

PHOSPHORUS FERTILIZATION AND CROPPING SYSTEM EFFECTS ON BIOMASS AND NUTRIENT DYNAMICS IN MAIZE–COWPEA INTERCROPPING

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ABSTRACT

Maize–cowpea intercropping has been widely advocated as a strategy to enhance resource-use efficiency in low-input systems, but the magnitude of the effect of phosphorus supply on biomass production and nutrient partitioning is context dependent. Four rates of P (0, 50, 100 and 150 kg P ha⁻¹) and three cropping systems (sole maize, sole cowpea, and intercropping maize with cowpea in a split plot randomized complete block design with three replications) were used in this study. Most of the effects of phosphorus application were minimal for stover dry matter and for most macro and micron nutrient concentrations while cropping system significantly affected biomass production and tissue nutrient composition. Maize generally did not accumulate as high concentrations of several macronutrients as did intercropped cowpea which produced the highest dry matter. Phosphorus concentration increased gradually with increasing P rate in cowpea seed, and peaked at 150 kg P ha⁻¹; the same was true for Mg that responded significantly to fertilization. The sole cropped cowpea seeds had higher P, K, Ca and Mg concentrations compared to intercropped seeds while Cu concentration in intercropped seeds was higher than that of sole cropping. Positive correlations between seed P and Mg, K and Ca and negative correlation between seed P and Fe, Cu and Mo were found by the correlation analysis. In general, cropping arrangement had more impact than phosphorus rate on biomass production and nutrition, which further emphasizes the need to consider the crop configuration along with the phosphorus rate in low-fertility environments.

KEYWORDS: maize–cowpea intercropping; phosphorus fertilization; nutrient partitioning; biomass production; seed mineral composition

1. INTRODUCTION

Maize–cowpea intercropping, which is gaining more attention, has been demonstrated to be an effective approach to enhance resource-use efficiency, crop productivity and resilience in low-input and nutrient-constrained farming systems. Maize is a cereal that requires a high level of nutrients while cowpea is a legume with biological nitrogen fixation and can help to enhance nutrient cycling in diversified cropping systems. These crops, when grown together, utilize soil, root volume, nutrients and light more efficiently than do individual crops grown alone. Cereal–legume intercropping has been proven to improve PUE by complementing the way in which resources are acquired by the two plant species (Tang et al. 2021). Namatsheve et al. (2021) also showed the capacity of maize–cowpea intercropping to enhance productivity, biological N₂ fixation and mineral content of grain in low input farming systems.

One of the most limiting nutrients for crop production in many tropical and subtropical soils is the availability of phosphorus, as it is highly fixed by the soil minerals. The deficiency of phosphorus may inhibit root growth, energy transfer, photosynthetic production, reproductive growth, and final biomass and yield formation. It is especially significant in leguminous systems due to the need for biological nitrogen fixation to have sufficient phosphorus. The efficiency of applied P acquisition and utilization, however, is very variable among crop species and cropping systems. Under nutrient limited conditions, interspecific interactions may lead to enhanced P acquisition as found by Tang et al. (2021) for cereal–legume intercropping.

The rhizosphere processes are important to consider in the acquisition of nutrients in intercropping systems. Multiple species of crops can alter root distribution, rhizosphere chemistry, microbial activity and nutrient mobilization. Under intercropping, N and P uptake and thus maize yield was positively affected by interspecific interactions in the rhizosphere by Schwerdtner and Spohn (2022). Intercropping also altered the soil P composition and microbially mediated P dynamics which were favourable to maize P uptake and productivity as reported by Yang et al. (2022). The results indicate that the positive effect of intercropping is not only spatial complements but also some biological and biochemical mechanisms which enhance the nutrient availability.

Maize–cowpea associations are of specific relevance to the smallholder agriculture because it is a combination of a nutrient demanding cereal with nitrogen fixing legume. This mix can enhance system productivity and soil nutrient cycling and quality. Namatsheve et al. (2021) showed that biological N₂ fixation and also enrichment of maize grains by intercropping with cowpea under low-input systems was effective in enhancing productivity. Intercropping the maize–cowpea combination also improved land use efficiency and economic return as reported

by Akter Suhi et al. (2022), suggesting the benefits of intercropping with maize-cowpea could go beyond increased biological output to more efficient use of the resources available on the farm.

Nutrient management however plays a significant role in determining the performance of maize-cowpea intercropping. Competitive and complementary interactions among component crops can be changed by availability of fertilizers, nutrient balance and soil fertility status. Roohi et al. (2022) demonstrated how the fertilization regime influenced the yield in maize-cowpea intercropping grown on low-fertility soils and the capacity for C sequestration by the soil. Similarly, Yadav et al. (2022) found that use of integrated nutrient management increased the productivity and quality of the fodder in maize-cowpea system. These results highlight the importance of the nutrient input as a whole, instead of handling it as a separate nutrient management factor when configuring crops.

Cowpea performance may also be directly affected due to phosphorus application. An adequate phosphorus supply will promote root growth, nodulation, energy metabolism and reproductive development with the extent of response varying due to genotypic and environmental differences. There was a significant variation in the response to P application between cowpea lines, as reported by Suzuki et al. (2022). This variation is significant especially when plants are grown in inter-crops where competition and facilitation are both present and can lead to changes in nutrient uptake and partitioning. Hence, understanding the effect of phosphorus supply on cropping arrangement is crucial for determining management practices to enhance nutrient acquisition while minimising the use of fertilisers.

Maize-cowpea systems can be further modified by other management factors. During the development of the crop, interspecific competition and availability of resources can change due to change in planting arrangement, crop proportion and timing of fertilizer application. Maize and forage cowpea intercropping performance under different intercropping patterns and nitrogen fertilizer scheduling was found to be influenced significantly by intercropping pattern and nitrogen fertilizer scheduling by Salama et al. (2022). The results show the responsiveness of cereal-legume systems to the spatial arrangement and nutrient-management practices.

Although cereal-legume intercropping technology is gaining momentum, little information is available regarding the effect of the various P application rates on biomass production and accumulation of both macro- and micronutrients in maize and cowpea under intercropping and sole cropping system in low-fertility soils. The response of dry matter production, cowpea seed yield and nutrient concentration of maize and cowpea to different levels of phosphorus application and cropping system was, therefore, investigated. Focus was paid to changes in nutrient accumulation as a result of cropping systems, and to associations between tissue phosphorus concentration and other macro- and micronutrients.

2. MATERIALS AND METHODS

2.1 Study Site and Initial Soil Characteristics

The field experiment was carried out at the Botswana University of Agriculture Farm, Sebele at 24°33' S and 25°57' E with an altitude of 994 m above sea level. The LMA annual precipitation at the site is around 538 mm with minimum and maximum monthly temperatures of 12.8°C and 26.6°C, respectively. The soil used in the experiments was a Luvisol and mainly comprised of coarse- and medium-textured sand in the surface horizon. Representative soil samples were taken and examined prior to establishment of the trial in order to determine the initial fertility of the site. The soil was slightly acidic (pH 4.92), low in organic carbon (0.24 %), exchangeable Ca (1.82 cmol kg⁻¹), Mg (1.82 cmol kg⁻¹), K (0.76 cmol kg⁻¹) and Na (0.34 cmol kg⁻¹), and had a relatively low P concentration (6.15 mg kg⁻¹); hence, the soil was generally poor in fertility.

2.2 Experimental Design and Crop Establishment

The experiment was laid out as split plot treatment structure with three replications of randomized complete block design. The main-plot treatments comprised of four phosphorus applications, 0, 50, 100 and 150 kg P ha⁻¹, using single superphosphate as the P source. The sub-plot factor included three cropping systems: sole maize, sole cowpea and intercropping maize and cowpea. The test maize varieties were Kalahari Early Pearl (KEP) and the local cowpea landrace Tswana, mogweokgotsheng.

A total of 36 plots (3 m × 2 m) were set up. Two weeks before planting, phosphorus fertilizer was applied as basal treatment and applied evenly to the respective plots. The inter-row spacing was 45 cm and intra-row spacing was 30 cm, which resulted in an estimated plant population of 74,000 plants ha⁻¹. For intercropping, the maize was planted with cowpea in alternating rows. As needed during the growing season, standard practice for crop management was followed, such as weeding, irrigating to field capacity, and handling pests.

2.3 Sampling, Yield Determination, and Nutrient Analysis

Three plants were randomly sampled from the inner three rows of each plot in each replication at crop maturity. Seeds of cowpea were threshed and weighed by using electronic balance. After adding up seed mass from the plants sampled, the mean seed mass per plant was calculated and yield was expressed in ha⁻¹. Whole plant biomass and seed samples were oven dried, ground and then digested using concentrated sulphuric acid.

The Kjeldahl method was used to determine total nitrogen in the stover. The concentrations of P, Na, K, Mg, Ca, Fe, Zn, Mo, Cu and Mn in the plant tissues were measured by inductively coupled plasma (ICP) analysis using AOAC protocol. The concentration of nitrogen in the seeds was not determined as the analytical system employed for the other elements did not allow for nitrogen determination and adequate seed samples were not available.

2.4 Statistical Analysis

The normality of data with respect to whole plant dry matter, cowpea seed weight, and macro- and micronutrient levels were initially evaluated. The main effects of P application rate, cropping system and its interaction were subsequently tested using a two way analysis of variance. If interactions were significant, interaction plots were produced to help in interpretation of the significant interactions. Correlation analysis was made to analyze the relationship between tissue P concentration and DM accumulation, as well as other nutrients in stover and cowpea seeds. Duncan's Multiple Range Test (5% probability) was used to separate the treatment means. Data were analysed using the software STATISTICA 2010.

3. RESULTS

3.1 Effects of Phosphorus Application and Cropping System on Biomass and Stover Macronutrients

There was no significant difference in whole plant dry matter, or in the concentrations of N, P, K, Na, Mg, and Ca in the stover with phosphorus application rate. Cropping system on the other hand had a significant effect on dry matter as well as all measured macronutrients, with intercrop of cowpea yielding the highest amount of dry matter (219.9 ± 44.2 g plant⁻¹). There were no significant interactions between cropping-system and phosphorus for these variables. The details of complete treatment responses are shown in Table 1.

Table 1. Effects of phosphorus application rate and cropping system on dry matter and stover macronutrient concentrations

Treatment	Dry matter g plant ⁻¹	N mg kg ⁻¹	P mg kg ⁻¹	K mg kg ⁻¹	Na mg kg ⁻¹	Mg mg kg ⁻¹	Ca mg kg ⁻¹
P rate 0 kg ha ⁻¹	86.1 ± 18.7	2877.6 ± 351.5	1150.8 ± 151.9	10289.8 ± 1321.9	500.9 ± 26.6	1566.2 ± 169.1	3251.7 ± 455.9
P rate 50 kg ha ⁻¹	78.8 ± 11.7	3022.7 ± 354.2	1172.6 ± 179.9	10947.2 ± 1412.8	505.8 ± 41.8	1641.4 ± 181.3	3177.0 ± 481.2
P rate 100 kg ha ⁻¹	124.0 ± 36.2	3064.8 ± 401.4	1029.8 ± 154.7	10379.5 ± 1417.5	451.7 ± 35.9	1629.1 ± 185.0	3689.5 ± 598.4
P rate 150 kg ha ⁻¹	110.5 ± 29.1	2854.0 ± 467.3	1125.2 ± 175.7	9666.1 ± 1299.7	467.0 ± 40.1	1670.7 ± 193.8	3388.0 ± 531.9
Sole maize	39.0 ± 6.0 ^c	1509.8 ± 185.2 ^b	1113.7 ± 115.2 ^a	8256.8 ± 933.1 ^{bc}	624.5 ± 38.6 ^a	969.0 ± 86.7 ^b	678.6 ± 43.2 ^b
Sole cowpea	94.3 ± 8.7 ^b	4597.1 ± 252.4 ^a	1543.6 ± 189.9 ^a	13483.6 ± 1628.9 ^a	470.5 ± 16.5 ^b	2473.4 ± 132.5 ^a	6157.2 ± 267.1 ^a
Intercropped maize	47.0 ± 4.2 ^b	1378.1 ± 178.2 ^b	349.4 ± 53.1 ^b	6995.5 ± 1138.0 ^c	404.7 ± 50.5 ^b	732.0 ± 133.2 ^b	312.6 ± 70.4 ^b
Intercropped cowpea	219.9 ± 44.2 ^a	4334.1 ± 487.4 ^a	1471.5 ± 181.1 ^b	12546.7 ± 1334.8 ^{ab}	425.6 ± 16.2 ^b	2333.1 ± 143.8 ^a	6358.0 ± 235.6 ^a

3.2 Effects of Phosphorus Application and Cropping System on Stover Micronutrients

The applied phosphorus rate had no significant effect on the concentrations of Mn, Fe, Cu, Zn and Mo, while cropping system had significant effects for all measured micronutrients. The cowpea was intercropped with the highest Mn concentration, and sole maize had the highest Fe and Zn concentrations. A cropping system × phosphorus interaction was significant for Fe and Cu. The micronutrient responses are detailed in Table 2. The differences in the Fe and Cu concentrations in cropping systems are presented in Figure 1.

Table 2. Effects of phosphorus application rate and cropping system on stover micronutrient concentrations

Treatment	Mn mg kg ⁻¹	Fe mg kg ⁻¹	Cu mg kg ⁻¹	Zn mg kg ⁻¹	Mo mg kg ⁻¹
P rate 0 kg ha ⁻¹	259.2 ± 44.9	418.5 ± 68.5	5.1 ± 1.2	55.7 ± 3.8	4631.5 ± 509.3
P rate 50 kg ha ⁻¹	196.0 ± 35.0	386.4 ± 69.0	3.2 ± 0.5	58.1 ± 3.9	4708.4 ± 415.2
P rate 100 kg ha ⁻¹	277.0 ± 53.2	389.1 ± 74.6	5.1 ± 1.3	56.2 ± 5.1	4342.0 ± 3472.1
P rate 150 kg ha ⁻¹	274.8 ± 58.7	501.4 ± 116.9	5.6 ± 1.1	57.8 ± 4.0	4740.7 ± 529.7
Sole maize	154.0 ± 19.9 ^b	749.2 ± 124.1 ^a	6.2 ± 1.3 ^{ab}	78.5 ± 3.7 ^a	2884.2 ± 565.4 ^b
Sole cowpea	333.4 ± 46.1 ^a	480.3 ± 71.9 ^b	3.7 ± 0.9 ^{bc}	51.5 ± 2.0 ^b	6084.3 ± 213.0 ^a
Intercropped maize	49.5 ± 9.1 ^b	156.5 ± 28.7 ^c	1.5 ± 0.3 ^c	47.5 ± 5.6 ^b	3336.9 ± 499.1 ^b
Intercropped cowpea	470.1 ± 63.6 ^a	309.5 ± 44.9 ^{bc}	7.6 ± 1.2 ^a	50.4 ± 2.3 ^b	6117.5 ± 255.9 ^a

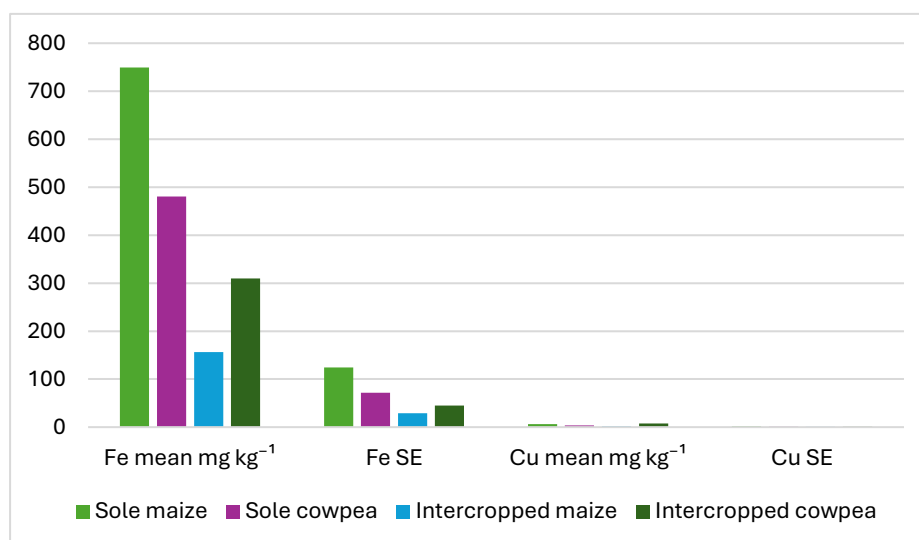


Figure 1. Fe and Cu concentrations in stover under different cropping systems

3.3 Cowpea Seed Yield and Macronutrient Composition

Similarly, no significant difference in the mean seed weight of cowpea was observed among different rates of P application (0, 75, 150 kg P ha⁻¹) but increased from 28.38 ± 5.09 g plant⁻¹ at 0 kg P ha⁻¹ to 52.28 ± 9.17 g plant⁻¹ at 150 kg P ha⁻¹. There was a significant difference between phosphorus rates for seed P and Mg, and for seed P, K, Ca and Mg, cropping system had a significant influence. Ca, Mg, and Na were found to have significant cropping-system interactions. These are the responses and they are presented in Table 3. The continuous increase of P concentration in cowpea seeds as a function of the applied P levels is presented in Figure 3.

Table 3. Effects of phosphorus application rate on cowpea seed weight and macronutrient concentrations

P application rate kg ha ⁻¹	Seed weight g plant ⁻¹	P mg kg ⁻¹	K mg kg ⁻¹	Ca mg kg ⁻¹	Mg mg kg ⁻¹	Na mg kg ⁻¹
0	28.38 ± 5.09	88.0 ± 9.8 ^c	114.0 ± 5.4 ^b	14.1 ± 0.5 ^a	64.4 ± 2.4 ^b	5.0 ± 0.8 ^a
50	34.03 ± 3.00	92.8 ± 9.9 ^{bc}	118.6 ± 4.7 ^{ab}	14.8 ± 1.1 ^a	65.5 ± 2.7 ^{ab}	5.1 ± 0.8 ^a
100	34.87 ± 4.70	104.2 ± 8.0 ^{ab}	116.8 ± 6.4 ^{ab}	14.1 ± 0.7 ^a	68.6 ± 1.1 ^a	4.3 ± 1.0 ^{ab}
150	52.28 ± 9.17	115.5 ± 8.3 ^a	127.4 ± 7.4 ^a	13.7 ± 0.4 ^a	67.9 ± 1.1 ^{ab}	3.5 ± 1.1 ^b

3.4 Cowpea Seed Micronutrient Responses

Seed concentrations of Mn, Fe, Cu, Zn and Mo were not significantly influenced by the rate of application of phosphorus. The cropping system was a significant effect on Cu concentration, with intercropped cowpea seeds having a higher mean than sole cowpea seeds. Another important effect of cropping system was reported for the case of Cu. Table 4 shows all the responses of seed micronutrients. The difference in seed Cu concentration between sole and intercropped cowpea is shown in Figure 2.

Table 4. Effects of phosphorus application and cropping system on cowpea seed micronutrient concentrations

Treatment	Mn mg kg ⁻¹	Fe mg kg ⁻¹	Cu mg kg ⁻¹	Zn mg kg ⁻¹	Mo mg kg ⁻¹
P rate 0 kg ha ⁻¹	1.1 ± 0.3	0.3 ± 0.2	8.5 ± 2.1	0.14 ± 0.08	0.2 ± 0.1
P rate 50 kg ha ⁻¹	0.9 ± 0.1	0.2 ± 0.0	12.5 ± 4.0	0.05 ± 0.03	0.1 ± 0.0
P rate 100 kg ha ⁻¹	0.9 ± 0.1	0.2 ± 0.0	9.6 ± 3.5	0.02 ± 0.01	0.0 ± 0.0
P rate 150 kg ha ⁻¹	0.8 ± 0.0	0.1 ± 0.0	5.9 ± 1.5	0.06 ± 0.0	0.1 ± 0.0
Sole cowpea	0.9 ± 0.1	0.1 ± 0.0	5.5 ± 5.5	0.03 ± 0.03	0.03 ± 0.0
Intercropped cowpea	1.0 ± 0.2	0.3 ± 0.1	12.8 ± 2.2	0.11 ± 0.04	0.1 ± 0.0

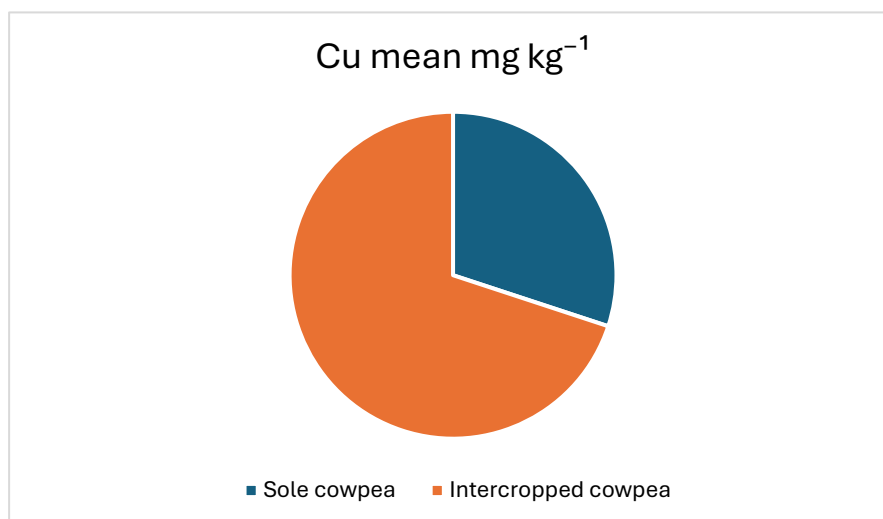


Figure 2. Cowpea seed Cu concentration under sole and intercropped cropping systems

3.5 Relationships Between Stover Phosphorus, Biomass, and Nutrient Concentrations

Dry matter and K, Ca, Mn, Fe and Mo were positively correlated with whole plant P concentration. The highest positive correlation was obtained with Mn ($r = 0.8577$), K ($r = 0.7971$) and dry matter, with positive correlations obtained with Fe, Ca, Mo and dry matter. These coefficients and significance levels are presented in Table 5.

Table 5. Correlations between whole-plant phosphorus concentration and selected response variables

Response variable	r	p-value	Direction
Dry matter	0.3082	0.0002	Positive
K	0.7971	<0.001	Positive
Ca	0.4430	<0.001	Positive
Mn	0.8577	<0.001	Positive
Fe	0.6160	<0.001	Positive
Mo	0.4240	<0.001	Positive

3.6 Relationships Between Cowpea Seed Phosphorus and Nutrient Concentrations

Cowpea seed P concentration was positively associated with Mg, K, and Ca, with particularly strong correlations for K and Mg. In contrast, significant negative correlations were observed between seed P and Mo, Fe, and Cu, indicating lower concentrations of these micronutrients at higher seed P concentrations. The correlation statistics are summarized in Table 6.

Table 6. Correlations between cowpea seed phosphorus and selected nutrient concentrations

Nutrient	r	p-value	Direction
Mg	0.7915	0.000004	Positive
K	0.7949	0.000003	Positive
Ca	0.5471	0.0057	Positive
Mo	-0.4525	0.0264	Negative
Fe	-0.4662	0.0217	Negative
Cu	-0.4147	0.0439	Negative

DISCUSSION

Application rate of phosphorus was less important in influencing biomass production and nutrient accumulation than cropping system. The whole plant dry matter and nutrient (N, P, K, Na, Mg, and Ca) contents in stover were not significantly different among the four P treatments. However, significant differences were observed between sole and intercropped maize and cowpea. Intercropping cowpea yielded highest for dry matter, and in general cowpea showed higher levels of N, K, Mg and Ca than maize. This is in line with Chhetri and Sinha (2020) who found benefits for maize intercropped under proper nutrient management. The findings of Kussie et al. (2024) also demonstrated that intercropping maize—cowpea has the potential to yield better agronomic performance and resource use than sole cropping.

The limited sensitivity of whole plant biomass and macronutrient concentration to P application rate could be associated with the low fertility of the experimental soil. The original thesis was limited P response was related to

low organic matter and acidic soil conditions. In these situations, higher rates of fertilizer application do not necessarily lead to higher nutrient uptake if the chemical reactions in the soil limit the availability of the fertilizer. Similarly, Bawa (2020) has shown that the effect of phosphorus fertilization on the cowpea may be quite variable depending on soil and production conditions. Rahman et al. (2025) also demonstrated that cropping system plays a significant role in the benefit of phosphorus fertilization in intercropping, suggesting that the benefit of cropping system and nutrient management should be considered simultaneously.

The differences were also observed between cropping systems for the micronutrient accumulation in stover. The application of phosphorus alone did not have a significant effect on Mn, Fe, Cu, Zn, and Mo while cropping system had a significant effect on all five micronutrients. Maize grown in isolation had the highest Fe and intercropped cowpea had the highest Cu concentration. Maize intercropped generally had the lowest levels of some micronutrients. P application rate $\times$ cropping system was significant for Fe and Cu. The answers also indicated that both nutrient acquisition and the interactions between maize and cowpea, as well as the nutrient supply, were factors that influenced nutrient accumulation. Begam et al. (2024) also noted that the intercropping pattern and the nutrient management had a significant effect on the maize growth, yield, and nutritional characteristics.

The response to phosphorus was more easily detected in cowpea seeds. The seed P concentration was higher at 150 kg P ha⁻¹ (115.5 mg kg⁻¹) than at 0 kg P ha⁻¹ (88.0 mg kg⁻¹), indicating increased P accumulation in the seed at high fertilizer rates. Seed Mg was also significantly affected by P application, with no significant main effects for K, Ca or Na. Seed P, K, Ca and Mg concentrations were significantly affected by cropping system, and generally sole-cropped cowpea had higher values than intercropped cowpea. The higher seed P concentration found with fertiliser application is similar to that reported by Bawa (2020) who found that cowpea performance improved with P addition. It corroborates the overall findings of Rahman et al. (2025) that the P responses to intercropping are related to the nutrient environment and to the crop combination.

This is because in intercropped cowpea with other crops, the levels of several macronutrients were lower than in sole cowpea, which could be due to competition for available nutrients in cowpea's reproductive development. While the use of intercropping has been found to enhance the overall efficiency of resource use, the component crops are still competitors for water and mineral nutrients, and especially if the soil fertility is low. Kussie et al. (2024) found that the agronomic performance and nutritional value of maize–cowpea systems were found to differ depending on the cropping system, suggesting that intercropping benefits are specific to certain nutrients rather than all measured traits. Similarly, Chhetri and Sinha (2020) noted that with regard to maize-based intercropping the advantage in productivity is dependent on the management of the nutrients.

Seed micronutrient responses were more selective than the macronutrient responses. No significant effect was observed with the application of phosphorus on seed Mn, Fe, Cu, Zn, Mo or seed weight. But the concentrations of Cu differed among the cropping systems as intercropped cowpea seeds had more Cu than sole cowpea seeds. A significant interaction between application rate of P and cropping system was also observed for seed Cu. This suggests that the effect of intercropping on mineral composition might vary depending on the nutrient. It also implies that alteration of nutrients availability in the rhizosphere could affect nutrient partitioning into seeds in a different way from that into vegetative tissues.

Furthermore, the contrasting nutrient relationships between stover and seeds were observed based on the correlation analysis. Phosphorus concentration was positively related to dry matter and some nutrients in whole plant material. The phosphorus demonstrated positive correlation with Mg, K, and Ca in cowpea seeds while negative correlation with Mo, Fe and Cu. The contrasting trends imply that in this context, increased P accumulation does not lead to the simultaneous enrichment of all nutrients in the seed. Rather, the nutrient partitioning can change with plant development and during seed formation. This is crucial because management techniques to boost phosphorus nutrition would need to account for the potential effects on mineral composition in the grain.

Overall, the results indicated that crop arrangement had a greater effect on most biomass and nutrient traits than did increasing the phosphorus rate. This is similar to the trend in the literature on intercropping, where responses are found to be very sensitive to species interactions, nutrient levels, and management. Both Begam et al. (2024) and Kussie et al. (2024) found that intercropping had an impact on the performance of crops and their nutrient characterizations, while Rahman et al. (2025) highlighted that the benefits of phosphorus fertilization are context-dependent. If this is the case, then implementing appropriate phosphorus management practices with intercrop maize-cowpea could thus be more effective than a higher rate of fertilizer application for low-fertility production systems.

CONCLUSION

Maize–cowpea cropping system had a greater effect on biomass production and nutrient accumulation than did the phosphorus application rate. Maize generally had a lower whole-plant dry matter production than intercropped cowpea while maize had the lowest accumulation of several macronutrients among the varieties. The application of phosphorus did not significantly influence stover dry matter or the levels of most macro- and micronutrients, but there were significant interactions between cropping system and phosphorus rate for Fe and Cu. Cowpea seed composition was more sensitive to P supply. Seed phosphorus concentration responded positively with phosphorus application and was maximum at 150 kg P ha⁻¹ and seed Mg responded significantly with phosphorus treatments.

The P, K, Ca and Mg content in the sole cropped cowpea seeds was usually higher than intercropped cowpea seeds. Cropping system, as well as the interaction between cropping system and phosphorus application significantly affected Cu among the micronutrients in the seeds. Correlation analysis also revealed that there was a positive relationship between cropping system and P, Mg, K, and Ca while seed P showed a negative relationship with Fe, Cu, and Mo. Overall, the results show that nutrient dynamics are significantly influenced by cropping system. Maize–cowpea intercropping can thus be an effective tool to enhance nutrient-use efficiency in low-fertility soils when introducing both crops, which may lead to better production and yield.

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