well as the quantities applied per plot, are presented in Table 2. Each experimental unit consisted of four rows spaced 0.50 m apart and 3.0 m long, totalizing an area of 6.0 m². The useful area was considered to be the two central rows, disregarding 1 m at each end, resulting in an area of 1.5 m².

Table 2 - Sources and doses of phosphate fertilizers applied in field experiments

Source of phosphorus	Phosphorus content of the fertilizer (% P_2O_5)	Fertilizer dose applied (kg ha^{-1})	Amount of fertilizer applied to the split-split-plots (g in 6 m²)
OMF1	11.43	437.45	262.47
OMF2	12.26	407.83	244.70
SSP	18.00	277.78	166.67
Control	0.00	0	0

Abbreviations: OMF1: organomineral 1; OMF2: organomineral 2; SSP: simple superphosphate.

Implementation, fertilization and experimental procedures

Urochloa ruziziensis was sown before the corn crop by broadcasting and manually. A total of 4.5 kg ha^{-1} of 70% pure viable seeds was used, as recommended by Ceccon *et al.* (2018). The corn was mechanically sown using a seed drill with a furrow opener (knife) mechanism for no-till farming at a depth of approximately 3 cm, with a spacing of 0.50 m and three corn seeds per meter, to achieve a final stand of 55,000–60,000 plants per hectare. Both sowings were carried out on December 8, 2022. Base fertilization consisted only of the application of P sources (organomineral and superphosphate) in the sowing furrow. Corn seeds were previously treated with 70 g ha^{-1} of cyantraniliprole + 70 g ha^{-1} + 0.6, 4.5 and 0.75 g ha^{-1} of metalaxyl-M + thiabendazole + fludioxonil.

Weed control was carried out 20 days after the emergence (DAE) of the corn plants, using 1.5 L ha^{-1} of the herbicide atrazine. To retard the growth of *Urochloa ruziziensis* plants, nicosulfuron was applied at a dosage of 8 g ai ha^{-1}, as recommended by Ceccon *et al.* (2018). To spray both herbicides, 0.5% mineral oil (v/v) was also added.

At 30 DAE of corn plants (V4 - four fully expanded leaves), 140 kg ha^{-1} of N and 60 kg ha^{-1} of K_2O were applied, using urea and potassium chloride as sources, respectively. The insecticides methomyl and acetamiprid + bifenthrin were also applied at doses of 129 and 30 + 30 g ha^{-1}, respectively. Corn fertilization was carried out according to the nutritional requirements of the species and the chemical analysis of the soil, aiming for the highest yield potential, as recommended by Sousa and Lobato (2004). The nitrogen (N), potassium (K), and phosphorus (P) sources for the corn were urea (45% N), potassium chloride (60% K_2O), and P_2O_5 (these were the treatments).

Variables evaluated

In the silking stage (R1 stage), after the female inflorescence emerged, the relative chlorophyll index (RCI) in the corn leaves was measured using a portable chlorophyll meter (model Falker CFL 1030; Falker, Porto Alegre, RS), as recommended by Costa *et al.* (2012).

When the crop reached physiological maturity, the following variables were evaluated: plant height (cm), which was determined from the soil surface to the insertion of the last leaf using a graduated ruler, and ear insertion height (cm), which was determined from the soil surface to the insertion of the first ear. Ear length, number of rows per ear, number of grains per row, and ear diameter were subsequently determined. Manual harvesting of the corn and mechanical threshing with the aid of a plot thresher were performed to evaluate the production components and grain yield (useful area of the plot). The harvesting was carried out in the useful area, the ears were mechanically threshed, and the production was converted to kg ha^{-1} of grain, standardized to 13% moisture. Afterward, the mass of one thousand grains (g) was measured according to the methodology described in Brazil (2009).

Statistical analysis

Principal component analysis (PCA) was performed on the basis of the correlation matrix of the normalized data. The GGE biplot model used is $Yij - yj = y1\ \varepsilon i1 \varrho j1 + y2\ \varepsilon i2 \varrho j2 + \varepsilon ij$, where Yij represents the agronomic characteristics of genotype *i* in environment j; yj is the overall mean of all genotypes in environment j; $y1\ \varepsilon i1 \varrho j1$ corresponds to the first principal component (PC1); $y2\ \varepsilon i2 \varrho j2$ represents the second principal component (PC2); and y1 and y2 are the eigenvalues associated with the first and second principal components (PCA1 and PCA2, respectively). In this model, ε1 and ε2 are the PC1 and PC2 values for genotype i, respectively, while $\varrho j1$ and $\varrho j2$ are the corresponding values for environment j. Finally, εij represents the error associated with the *i-th* genotype in the *j-th* environment (Yan & Rajcan, 2002).

All analyses were performed using the statistical software R (R Core Team, 2024; v. 4.4.1) with the following packages: dplyr (Wickham *et al.*, 2023) for data manipulation and aggregation; MASS (Venables & Ripley, 2002) for Box–Cox transformations in linear models; lme4 (Bates *et al.*, 2015) for mixed modeling; agricolae (Mendiburu, 2023); and functions from the utils and base packages. For GGE biplot analysis, graphical outputs, and other analyses, additional functions from the GGEBiplot, statistics, and graphics packages were used. For scatterplot analysis containing Pearson correlations, the GGally package (Schloerke *et al.*, 2021) was used.

Canonical variable analysis was used to study the interrelationship between sets (vectors) of independent variables (cropping system, corn cultivars, and organomineral supplements) and dependent variables (agronomic characteristics) (Viçosa, MG, BRA). A scatterplot containing the Pearson correlations between the evaluated traits and their distributions was subsequently constructed. All analyses were performed using Rbio software version 140 for Windows (Rbio Software, UFV, Viçosa, MG, BRA).

RESULTS AND DISCUSSION

Principal component analysis (PCA) explained 79.6% of the total variance in the data, with 65.9% and 13.7% attributed to PC1 and PC2, respectively (Figure 2). PC1 clearly differed between the growing seasons, indicating a strong influence of environmental conditions on the agronomic performance of the cultivars and their response to phosphate fertilization (Figure 2). Compared with the 2023/2024 growing season, the 2022/2023 growing season had higher accumulated rainfall (Figure 1). Additionally, a distinction was observed between the cropping systems, demonstrating that intercropping with *Urochloa ruziziensis* was decisive in discriminating the treatments. In the 2022/2023 growing season, greater dispersion of treatments was observed, suggesting variability in the response to P sources. In contrast, in the 2023/2024 growing season, the treatments showed greater clustering and association with the agronomic performance variables (Figure 2).

The grain yield (GY) and thousand-grain weight (M1000) were strongly correlated with the NK555 VIP3 cultivar and with the treatments that received fertilization (SS, OM1, and OM2) (Figure 2). The GY vector tended toward the upper right quadrant, indicating higher yields during this period. In parallel, the ear morphology components, such as the number of rows per ear (NRE), number of grains per row (NGR), and ear diameter (ED), in addition to the relative chlorophyll index (RCI),

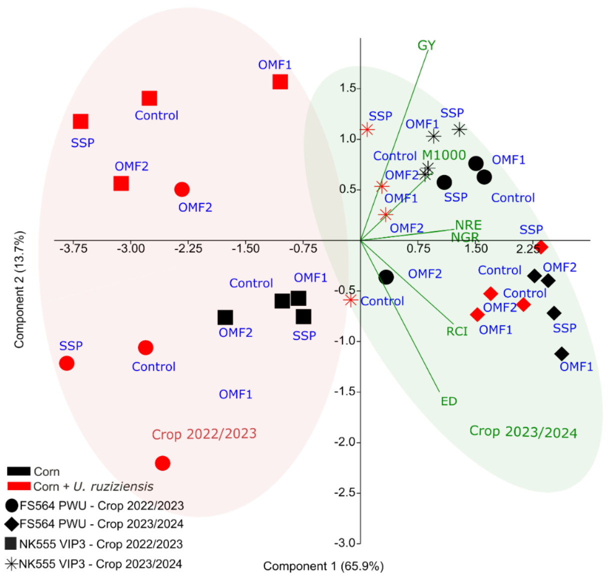

Figure 2 - Principal component analysis (PCA) of the agronomic traits of maize crops in response to cropping system (corn monoculture and corn intercropped with *Urochloa ruziziensis*) and phosphorus source (single superphosphate - SS, organomineral 1 – OMF1 and organomineral 2 – OMF2) and control (without phosphate fertilization). Abbreviations: RCI: relative chlorophyll index, NRE: number of rows per ear, NGR: number of grains per row, ED: ear diameter, M1000: thousand grain mass and GY: grain yield.

showed vectors with similar directions, demonstrating greater affinity with the FS564 PWU cultivar in the 2023/2024 crop season, regardless of the cropping system (Figure 2). The appropriate choice of genetic material influences the response to fertilization management, enhancing the efficiency of nutrient use in the intercropping system (Demie *et al.*, 2022).

The results of the intercropping treatments were more similar to those of the vectors associated with GY and production components, suggesting potential gains in productive efficiency in this system. Under these conditions, the organomineral sources (OM1 and OM2) and single superphosphate (SS) showed similar behavior, with a consistent association with the agronomic variables (Figure 2). This behavior may be related to the greater nutrient cycling promoted by *Urochloa ruziziensis*, as well as the improvement of the chemical, physical, and biological characteristics of the soil, which can increase the availability of P throughout the crop cycle.

On the other hand, in the monoculture systems, a greater dispersion of treatments was observed, especially in the control, indicating lower performance in the absence of fertilization and highlighting the responsiveness of the soils to phosphate fertilization (Figure 2). The magnitude and pattern of these responses varied according to the production system and cultivar. Notably, the behavior of organomineral sources is dependent on the cropping system. In the intercropping system, these fertilizers clustered in regions associated with better agronomic responses, whereas in the monoculture system, the distribution was heterogeneous. This pattern corroborates the effectiveness of organomineral fertilizers in maintaining cultivar performance, equaling the conventional mineral source (SS), and indicates that corn–*U. ruziziensis* intercropping can enhance the effects of these types of fertilization, contributing to greater productive stability. Similar results were obtained by Grohskopf *et al.* (2019), who highlighted the advantage of organomineral fertilizers in corn nutritional management, surpassing mineral control, with a relative increase in agronomic efficiency of 20%.

The GGE biplot analysis for the 2022/2023 crop season explained 100% of the total variance (Axis 1: 91.4%; Axis 2: 8.6%), indicating the high reliability of the interpretation of the cultivar ranking (Figure 3A). The NK555 VIP3 cultivar was positioned to the right of the origin of the AEC axis, showing the highest average performance compared to the FS564 PWU cultivar. However, its greater distance from the horizontal axis indicates lower phenotypic stability, suggesting a specific response to variations in growing environments. The FS564 PWU cultivar, on the other hand, was located to the left of the overall average (Figure 3A), characterized by inferior agronomic performance during that crop season.

With respect to the characterization of the environments, as represented by the combinations of cropping systems and phosphorus sources, all the treatments conducted in the intercropping system (corn + *Urochloa ruziziensis*) were positioned on the right side of the biplot (Figure 3A), indicating that

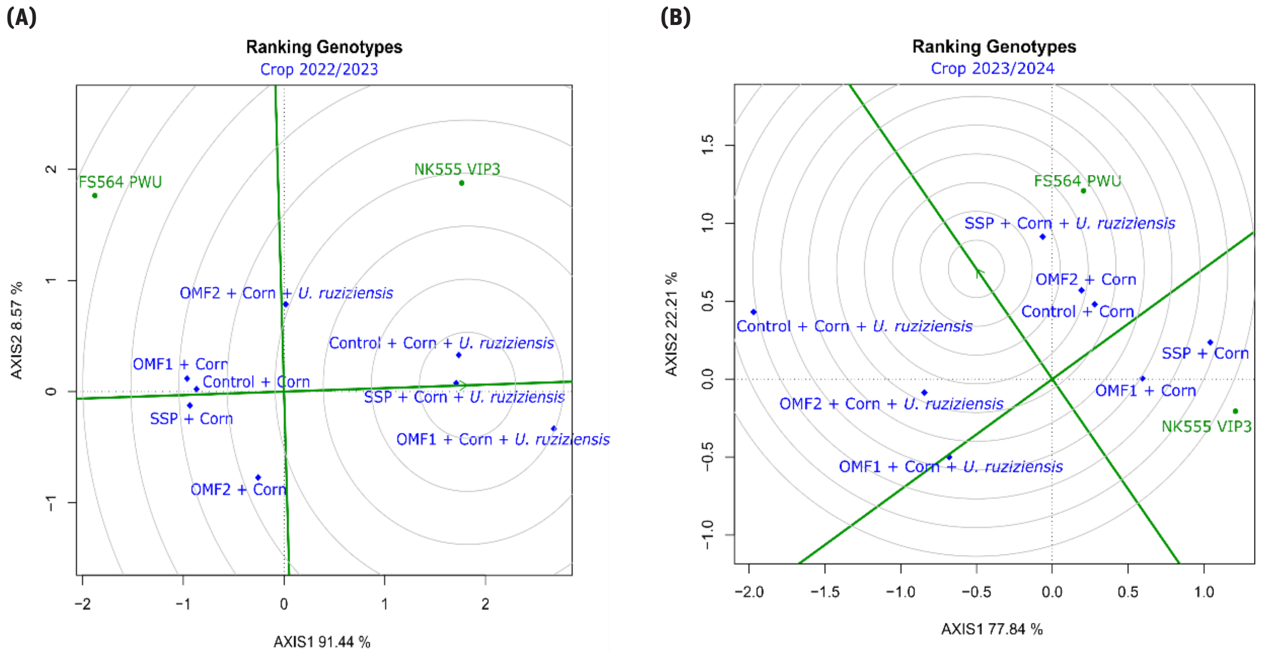

Figure 3 - GGE biplot illustrates the ranking and stability of maize cultivars in response to phosphorus sources and cropping system in the 2022/2023 (A) and 2023/2024 (B) growing seasons.

these treatments were associated with the cultivar with the greatest productive performance (NK555 VIP3). Notably, the treatments involving single superphosphate (SSP) and organomineral phosphate (OMF1) in the intercropping system, as well as the control treatment (non-fertilized with phosphorus), were located closer to the ideal genotype (center of the concentric circles). This positioning indicates that these combinations provided more favorable environments for the performance of the cultivars, suggesting that the interaction between phosphorus sources (especially SSP and OMF1) and the intercropping system enhances the productive expression of corn.

On the other hand, the monoculture treatments (corn) clustered to the left of the vertical axis (Figure 3A). These findings indicate that, regardless of the P source used (OMF1 and OMF2 or SSP), monoculture resulted in lower average yields than those observed in the intercropping system did. These results suggest that the cropping system had a decisive environmental effect on the 2022/2023 crop season, with intercropping with *U. ruziziensis* being the management strategy that allowed for greater expression of the productive potential of the cultivars, especially when associated with more soluble (SSP) or organomineral P sources.

For the 2023/2024 crop season (Figure 3B), a reversal in the behavior of the cultivars and a more complex interaction between treatments were observed. The GGE biplot in this crop season explains 100% of the total variance (77.8% on Axis 1 and 22.2% on Axis 2), ensuring maximum precision in the interpretation. In the 2023/2024 crop season, the GGE biplot analysis revealed a change in the ranking of the cultivars compared with the previous cycle. The NK555 VIP3 cultivar remained positioned to the right of the environmental average, reaffirming its higher average yield potential (Figure 3B). However, the FS564 PWU cultivar significantly approached the ideal genotype, being more in the center of the concentric circles, showing a superior balance between performance and phenotypic stability in the 2023/2024 crop season.

Unlike the previous crop season, the environments (treatments) were more dispersed among the quadrants, indicating that the response of the cultivars was more dependent on the specific combination of P source and cropping system. The SSP + Corn + *U. ruziziensis* treatment stood out again for its proximity to the ideal genotype and to the FS564 PWU cultivar, suggesting that the use of SSP in the intercropping system promoted a more favorable and stable environment (Figure 3B).

Notably, monoculture treatments with mineral sources (SSP) and organomineral sources (OMF1) shifted to the lower right quadrant, indicating a strong association with the NK555 VIP3 cultivar. (Figure 3B). This finding indicates that during this crop season, the aforementioned cultivar responded more significantly to phosphate fertilization when it was grown in a monoculture system or had specific sources.

On the other hand, the treatments in combination with organomineral fertilizers (OMF1 + Corn + *U. ruziziensis* and OMF2 + Corn + *U. ruziziensis*) are located on the left quadrant and are associated with lower average performance for the variables analyzed in this cycle (Figure 3B). The control treatment + Corn + *U. ruziziensis* presented the greatest outlier performance, positioning itself at the opposite end to the vectors of higher productivity.

In summary, the results of the 2023/2024 crop season demonstrate that, although NK555 VIP3 has a higher yield potential, FS564 PWU was more stable under intercropping and mineral fertilization conditions (Figure 3B). This highlights the importance of choosing the genotype according to the technological level and production system adopted.

The variation in cultivar behavior between harvests strongly correlated with genotype, environment, and management. In the 2022/2023 harvest, the intercropping system favored productive performance; however, in the 2023/2024 harvest, greater variability was observed between treatments, with responses dependent on the combination of P source and cropping system. These results indicate that the efficiency of organomineral fertilizers and the intercropping system depends on environmental factors, such as the water regime and the P dynamics in the soil. The addition of organic matter contributes to greater water retention in the fertilizer application area, prolonging soil moisture and promoting the diffusion of P in the soil solution, which increases its flow toward the roots (Crusciol *et al.*, 2020).

Pearson correlation analysis revealed positive and significant associations between all the evaluated agronomic variables, indicating synergy between the production components and the final yield (Figure 4). The grain yield (GY) was positively correlated with all the parameters, with a particular emphasis on the associations with the number of rows per ear (NRE; r = 0.418***) and the number of grains per row (NGR; r = 0.362***).

The thousand-grain weight (TGW) was also significantly correlated with productivity (r = 0.340***), confirming that grain filling is a determining component of the productive success of the evaluated cultivars. Furthermore, the relative chlorophyll index (RCI), although it had the lowest correlation with GY (r = 0.266**), correlated strongly with the primary components of the ear, such as NRE (r = 0.664***), NGR (r = 0.636***) and ear diameter (ED; r = 0.693***).

These strong correlations between the RCI and ear components suggest that the nutritional status of the plants and their photosynthetic capacity during the initial phenological and flowering stages are fundamental for defining the productive potential (number of rows and grains). Ear diameter (ED) was strongly dependent on NRE (r = 0.543***),

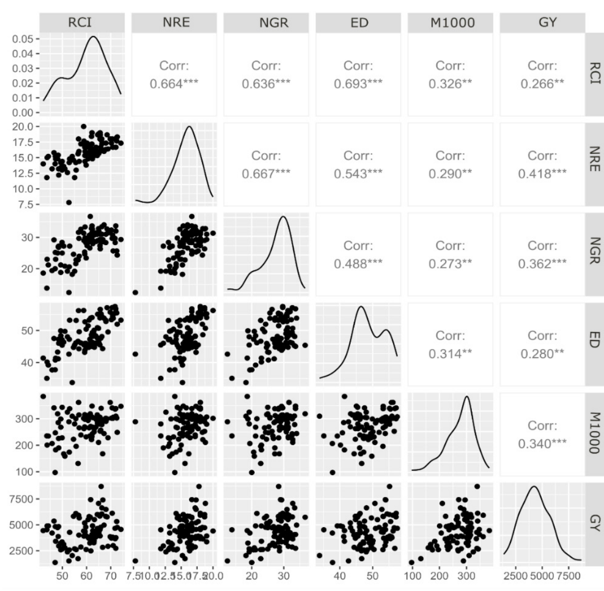

Figure 4 - Scatterplot illustrating the Pearson correlations between the agronomic traits. Abbreviations: RCI: relative chlorophyll index; NRE: number of rows per ear; NGR: number of grains per row; ED: ear diameter; M1000: thousand grain weight; GY: grain yield. The values presented correspond to the Pearson correlation coefficients (r), with *** and ** being significant at 1% and 5% probability, respectively.

which is morphologically expected, since more vigorous ears tend to support a greater number of grain rows.

In general, the strong interdependence observed between the morphological variables (NRE, NGR, and ED) and grain productivity reinforces that the management adopted, including organomineral fertilization and the intercropping system, acted in an integrated way to improve yield components, culminating in increases in final grain productivity.

The combined analysis of the data revealed that the dispersion observed in the lower strata according to the Pearson correlations (Figure 4) is related to fertility management and the cropping system. The minimum values of the productivity and ear components coincide with those of the low-performance regions identified in the PCA (Figure 2) and the GGE biplot (Figure 3), corresponding mainly to the control treatment and the monoculture system in the 2022/2023 crop season. This pattern reinforces that the absence of phosphate fertilization, combined with the lower complexity of the single-crop system, limits the expression of the productive potential of the cultivars, resulting in lower chlorophyll accumulation (RCI) and a drastic reduction in the number of rows (NRE) and grains per ear (NGR).

CONCLUSIONS

Corn intercropped with *Urochloa ruziziensis* has greater yield stability than monoculture systems; however, its effects on grain yield depend on environmental conditions and interactions with the phosphorus source used. Organomineral fertilizers perform similarly to single superphosphate, representing a viable alternative source for tropical corn cultivation.

The NK555 VIP3 cultivar presented greater yield potential, whereas the FS564 PWU cultivar demonstrated greater stability, highlighting genotypic differences in response to management. Therefore, adopting genotypes responsive to intercropping, combined with the use of organomineral fertilizers, constitutes an efficient strategy to optimize corn crop productivity.

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