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Scientific Article

Root growth and dry mass production in orange sweet potato under phosphorus doses

Crescimento radicular e produção de massa seca em batata-doce alaranjada sob doses de fósforo

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ABSTRACT - Sweet potato is a root of great global importance in nutrition. Therefore, it is crucial to evaluate its aerial part production and root growth, especially with the application of phosphorus (P). This nutrient is essential for many plants, promoting root growth and energy production (ATP). Thus, this study aims to evaluate root growth and dry matter production in sweet potato under phosphorus fertilization and at two planting times (S1 and S2). The study was conducted in an experimental area of the Universidade Federal Rural do Semi-Árido (UFERSA), Mossoró, RN, Brazil. The experimental design was randomized blocks with four replicates. The treatments consisted of P doses (0, 60, 120, 180, and 240 kg ha^{-1} of P_2O_5). At 153 days after planting, the dry mass of the aerial part (APDM) and commercial roots (DMCR), aerial part dry mass production (APDMP), the harvest index (HI), classification, and length (LCR), diameter (DCR), and shape (SCR) of the commercial roots were evaluated. The 60 kg ha^{-1} dose of P_2O_5 promoted the highest number of commercial roots, mainly for S2, and the predominance of roots with the same shape in both growing seasons for the same dose. The DMCR and HI were higher in S2, essentially for the 120 kg ha^{-1} dose of P_2O_5. Dry mass production was higher for S1, showing a strong correlation, with the 60 kg ha^{-1} dose of P_2O_5 standing out.

Keywords: *Ipomoea batatas*. Commercial roots. Growing seasons. Fertilization.

RESUMO – A batata-doce é uma raiz de grande importância global na nutrição. Portanto, é fundamental avaliar a produção da parte aérea e o crescimento radicular, especialmente com a aplicação de fósforo (P). Esse nutriente é essencial para muitas plantas, promovendo o crescimento das raízes e a produção de energia (ATP). Assim, objetiva-se com esse trabalho avaliar o crescimento radicular e a produção de massa seca em batata-doce sob adubação fosfatada e em duas épocas de cultivo (S1 e S2). O estudo foi conduzido em área experimental da Universidade Federal Rural do Semi-Árido (UFERSA), Mossoró, RN, Brasil. O delineamento experimental foi em blocos casualizados, com quatro repetições. Os tratamentos consistiram em doses de P (0, 60, 120, 180 e 240 kg ha^{-1} de P_2O_5). Aos 153 dias após o plantio, foram avaliadas a massa seca da parte aérea (MSPA) e das raízes comerciais (MSRC), a produção de massa seca da parte aérea (PMSPA), o índice de colheita (IC), a classificação, o comprimento (CRC), o diâmetro (DRC) e o formato (FRC) das raízes comerciais. A dose de 60 kg ha^{-1} de P_2O_5 promoveu o maior número de raízes comerciais, principalmente em S2, e a predominância de raízes com o mesmo formato em ambas as épocas de cultivo para essa mesma dose. A MSRC e o IC foram maiores em S2, especialmente para a dose de 120 kg ha^{-1} de P_2O_5. A produção de massa seca foi maior em S1, apresentando forte correlação, com destaque para a dose de 60 kg ha^{-1} de P_2O_5.

Palavras-chave: *Ipomoea batatas*. Raízes comerciais. Épocas de cultivo. Adubação.

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INTRODUCTION

Sweet potato [*Ipomoea batatas* (L.) Lam] is an important crop and can be used for food, feed, and raw materials in the business sector (LIU et al., 2022). Worldwide, China stands out as the largest producer of sweet potatoes (HOSSAIN et al., 2022). Storage roots are rich in dietary fiber, minerals, vitamins, and carotene, most notably in orange-colored sweet potatoes (ALAM et al., 2020). This vegetable emerges in the commercial sector, essentially for farmers, generating significant profits. Therefore, given the importance of the crop, it is essential to apply good crop management practices, such as soil nutrition (MUSTACISA-LACABA; TAN; VILLANUEVA, 2023).

Phosphorus (P) is an essential nutrient that benefits the growth and development of plants (DING et al., 2021; ZHAO et al., 2021). As it is directly related to cellular energy synthesis, P deficiency reduces ATP production, photosynthetic rate, yield, and quality of sweet potato (MINEMBA et al., 2019; LI et al., 2020). Proper P application can promote a sound root system, favoring carbohydrate production, transport, and storage, especially stored starch (BORU; KEBEDE; TANA, 2017). It should be noted that P is immobile in the soil. It can become unavailable to plants through adsorption and precipitation processes, to the detriment of its efficient uptake (YU; KEITEL; DIJKSTRA, 2021).

In general, distinct responses are observed in plants subjected to P doses and under environmental influence. Villordon, Gregorie and Labonte (2020) mention the importance of understanding the action of environmental and biological factors on the length of sweet potato roots since the interaction with these factors is related to the determination of the length and shape of the storage root. Silveira et al. (2023) tested P doses (0, 60, 120, 180 and 240 kg ha^{-1}) in table cassava and found that the cultivars showed high yields, regardless of P doses, demonstrating that they are adapted to local climatic conditions, even in soils with low P availability.

Sweet potato has high genetic diversity, so verifying the growth responses when subjected to different technologies is essential since individuals of the same species respond differently under the same conditions. Thus, it is hypothesized that phosphorus doses influence aerial part and root growth and favor the formation of storage roots. Therefore, the aim of this study was to evaluate root growth, dry mass and aerial dry mass production in sweet potato cv. Paraná as a function of phosphorus doses in two growing seasons.

MATERIAL AND METHODS

Sweet potato plants (cv. Paraná) that have periderm and orange pulp were cultivated at the Rafael Fernandes Experimental Farm, belonging to the Federal Rural University of the Semi-Arid Region (UFERSA), Mossoró, RN, Brazil (5º03′37"S, 37º23′50"W, and 72 m above sea level). The research was conducted over two growing seasons (S), from April to August 2021 and from December 2021 to April 2022, respectively S1 and S2. The study region has an average temperature of 27.8 °C, relative humidity of 68.9%, and precipitation of approximately 555 mm (CLIMATE, 2021), with the region classified as BSh, hot and dry, according to Köppen's classification (ALVARES et al., 2013). At the end of the research, average data of air temperature, relative humidity, rainfall, solar radiation, and wind speed (Figure 1) were collected from the Automatic Weather Station at the experimental farm.

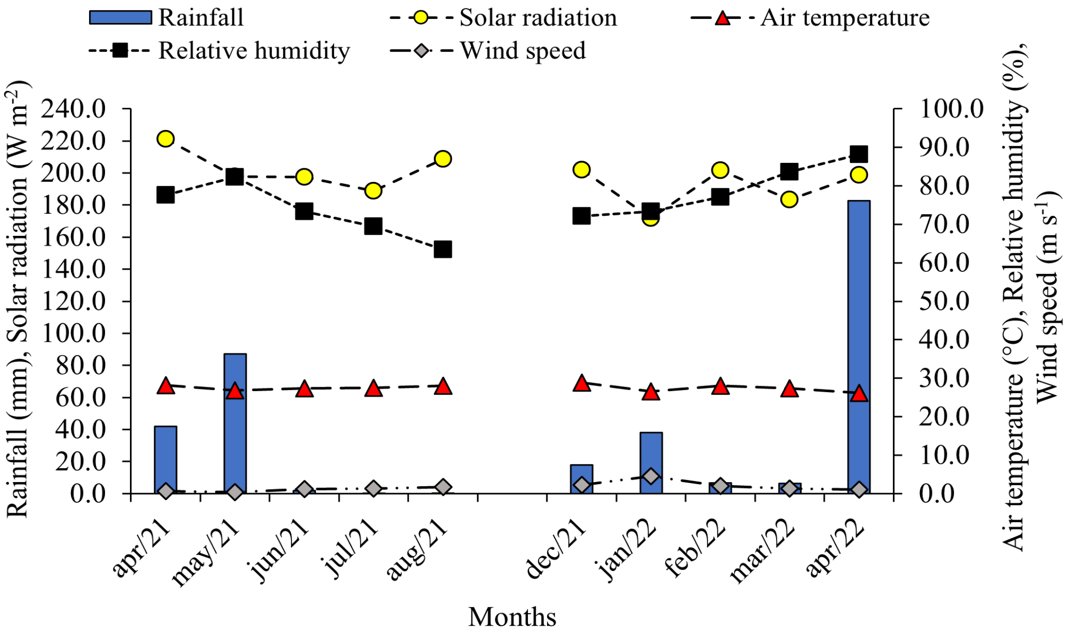

Figure 1. Meteorological data collected at the Rafael Fernandes Experimental Farm during the two growing seasons.

The experiment was conducted using a randomized block design with four replicates. The treatments included different doses of phosphorus (P) applied during planting fertilization. Monoammonium phosphate (MAP) (containing 61% P_2O_5 and 12% N) was the P source at doses of 0, 60, 120, 180, and 240 kg ha^{-1} of P_2O_5. Nitrogen (N) and potassium (K) fertilization followed the recommendations of Gomes, Silva, and Coutinho (2008). The sources of N and K used were urea (46% N) and potassium chloride (KCl) (60% K_2O) at rates of 40 and 60 kg ha^{-1}, respectively. The N application was adjusted according to Gomes, Silva, and Coutinho (2008), with 80% of the total N being applied 15 days after planting (DAP). Potassium was applied in split doses, 50% at 20 DAP and 50% at 45 DAP. The amount of N applied was adjusted by accounting for the N present in the MAP used in the basal fertilization.

In the experimental area, before setting up the experiments, soil samples were collected at depths of 0 – 0.20 m and 0.20 – 0.40 m to assess the chemical properties (Table 1). The area was prepared by performing plowing and harrowing operations, followed by raising the beds to a height of 0.30 m. The irrigation system used was drip irrigation, with emitters spaced 0.30 m apart, applying an average daily depth of 11 mm. Tensiometers were installed to monitor soil moisture. Daily irrigation was conducted until 30 DAP. Between 30 and 75 DAP, irrigation was carried out when the tensiometers indicated -20 kPa, as adapted from Embrapa (2021). From 75 to 90 DAP, irrigation was suspended, then resumed and carried out weekly until harvest, always maintaining soil moisture levels between -15 and -25 kPa.

Table 1. Chemical analysis of the experimental area's soil before setting up the experiments for seasons (S) 1 and 2.

Analysis	S1		S2	
	Depth (m)			
	0 – 0.20	0.20 – 0.40	0 – 0.20	0.20 – 0.40
pH (water)	6.34	6.03	5.10	5.37
EC (dS m^{-1})	0.70	0.71	1.00	0.80
P* (mg dm^{-3})	4.69	4.57	4.20	2.37
K^+ ($cmol_c$ dm^{-3})	0.15	0.13	0.15	0.13
Na^+ (cmolc dm^{-3})	0.05	0.05	0.00	0.06
Ca^{2+} ($cmol_c$ dm^{-3})	1.43	1.36	1.06	0.79
Mg^{2+} ($cmol_c$ dm^{-3})	0.35	0.89	0.49	0.23
Al^{3+} ($cmol_c$ dm^{-3})	0.00	0.00	0.00	0.00
SB ($cmol_c$ dm^{-3})	1.99	2.44	1.70	1.21
t ($cmol_c$ dm^{-3})	1.99	2.44	1.70	1.21
CEC ($cmol_c$ dm^{-3})	1.99	2.44	1.70	1.21

*Extractant: Mehlich-1; EC – Electrical conductivity of soil saturation extract; SB – Sum of bases; t – Effective cation exchange capacity; CEC – Cation Exchange Capacity.

Each plot consisted of four beds, each 2.4 m long and spaced 1 m apart, totaling an overall area of 9.6 m², with a usable area of 3.6 m². Apical branches with five to six buds were used, with two branches planted per hole, spaced 0.30 m apart. Manual weeding was performed four times per growing season. No pesticides were used as no pests or diseases of economic significance were found in the crop.

At 153 DAP, the tuberous roots were harvested and taken to the Laboratory for Plant and Sample Reception of the Semi-Arid Plant Research Center (LABRPA/CPVSA), affiliated with the Department of Agronomic and Forestry Sciences (DCAF) of the Center for Agrarian Sciences (CCA). In the laboratory, the commercial roots were separated for analysis. The dry mass (DMCR) and the classification of the roots into categories were evaluated. The categories were defined as: Extra A (301 to 400 g), Extra B (201 to 300 g), Special (151 to 200 g), and Miscellaneous (80 to 150 g or over 400 g) (EMBRAPA, 2008).

The length (LCR), diameter (DCR) and shape of commercial roots (SCR) were also evaluated. For LCR and DCR, eight commercial roots were used, with the length obtained with the aid of a graduated ruler (cm), while the diameter was obtained with the aid of a digital caliper, measured in the center of the root, without cross-section, in (mm). For SCR, six commercial roots were used, where the shape was determined using a scale of scores ranging from 1 to 9, respectively: round, round elliptical, elliptical, ovate, obovate, oblong, long oblong, long elliptical and long irregular or curved (HUAMÁN, 1992), and the mode was adopted as a comparative parameter. The roots used for determining the previously mentioned variables were taken from the usable areas of the respective replicates.

The percentage of aerial part dry mass (APDM) and aerial part dry mass production (APDMP), expressed in kg DM ha^{-1}, were also evaluated. For the measurement of APDMP, four plants of the usable area of each replicate were used. The harvest index (HI) was determined by the ratio between the dry mass of commercial roots and the total dry mass (QUEIROGA et al., 2007). The dry mass of the commercial roots and aerial part was obtained by weighing 300 g of both parts and then taking them to the oven at 65 °C, where they were kept until reaching constant weight.

Data were assessed for normal distribution using homoscedasticity and Shapiro-Wilk tests and then subjected to analysis of variance using the F test for each growing season. A joint analysis was applied to the homogeneous data between the P doses and the growing seasons. Tukey's test was used to compare the doses within their respective seasons and between the seasons. The analyses were performed using the statistical program Sisvar 5.6 (FERREIRA, 2014). Pearson's correlation and principal component analysis (PCA) were used to verify the relationship between the variables analyzed.

RESULTS AND DISCUSSION

There was a significant difference for the season and dose factors alone for the Extra A and miscellaneous classifications. On the other hand, the effect of the dose factor was also the same for the classification of several different factors. For S2, the 60 kg ha^{-1} dose of P_2O_5 promoted higher averages than the 120, 180 and 240 kg ha^{-1} doses of P_2O_5 in the miscellaneous classification (Table 2). In S2, the number of commercial roots was higher for the miscellaneous classification, followed by Extra A, Extra B and Special. The commercial roots classified as Extra A were predominant in S2, with increments of 93.75 and 81.48%, respectively, at 0 and 60 kg ha^{-1} of P_2O_5, when comparing S2 to S1. Different results were evidenced by Azevedo et al. (2015), who found commercial roots classified as Special and diverse when evaluating the yield of commercial roots of sweet potato clones. Silva et al. (2018), who worked with sweet potato clones, obtained the prevalence of commercial roots classified as Extra B.

Table 2. Number of commercial roots and mean values followed by the standard error of the mean for type classification by weight (Extra A-301 to 400 g; Extra B-201 to 300 g; Special-151 to 200 g; Miscellaneous-80 to 150 g or greater than 400 g) of sweet potato cv. Paraná subjected to phosphorus doses for S1 (April to August 2021) and S2 (December 2021 to April 2022).

Doses (kg ha^{-1})	Classification of commercial roots							
	Extra A		Extra B		Special		Miscellaneous	
	N°	Mean	N°	Mean	N°	Mean	N°	Mean
S1								
0	1	0.25±0.25aB	3	0.75±0.47aA	8	2.00±1.35aA	16	4.00±1.58aA
60	5	1.25±0.75aB	13	3.25±0.94aA	16	4.00±0.40aA	29	7.25±1.75aA
120	6	1.50±0.64aA	9	2.25±0.85aA	14	3.50±1.25aA	15	3.75±1.31aA
180	1	0.25±0.25aA	7	1.75±0.62aA	10	2.50±1.04aA	23	5.75±0.94aA
240	2	0.50±0.28aA	9	2.25±0.85aA	12	3.00±1.08aA	14	3.50±1.75aA
S2								
0	16	4.00±2.82aA	15	3.75±2.13aA	6	1.50±0.95aA	22	5.50±2.32abA
60	27	6.75±3.03aA	19	4.75±1.93aA	17	4.25±1.75aA	48	12.0±3.02aA
120	9	2.25±1.65aA	4	1.00±0.70aA	12	3.00±1.77aA	25	6.25±2.13abA
180	8	2.00±1.22aA	16	4.00±2.12aA	9	2.25±1.60aA	34	9.00±3.80abA
240	7	1.75±1.10aA	12	3.00±1.68aA	7	1.75±1.18aA	18	4.50±1.65bA
OM	-	2.05	-	2.67	-	2.77	-	6.15
CV (%)	-	35.38	-	27.82	-	33.11	-	27.26
D	-	ns	-	ns	-	ns	-	*
S	-	**	-	ns	-	ns	-	*
D x S		ns		ns		ns		ns

Means followed by different lowercase letters indicate significant differences between the doses, while means followed by different uppercase letters indicate significant differences between the growing seasons, at 5% probability level by Tukey's test ($p<0.05$). OM – Overall mean. CV (%) – Coefficient of variation. (D) doses; (S) season; (D x S) interaction. * and **- significant at 5% and 1% probability levels by the F test; ns – not significant; N° – number of roots.

Classifying sweet potatoes into types by weight is important, as commercial roots with a lower average standard can be used for processing in industrial kitchens or factories of sweets and jellies in conjunction with other types of classes (EMBRAPA, 2021). Thus, the commercial roots classified as Extra A fit these requirements, with the 60 kg ha^{-1} dose of P_2O_5 standing out. Minemba et al. (2019) highlighted in their research that there were no changes in the root characteristics of three sweet potato cultivars subjected to P doses (0, 10, 20, 40, 60, 120 and 360 mg kg^{-1} of soil) in soil with low P. These results are similar to those found in the present study, where no significant doses were observed in all classifications of S1 and for the Extra A, Extra B and Special classifications of S2. One explanation for this is that the high supply of P to plants decreases the growth of primary roots and the size and number of tuberous roots (SHUKLA; RINEHART; SAHI, 2017).

There was no significant difference between phosphorus doses and the interaction (dose x season) concerning the length and diameter of commercial roots. Only an isolated influence of the growing season on the diameter of commercial roots was observed (Table 3). Root diameter was higher in S2 at doses of 0 to 180 kg ha^{-1} of P_2O_5 compared to S1. It is also observed that the treatment without phosphorus addition showed a 43.34% increase in root length in S2 compared to S1. It is important to highlight that cultivars can respond differently to the applied phosphorus, indicating that changes in fertility over time affect phosphorus requirement, even in plants of the same species, emphasizing the importance of reviewing phosphorus recommendations (OMONDI et al., 2019). Another explanation is that sweet potatoes directed their carbon resources to filling the roots, reducing the investment in morphological adaptations of the roots (MINEMBA et al., 2019).

In S1, doses 0 and 180 kg ha^{-1} of P_2O_5 led to largely round-shaped commercial roots (Table 3). In addition, the doses of 120 and 240 kg ha^{-1} of P_2O_5 promoted elliptical shape, while the 60 kg ha^{-1} dose of P_2O_5 resulted in a predominance of the obovate shape. In S2, doses 120 and 180 kg ha^{-1} of P_2O_5 led to a predominance of roots with round shapes, while doses 0 and 240 kg ha^{-1} of P_2O_5 resulted in elliptical round shapes. Also, for S2, the 60 kg ha^{-1} dose of P_2O_5 promoted a predominance of the obovate shape (Figure 2). Evaluating the shape of this vegetable is an important parameter, mainly because it is a material intended for the table and because it interferes with the quantity and commercial value of sweet potatoes (COELHO et al., 2022).

Table 3. Mean values and standard error of the mean for length of commercial roots (LCR), diameter of commercial roots (DCR) and shape of commercial roots shape (SCR) of sweet potato cv. Paraná subjected to phosphorus doses for S1 (April to August 2021) and S2 (December 2021 to April 2022).

Doses kg ha^{-1}	LCR (cm)	DCR (cm)	SCR
S1			
0	11.12±0.97aB	5.346±0.39aB	1
60	12.12±0.95aA	5.971±0.24aB	5
120	13.93±3.25aA	4.832±1.06aB	8
180	10.37±0.71aA	5.605±0.20aB	1
240	10.43±1.65aA	5.003±0.80aA	3
S2			
0	15.94±0.79aA	7.020±0.36aA	2
60	14.25±0.89aA	7.635±0.30aA	5
120	11.08±0.39aA	6.883±0.41aA	1
180	13.33±1.01aA	7.343±0.27aA	1
240	10.93±0.54aA	5.930±0.45aA	2
OM	12.35	6.15	-
CV (%)	18.28	23.97	-
D	ns	ns	-
S	ns	**	-
D x S	ns	ns	-

Means followed by different lowercase letters indicate significant differences between the doses, while means followed by different uppercase letters indicate significant differences between the growing seasons, at 5% probability level by Tukey's test ($p<0.05$). OM – Overall mean. CV (%) – Coefficient of variation. (D) doses; (S) season; (D x S) interaction. * and **- significant at 5% and 1% probability levels by the F test; ns – not significant; N° – number of roots.

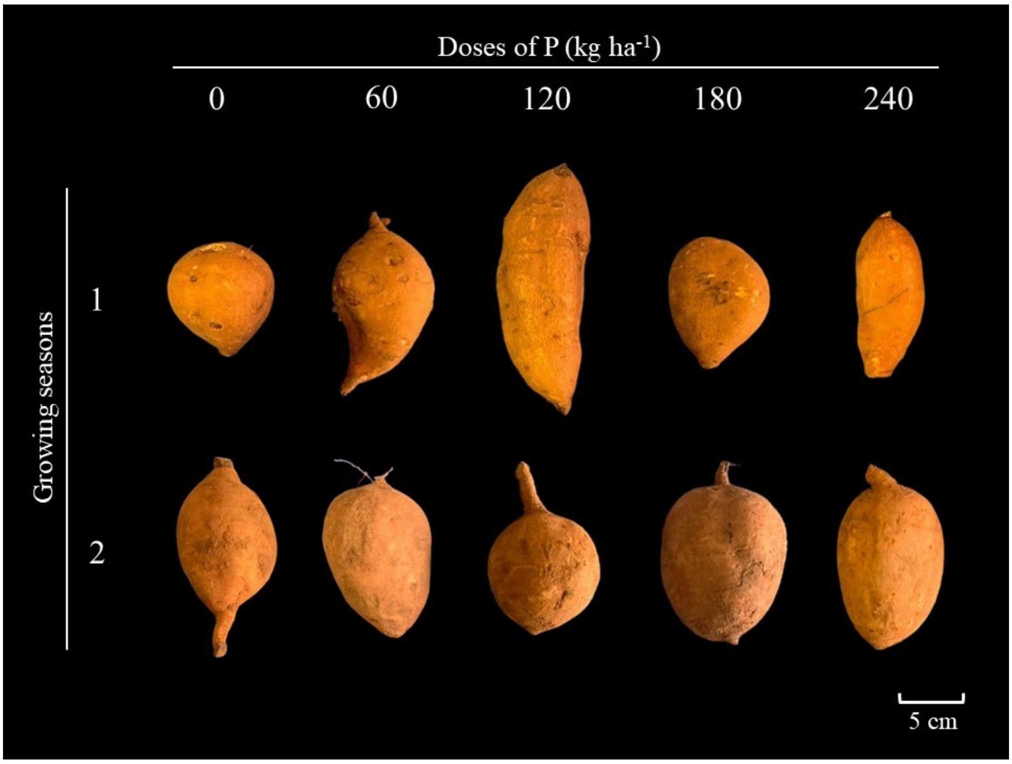

Figure 2. Predominance of the shapes of sweet potato cv. Paraná subjected to different phosphorus doses in S1 (April to August 2021) and S2 (December 2021 to April 2022).

The size and shape of sweet potatoes are essential for marketing, and preferences regarding the product's quality vary from region to region (RÓS, 2017). This diversity of shapes is due to the fact that sweet potato genotypes have significant variations in the cultivation cycles and that these variations depend on characteristics related to the material, cultural management, as well as the interaction and influence of the environment to which the genotype was introduced (COELHO et al., 2022), and that the interactions between the environment and the genotype influence architectural modifications of the sweet potato root system in relation to the availability of P (VILLORDON; GREGORIE; LABONTE, 2020).

There was only significance of the season factor for the DMCR, APDM, APDMP and HI variables (Table 4). In S2, 60 and 120 kg ha^{-1} doses of P_2O_5 led to higher percentages of DMCR than in S1. The DMCR ranged from 10.85 to 17.33% and from 17.86 to 24.85%, respectively, in S1 and S2. These findings are in agreement with those of Hossain et al. (2022), who obtained DMCR ranging from 20.26 to 35.16%. It is worth mentioning that in S2, the percentage of DMCR was higher than the APDM, while for S1, the opposite was obtained, favoring the aerial part (source), mainly mature leaves, and harming the storage root (sink). This finding is in agreement with Hossain et al. (2022), who showed that the sweet potato genotype (G2) had a higher APDM content, causing a reduction in the yield of storage roots. In addition, an explanation for this behavior is that excess P induces bud flowering, reducing photoassimilate transport and decreasing the sink/source ratio and, consequently, the final yield (LIU et al., 2022).

Table 4. Mean values and standard error of the mean for commercial root dry mass (DMCR), aerial part dry mass (APDM), aerial part dry mass production (APDMP) and harvest index (HI) of sweet potato cv. Paraná subjected to phosphorus doses for S1 (April to August 2021) and S2 (December 2021 to April 2022).

Doses	DMCR		APDM		APDMP		HI	
	------------------------ % ------------------------				------------- kg DM ha^{-1} -------------		------------- % -------------	
	S1	S2	S1	S2	S1	S2	S1	S2
0	17.33±4.11a	17.86±5.96a	19.88±2.09a	12.22±0.69b	5210.74±1880.6a	2791.46±569.89a	43.30±2.30a	49.46±16.52a
60	16.34±0.47b	24.85±3.30a	18.62±1.09a	9.91±0.78b	10690.7±359.79a	3219.42±376.66b	46.85±1.74a	65.00±8.52a
120	10.85±3.62b	21.99±0.72a	19.37±0.94a	8.93±1.89b	9863.81±607.11a	1838.93±600.16b	32.53±10.92b	67.42±7.53a
180	15.23±0.39a	19.90±1.82a	20.70±0.47a	10.65±1.56b	9865.89±777.15a	2916.27±221.97b	42.38±0.86b	65.12±4.20a
240	15.47±1.00a	19.68±1.73a	18.70±0.07a	10.02±1.55b	10514.2±2224.0a	1645.66±321.61b	38.40±5.89b	66.19±5.51a

Means followed by different letters show significant differences between the growing seasons at 5% probability level by Tukey's test ($p<0.05$).

The APDM and APDMP of season 1 showed significantly higher averages than S2 (Table 4). The APDM levels were similar to the findings of Donato et al. (2020), who used aerial part dry mass of sweet potato cultivars for hay production, with levels ranging from 17.27 to 18.74%. For sweet potatoes, dry mass is an essential trait in terms of quality; in addition, dry mass contents vary in different genotypes, usually due to cultivation practices, climate, day length, genetic composition, and soil factors (HOSSAIN et al., 2022). Omondi et al. (2019) evaluated cassava root production as a function of P concentrations and found that there was an increase in aerial part as P concentrations were increased. Similar behavior was evidenced in potato crops under phosphorus and potassium concentrations (ABBASIAN et al., 2018).

For S2, the HI showed increments of 107.25, 53.65 and 72.36%, respectively, for the doses 120, 180 and 240 kg ha^{-1} of P_2O_5 compared to S1. The HIs ranged from 38.40 to 46.85% and from 49.46 to 67.42%, in the same order for S1 and S2. Santos et al. (2017) analyzed sweet potato clones and found HI ranging from 55.6 to 80.2%. HIs do not need to be high to be ideal; the appropriate values vary according to the purpose of the crop; for example, if the purpose is to produce aerial parts, the values can be low and ideal (SILVEIRA et al., 2023). High-yielding clones generally have a high harvest index, which demonstrates that these clones have high efficiency in using photoassimilates in the root formation process (RAHAJENG et al., 2021).

The DCR showed strong positive correlations with DMCR (0.84) and HI (0.81), while the DCR showed strong negative correlations with APDM and APDMP, respectively -0.82 and -0.72 (Figure 3). These associations demonstrate that the exaggerated development of the aerial part impaired the growth in diameter of the roots to the detriment of the translocation of photoassimilates to favor DMCR and HI.

The principal component analysis (PCA) showed a total inertia of 91.37% of the total variation, coming from the sum of principal components (PC) 1 and 2, respectively, PC1 and PC2 (Figure 4). PC1 contributed 73.78% of the total variation and obtained a positive correlation with APDM, APDMP and S1 at all doses of P_2O_5 (0, 60, 120, 180 and 240 kg ha^{-1}), especially with the dose 60 kg ha^{-1} of P_2O_5. This result demonstrates that these variables are strongly associated with PC1 and essential for the original data's differentiation and structuring. In addition, the LCR variable showed a negative correlation, showing a different behavior from the other variables. PC2 contributed with 17.59% of the total variation and showed negative correlations with LCR, DCR and doses 0, 60 and 180 of P_2O_5 of the growing season S2, and positive correlations with DMCR, HI and doses 120 and 240 of P_2O_5 of S2.

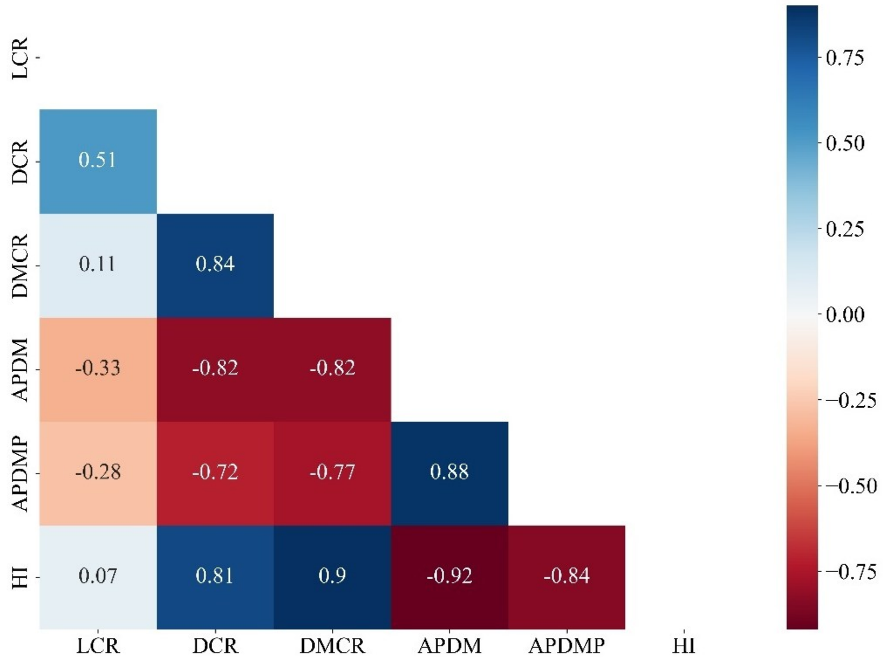

Figure 3. Pearson's correlation between root growth variables (LCR and DCR) and dry mass production (DMCR, APDM, APDMP and HI) of sweet potato cv. Paraná subjected to phosphorus doses in two growing seasons, S1 (April to August 2021) and S2 (December 2021 to April 2022).

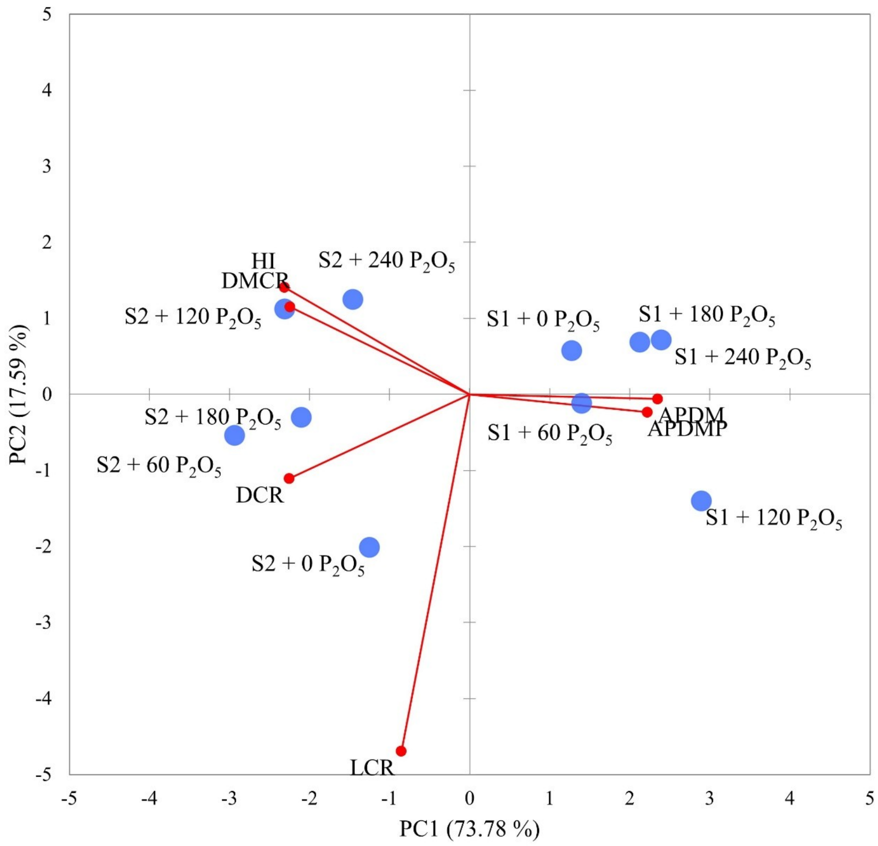

Figure 4. Principal component analysis (PCA) of root growth (LCR and DCR) and dry mass production (DMCR, APDM, APDMP and HI) variables as a function of phosphorus rates and growing seasons. S1 – growing season 1; S2 – growing season 2.

CONCLUSIONS

The dose of 60 kg ha^{-1} of P_2O_5 promoted the highest number of commercial roots, especially in growing season 2, and a predominance of roots with the same shape in both growing seasons, so this dose is recommended.

Commercial root dry mass and harvest index were higher in season 2, mainly for the 120 kg ha^{-1} dose of P_2O_5.

Dry mass production was higher in season 1, showing a strong correlation, with the 60 kg ha^{-1} dose of P_2O_5 standing out.

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