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Original Article

Nitrogen and potassium synergism influences the yield and quality of *Dioscorea cayennensis*

Sinergismo de nitrogênio e potássio influencia na produtividade e qualidade de *Dioscorea cayennensis*

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Abstract

This study aimed to evaluate yield, quality, nematode incidence, chlorophyll content, and primary foliar macronutrients of yam in response to nitrogen and potassium fertilization. A complete randomized block design was used in a factorial scheme (5 x 5), with five nitrogen (0; 60; 120; 180 and 240 kg ha^{-1} of N) and five potassium doses (0; 60; 120; 180 and 240 kg ha^{-1} of K_2O), with four replicates. The mass, total and commercial productivity of tubers, starch content, ash, leaf N, P, and K content, chlorophyll, and nematode incidence were evaluated. The average mass of tubers obtained was 1.935 kg with doses of 133 kg ha^{-1} of N and 105 kg ha^{-1} of K_2O. The dose of 178 kg ha^{-1} of N promoted maximum total tuber productivity (22.56 t ha^{-1}). The doses of 132 kg ha^{-1} of N and 118 kg ha^{-1} of K_2O resulted in maximum productivity of commercial tubers with 20.35 t ha^{-1}. Leaf N and K, starch, and ash contents were within the standards for yam. The incidence of *Meloidogyne*, *Scutellonema,* and *Pratylenchus* reduced with the increasing simple effect doses of N and K_2O. The maximum chlorophyll content was obtained at the dose of 240 kg ha^{-1} of N. The nitrogen and potassium interaction, despite the antagonistic effects on the accumulation of foliar P and starch, increased the productivity and average mass of commercial tubers, consequently ensuring the profitability of yam cultivation.

Keywords: mineral nutrition, nematodes, tuber quality, yam.

Resumo

Objetivou-se avaliar a produtividade, qualidade, incidência de nematoides, teor de clorofila e macronutrientes primários foliares do inhame em função das doses de nitrogênio e potássio. O delineamento experimental de blocos casualizados foi utilizado em esquema fatorial (5 x 5), com cinco doses de nitrogênio (0; 60; 120; 180 e 240 kg ha^{-1} de N), e cinco doses de potássio (0; 60; 120; 180 e 240 kg ha^{-1} de K_2O), com quatro repetições. As características avaliadas foram à massa média, produtividade total e comercial de túberas, teor de amido, cinzas, teor de N, P e K foliar, clorofila e a incidência de nematoides. A massa média de túberas foi de 1,935 kg com uso de 133 kg ha^{-1} de N e 105 kg ha^{-1} de K_2O. A dose de 178 kg ha^{-1} de N proporcionou máxima produtividade total de túberas (22,56 t ha^{-1}). As doses de 132 kg ha^{-1} de N e 118 kg ha^{-1} de K_2O, foram responsáveis pela produtividade máxima de túberas comerciais de 20,35 t ha^{-1}. Os teores de N e K foliar, amido e cinzas ficaram dentro padrão para o inhame. A incidência de *Meloidogyne*, *Scutellonema* e *Pratylenchus* foram reduzidas com aumento das doses de efeito simples de N e K_2O. A clorofila máxima foi observada na dose de 240 kg ha^{-1} de N. A interação nitrogênio e potássio apesar dos efeitos antagônicos sobre o acúmulo de P foliar e amido, promove aumento da produtividade e massa média de túberas comerciais, consequentemente, garante a rentabilidade do cultivo de inhame.

Palavras-chave: nutrição mineral, nematoides, qualidade de túberas, inhame.

1. Introduction

Yam (*Dioscorea* spp.) is widely consumed in the tropics and subtropics, being commonly used in African and Brazilian cuisine. This vegetable is cultivated in Brazil by family farming and plays an important socioeconomic role for the Northeast Region. In addition, it produces tubers of high nutritional value and its exploitation constitutes

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a viable alternative, as it has species adapted to tropical and subtropical conditions, relevant for supplying the domestic market and for export (Darkwa et al., 2020).

The growing dependence of crops on fertilizers and the concern about the environmental impact caused by their excess in the soil are factors that require constant attention with respect to the nutrient and quantity to be supplied (Rahman and Zhang, 2018). Nitrogen fertilization increases plant yield, as nitrogen constitutes compounds that act in various processes, such as photosynthesis and cell multiplication and differentiation (Taiz et al., 2017). Likewise, the supply of potassium favors plant development, due to its influence both in enzymatic activity and in the translocation of compounds to reserve organs (Hasanuzzaman et al., 2018).

In fertilization management, the most common interactions related to nitrogen are those with potassium, and these nutrients are absorbed in relatively high proportions and have non-competitive associations, where nitrogen promotes support for vegetative growth and potassium promotes the formation of tubers during the yam development cycle (Oliveira et al., 2015). This crop has nitrogen and potassium fertilization requirements, which vary according to the management (irrigated or rainfed), the species, and the soil and climatic conditions. However, doses ranging from 60 to 100 kg ha^{-1} of N (Santos and Macêdo, 1998; Santos et al., 2009; Cavalcante et al., 2008) and 30 to 90 kg ha^{-1} of K_2O (Cavalcante et al., 2008), are recommended for tubers yield incrementation.

Despite the lack of information on the N and K effects in *Dioscorea* spp. yield, Senanayake et al. (2022) reported an increase in biomass and yield of yam tubers due to increased nitrogen and potassium uptake given by nitrogen fertilization. However, when the isolated effect of nitrogen fertilization in different crops and yam species was evaluated, Hgaza et al. (2019) observed an increase in leaf area and tuber production. Moreover, in a potassium fertilization study, Oliveira et al. (2013) observed an increase in the commercial productivity of yams.

Thus, balanced fertilization with macronutrients can promote a profitable cultivation and reduce the phytosanitary problems common in yam tubers, including nematodes of the species *Scutellonema bradys* and *Pratylenchus* spp., which cause dry rot of yam, and *Meloidogyne* spp., which causes of root-knot nematode (Moura, 2006). Tubers with symptoms of the first-mentioned disease exhibit external cracks on the surface, darkened and dry areas, which extend from 2 to 4 cm deep, worsening throughout the storage period (Moura, 2006), consequently being excluded for export.

With regard to the root-knot nematode of the yam, it is possible to observe both a marked production of surface roots on the tubers, many of which with galls, because they do not have these roots when they are healthy, and large tumors with varied dimensions, where the nematodes at different stages are located, along with a mass of eggs (Moura, 2006). These tumors in the tubers are also factors that cause depreciation in the product for marketing, consequently reducing the profitability of the farmer. In addition, adequate nutrition can improve the quality of yams in relation to starch and ash contents (Oliveira et al., 2015). Therefore, the objective was to evaluate the yield, quality, nematode incidence, chlorophyll content and leaf primary macronutrients of yam as a function of nitrogen and potassium doses.

2. Material and Methods

The experiment was carried out under field conditions at the Chã-de-Jardim experimental farm of the Center for Agrarian Sciences of the Federal University of Paraíba (CCA/UFPB), Areia-PB, located in the *Brejo Paraibano* Microregion, Brazil (6° 57' 26" S and 35° 45' 30" W and altitude of 574.62 m). According to Köppen's classification, the climate is type As characterized as hot and humid, with average annual precipitation of 1.200 mm occurring from March to August. Weather conditions in the experimental period are presented in Figure 1.

The soil of the experimental area was classified as *Neossolo Regolítico* (Psamment) (Santos et al., 2018), with sandy loam texture. Soil samples were collected at 0-20 cm depth before setting up the experiment for analysis of chemical attributes. The chemical characteristics of the manure were also analyzed (Table 1), according to the Donagema et al. (2011).

The experimental design used was randomized blocks, with treatments distributed in a 5 x 5 factorial arrangement, corresponding to five nitrogen doses (0; 60; 120; 180 and 240 kg ha^{-1} of N), using ammonium sulfate as source, and five potassium doses (0; 60; 120; 180 and 240 kg ha^{-1} of K_2O) using potassium chloride as source, with four replicates. The experimental plots consisted of 60 plants (six rows of 10 plants), at 1.2 x 0.6 m spacing, and the usable area consisted of 32 plants contained in the four central rows.

Soil tillage was carried out by plowing, harrowing and raising of ridges with approximately 50 cm height, in order to provide favorable conditions for planting

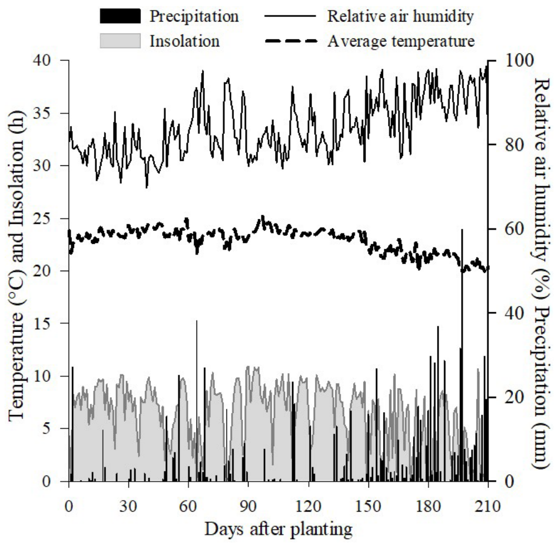

Figure 1. Maximum and minimum air temperature, relative air humidity, and precipitation during the period of cultivation for the yam.

Table 1. Chemical attributes of the soil in the experimental area and cattle manure.

Chemical characteristics soil										
pH	P	K^+	Na^+	$H^+ + Al^{3+}$	Al^{3+}	Ca^{2+}	Mg^{2+}	SB	CEC	O.M.
H_2O (1:2.5)	------ mg dm^{-3} -----		-----------------------------$cmol_c$ dm^{-3}------------------------							g kg^{-1}
6.48	85.14	95.05	0.22	2.39	0.00	2.35	1.15	6.15	8.54	8.79
Chemical characteristics cattle manure										
		M	N	P	K	Ca	Mg	O.M.		
		(%)	--------------------------g kg^{-1}--------------------------							
		4.95	7.22	4.1	9.45	2.10	3.00	120.2		

P = phosphorus; K^+ = Potassium; Na^+ = Sodium; H^+ = Hydrogen; Al^{+3} = Aluminum; Ca^{+2} = Calcium; Mg^{+2} = Magnesium; SB = Sum of Bases; CEC = Cation exchange capacity; O.M. = Organic Matter; M = Moisture; N = Nitrogen.

and development of the tubers. Fertilization at planting consisted of the application of 15 t ha^{-1} of bovine manure, 100 kg ha^{-1} of P_2O_5 (single superphosphate) and 50% of the potassium doses described in the experimental design, while top-dressing fertilization comprised nitrogen doses, split into equal portions and applied at 60 and 90 days after planting and 50% of potassium doses, respectively. Planting was carried out with pieces of seed-tubers, cultivar 'Da Costa', with average mass between 150 and 200 g.

During the field experiment, manual weeding was performed with a hoe to keep the area free of weeds. In each weeding operation, soil was piled up to keep the ridges well-formed and protect the tubers against the effect of sun rays. In the periods of absence of precipitation, water was supplied by a drip system (drip tape with 11 L h^{-1} m^{-1}), with a two-day irrigation interval.

SPAD index measurements were performed with the Portable Chlorophyll Meter SPAD-502 [Soil-Plant Analysis Development (SPAD) Section, Minolta Camera Co. Ltd., Japan], at 150 days after planting. Ten plants per plot were selected for the evaluations, carried out on the 6th to the 8th leaf positioned at the apex of the vine. From the three readings, the average of each sampled leaf was calculated using the SPAD meter itself. The values obtained in the 10 plants were used to calculate the average of the plot.

Initially, at 150 days after planting, 64 leaves were collected from the median part of the plants located in the four central rows of each plot, eliminating one plant from the ends of the rows. Subsequently, they were taken to the Soil Chemistry and Fertility Laboratory of the CCA/UFPB to determine the leaf N, P and K contents, according to the methodology of Tedesco et al. (1995).

For guiding plant growth, the traditional staking system was adopted (a stake of approximately 1.50 m height). Harvest was performed manually at seven months after planting, when the tubers were immature, characterized by the end of flowering and drying of flowers, called early harvest or "capação". Harvested tubers were transported to the storage sector to determine the production characteristics.

The average mass of marketable tubers was obtained through the relationship between the total mass of tubers and the number of marketable tubers, expressed in kilogram. Marketable tubers were considered those with a mass between 1.5 and 3.0 kg, as described by Santos (1996). Total yield corresponded to the weight of all tubers harvested, while marketable yield corresponded to the sum of the weights of tubers with mass ranging from 1.5 to 3.0 kg.

The incidence of diseases caused by nematodes was determined by counting yam tubers with symptoms of dry rot of yam (DR) and root-knot nematode (RK), with values expressed in percentage according to the formula: DR or RK% = (Diseased Tubers/Total of healthy tubers) x 100.

Quality parameters were analyzed by collecting five samples of fresh marketable tubers, taken at random of each plot, and transporting them to the Laboratory of Biology and Post-harvest Technology of CCA/UFPB, to determine the contents of ash and starch, according to the analytical standards of the Adolfo Lutz Institute (IAL, 2005).

Data were analyzed for normality by the Shapiro-Wilk test and homogeneity of variances by the Bartlett test and then submitted to analysis of variance by the F test ($p < 0.05$). The significant results (ANOVA) obtained were subjected to polynomial regression analysis to evaluate the effect of nitrogen and potassium doses on the evaluated characteristics, testing the linear, quadratic effects and N x K interaction. The significance of linear and quadratic coefficients and N x K interaction were verified. The criteria for choosing the model were the significance of the F test and a coefficient of determination (R^2) greater than 0.50. R Core Team (2022) software was used to perform the analyses and response surface graphs were made using the SigmaPlot®, 12.5-version software (Systat Software, San Jose, CA, EUA). The maximum efficiency doses were obtained by deriving the equation from the graph, using the 'GA' library of the R software (Scrucca, 2013).

3. Results

There were effects of interaction ($p < 0.01$) between nitrogen (N) and potassium (K) doses on both the average mass (Figure 2), the starch (Figure 3A) and ash (Figure 3B) contents, as well as on the marketable yield (Figure 4B) of yam tubers, that is, both nutrients interfere simultaneously

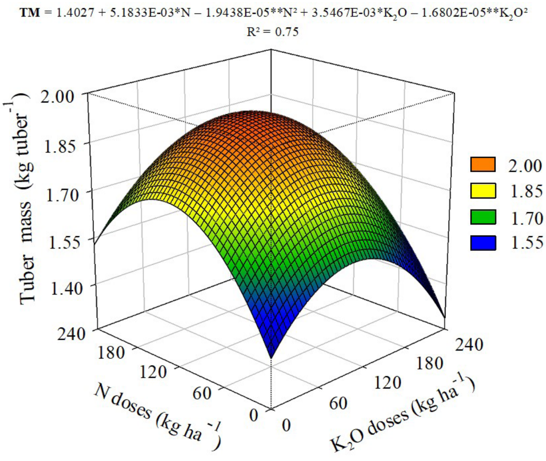

Figure 2. Average tuber mass as a function of nitrogen and potassium fertilization (**, * significant at 1%, and 5%, respectively). TM = Tuber mass.

in these variables. For total yield (Figure 4A) and incidence of root-knot (Figure 5A) and dry rot (Figure 5B), there were simple effects of N ($p < 0.01$) and K ($p < 0.01$) doses.

The average tuber mass increased by 1.935 kg with the use of 133 kg ha^{-1} of N and 105 kg ha^{-1} of K_2O, respectively (Figure 2), whereas higher doses of N and K reduced the average tuber mass.

The starch content decreased linearly with the increase of N and K_2O doses, reaching the maximum value of 27.30% (Figure 3A). Regarding the ash content, the N and K_2O doses of 133.60 and 154.75 kg ha^{-1}, resulted in the production of tubers with contents of 2.14% (Figure 3B), and these value were appropriate for the genus.

The N dose of 178 kg ha^{-1} promoted maximum total tuber yield of 22.56 t ha^{-1}, with an increase of 36.34%, followed by successive reductions with higher N doses. The mathematical models studied did not fit significantly to the data of K application, which showed an average of 19.74 t ha^{-1} as a function of K_2O doses (Figure 4A). In the

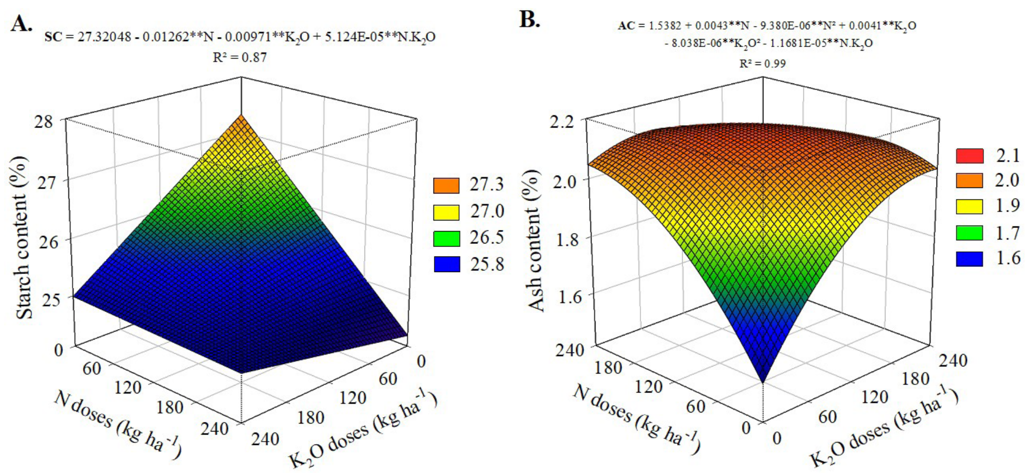

Figure 3. Starch (A) and ash (B) contents of tubers as a function of nitrogen and potassium fertilization (** significant at 1%). SC = Starch content. AC = Ash content.

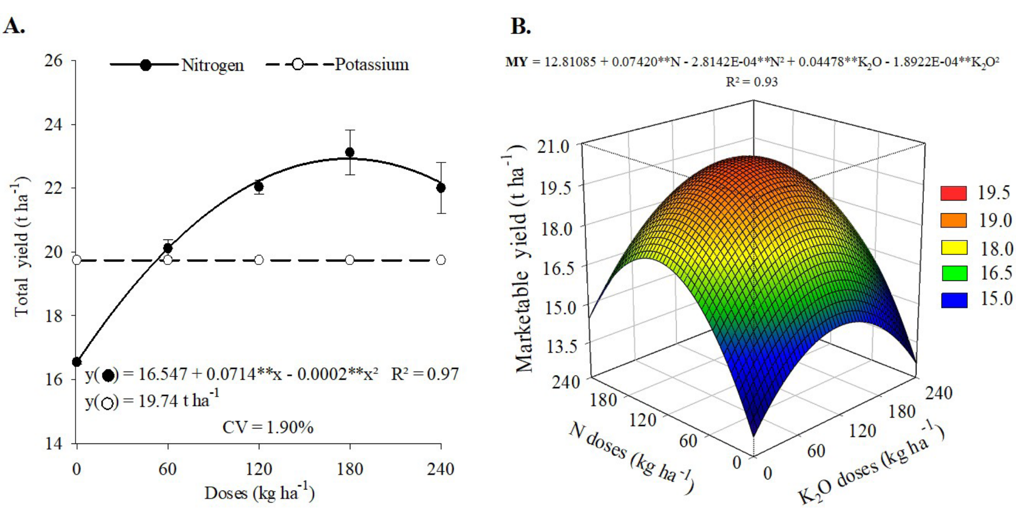

Figure 4. Total yield (A) and marketable yield (B) of tubers as a function of nitrogen and potassium fertilization (** significant at 1%). MY = Marketable yield. CV = Coefficient of variation.

marketable yield of yam, there was increment of 58.86% up to the doses of 132 kg ha^{-1} of N and 118 kg ha^{-1} of K_2O, with decreases from these doses (Figure 4B).

The application of N doses reduced the incidence of dry rot in yam tubers caused by *Pratylenchus* spp. and *Scutellonema bradys* nematodes, resulting in a minimum percentage of 4.4% at the dose of 195 kg ha^{-1}, with a reduction of 46% compared to the control treatment (8.1%). Incidence of 5.2% was observed as a function of the application of K_2O doses (Figure 5A). There was also a linear reduction in the incidence of root-knot disease caused by *Meloidogyne* spp. from 28 and 23.4% (control treatment) to minimum values of 10% and 11.7% with application of the maximum doses of N and K_2O, respectively, resulting in 64 and 50% reductions in the incidence of this disease in yam tubers (Figure 5B).

The SPAD index increased by 15.45% with N doses, reaching a maximum of 52.02 at the dose of 240 kg ha^{-1} (Figure 6A). Leaf N contents increased with the supply of N and K_2O doses, reaching maximum values of 41.3 g kg^{-1} at the highest N dose (240 kg ha^{-1}) and 38.0 g kg^{-1} at K_2O dose of 73 kg ha^{-1} (Figure 6B). Leaf P (Figure 6C) and K (Figure 6D) contents were influenced by the interaction between the doses and nutrients studied. Leaf P contents decreased with increasing N and K_2O doses, reaching a minimum value of 1.376 g kg^{-1} (Figure 6C).

There was no effect of interaction between N and K_2O doses for the SPAD index, only the simple effect of N. Leaf N content was affected by the simple effect of N and K_2O doses, but leaf P and K contents were influenced by the interaction between the doses and nutrients studied. Leaf K contents also decreased with increasing N doses. However, the supply of K_2O at the maximum dose led to a concentration of 26.5 g kg^{-1} in the yam leaf.

4. Discussion

The results showed that nitrogen (N) and potassium (K) act in increasing the production of yam tubers and reduce nematode infection, due to their functions in plant metabolism. As N is an essential constituent of enzymes and chlorophyll, consequently, it influenced the expansion of the leaf area (Liang et al., 2020a; Hussain et al., 2021), the photosynthetic rate and the increase in the concentration of photoassimilates in the leaves, which are later distributed to the storage organs (Coskun et al., 2017), increasing the production potential. Conversely, the action of K may be related to the activity of the starch synthase enzyme in the use of carbohydrates for starch formation (Hasanuzzaman et al., 2018). In addition, the nitrogen and potassium interaction also favors plant metabolism, mainly through co-operative uptake, internal transport and utilization of NO_3^- and K^+, as well as the alleviation of NH_4^+ toxicity, which are essential for source-sink ratio (Coskun et al., 2017).

The values of average tuber mass found in this study were adequate for marketing, as they are within the ideal range (1.5 to 3.0 kg) defined by Santos (1996), expressing the importance of these nutrients in improving the accumulation of mass by yam (Dantas et al., 2013). Therefore, combining N and K also favors biomass accumulation since optimum potassium levels can increase the nitrogen use efficiency involved in photosynthetic processes, which are based on the diffusion and fixation of CO_2, generating photoassimilates that are used by plants (Xu et al., 2020), such as tubers. Hence, these results show that the interaction between K and N positively affects the average mass accumulation of *Dioscorea* spp.

The yields obtained with both nutrients were higher than the average in the Northeast Region, of 9.6 t ha^{-1}, as described by Garrido et al. (2017), demonstrating that

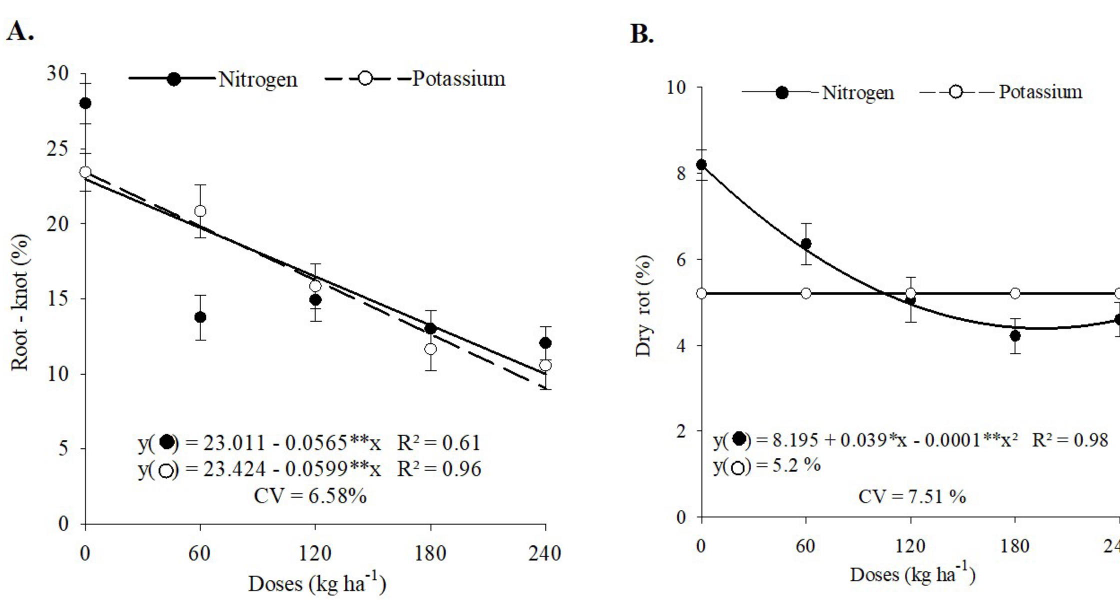

Figure 5. Root-knot (A) and dry rot (B) of yam tubers as a function of nitrogen and potassium fertilization (**, * significant at 1%, and 5%, respectively).

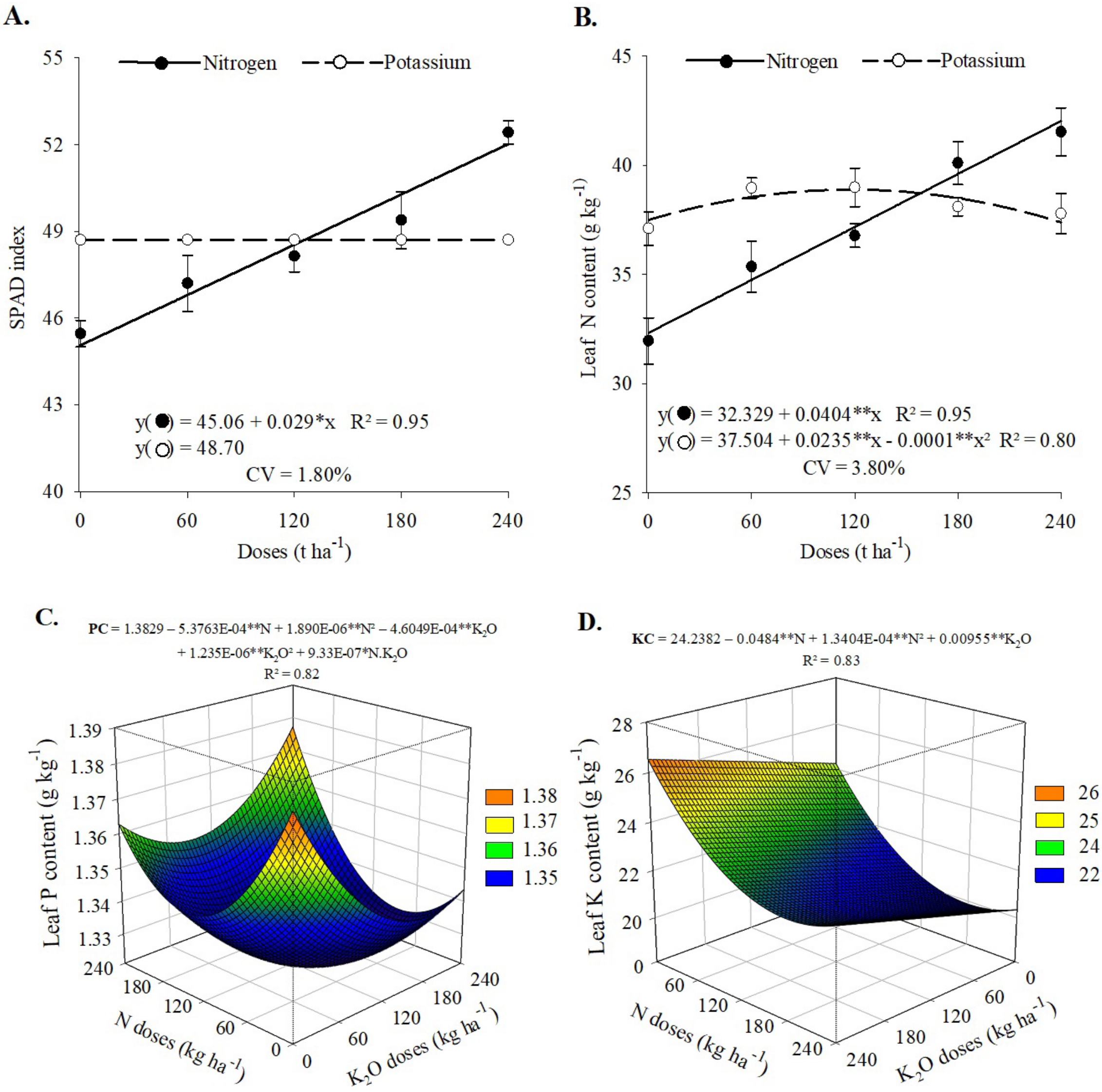

Figure 6. SPAD index (A) and leaf nitrogen (B), phosphorus (C) and potassium (D) contents as a function of nitrogen and potassium fertilization (**, * significant at 1%, and 5%, respectively). PC = Phosphorus content. KC = Potassium content.

high yields in yam can only be obtained when N and K are available for plants in all growth stages and with amounts capable of avoiding antagonism among them (Oliveira et al., 2015). The commercial productivity was evaluated isolated and reached 17.7 and 15.4 t ha^{-1}, respectively, in response to nitrogen and potassium fertilization. However, this productivity reached 20.3 t ha^{-1} due to the interaction of these nutrients, a total increment of 14.7% and 31.8% compared to the isolated fertilizations, respectively. The increase in commercial productivity can be attributed to photosynthetic activity and the water use by plants throughout the crop cycle, caused by the interaction of nitrogen and potassium.

Senanayake et al. (2022) evaluated the effects of the nitrogen and potassium interaction on the production of *Discorea alata* and attributed the higher yield of tubers to nitrogen fertilization due to an increase in the uptake of nitrogen and potassium by the plants. However, some scientific reports with the *Ipomoea batatas* (Pushpalatha et al., 2017; Foloni et al., 2013) have shown an increment in commercial yield due to the interaction between nitrogen and potassium fertilization, possibly due to the influence of nitrogen on the plant photosynthetic apparatus combined with the activity of potassium in the Rubisco enzyme, ensuring the synthesis of vital organic compounds for plant production (Taiz et al., 2017; Xu et al., 2020). Based on the results obtained, the interaction of these nutrients also increased the commercial productivity of *Dioscorea cayennensis*.

The recommendation for N application in yam (*D. cayennensis*) in the Northeast region ranges from 62 to 80 kg ha^{-1} (Santos et al., 2009; Cavalcante et al., 2008) and, when irrigated, can reach 100 kg ha^{-1} (Santos and Macêdo, 1998). These doses are lower than those estimated in the present study (131.8 kg ha^{-1}) required to obtain the maximum marketable yield of 17.7 t ha^{-1}, which can be explained by the low organic matter content initially found in the soil (8.79 g dm^{-3}). Dantas et al. (2013) emphasize that soils with low organic matter content can allow lower N availability to crops, resulting in one of the main limitations to agricultural yield.

In this context, Santos et al. (2015) evaluated the effect of N sources and obtained maximum marketable tuber yield of 19.7 t ha^{-1} at the N dose of 130.0 kg ha^{-1}. Therefore, a behavior similar to the study was observed, where the marketable yields were obtained with doses above those recommended in the Northeast Region, demonstrating the need for higher N doses under the edaphoclimatic conditions of *Brejo Paraibano*.

Regarding K, the required dose (118 kg ha^{-1}) for maximum marketable yield was also higher than that recommended by Santos (1996) and Cavalcante et al. (2008), which ranges from 30 to 90 kg ha^{-1} of K_2O for *D. cayennensis*. This may be related to the sandy characteristic of the experimental area, which favors the leaching of K present in the soil solution and due to the high level of calcium in the soil, which competes for the same adsorption site with potassium. As well as the high concentrations of sulfate present in the nitrogen source, capable of mobilizing/leaching this nutrient in the form of potassium sulfate (K_2SO_4), directly contributing to the increase in the potassium dose. (Motesharezadeh et al., 2021). Huang and Hartemink (2020) reported that sandy soils generally have high hydraulic conductivity and low cation exchange capacity, and to maintain crop yield in these soils, it is necessary to use irrigation and inorganic and organic fertilizers. Under the same soil conditions as the present study, Oliveira et al. (2013) evaluated K doses in yam and found that 189 kg ha^{-1} of K_2O was required for the yam to reach maximum marketable yield (17.4 t ha^{-1}), a dose higher than that of the present study and the recommendation for the Northeast Region, but showing the deficiency of the sandy soil and the response of this species to K.

However, the interaction between N and K in the plant is important to maintain the doses in adequate amounts for a profitable and environmentally friendly cultivation, considering the factors of cultivation and the edaphoclimatic conditions of the area. This is because the excess of these nutrients causes a reduction in yam yield and result in intense growth of the aerial part, to the detriment of tuber production. In this study, maximum marketable yields were reduced when the N and K_2O doses exceeded 132 and 118 kg ha^{-1}, respectively. Dantas et al. (2013) verified a reduction in the marketable yield of yam with N doses above 154 kg ha^{-1}, as well as Oliveira et al. (2013), when they supplied K_2O in amounts greater than 189 kg ha^{-1}. The recommendation of doses depends on several factors, such as the level of yield, nutrient content in the soil, type of soil, climate, irrigation, fertilizer efficiency, among others.

According to the results, the fertilization of the yam mainly with N may be an alternative to improve tuber health, as it reduced the incidence of nematodes, corroborating the findings of Liang et al. (2020b), who reported that the addition of N may restrict (>50 g of N m^{-2} $year^{-1}$) the survival capacity of some nematodes and reduce their abundance in the soil. In addition, N assimilation represents a direct link with the generation of nitric oxide (NO), which plays a positive role in the local and systemic resistance acquired by plants, as reported by Sun et al. (2020). In addition, K application also confers resistance to nematode attacks by increasing the concentration of phenolic acids, which are secreted by plant roots, conferring allelochemical effects on soil phytopathogens (Gao et al., 2018). Consequently, with the reduction of infection by these phytonematodes, the crop showed higher yield.

In relation to the quality of yam tubers, it was noticeable that there was a reduction in starch contents as a function of the increase in the doses of both nutrients, which is possibly related to the addition of N in high amounts, as it reduces the concentration of amylopectin under conditions of excess water in the soil (Wang et al., 2008). Despite favoring photosynthesis and translocation of assimilates from the source (photosynthetic leaves) to the sink (tubers) (Taiz et al., 2017), K can significantly reduce the amylose content and particle size of starch, when supplied in high quantities, as described by Zhang et al. (2018), working with potato. Amylose and amylopectin are major constituents of starch that possibly were in deficit due to the increasing doses of nitrogen and potassium which affected its accumulation in yam tubers.

However, the observed contents are considered adequate because they are within the acceptable range for *Dioscorea* spp., from 11 to 30% (Silva et al., 2019). Brito et al. (2011) reported starch content (29.5%) close to that of the present study for fresh tubers. In addition, other reports show values close to 40% (Riley et al., 2006). Therefore, this characteristic can vary according to both the intrinsic characteristics of each species and the edaphoclimatic conditions and crop management.

Regarding the N and K interaction on the starch content, there is a possible synergism that guarantees the accumulation of high amounts of both nutrients in the plant, resulting in an efficient accumulation of starch when the lower dose was applied since the increase in the dose caused a decrease in the starch content. It is noteworthy that a high internal concentration of potassium and nitrogen in the plant can favor moisture content in its organs and promote vegetative development (Hasanuzzaman et al., 2018). However, it reduces the mobilization of photoassimilates to storage organs and impairs starch composition (Wang et al., 2008; Zhang et al., 2018).

The increase in K_2O dose may be the main influence on the increase in the ash contents of yam tubers, since Oliveira et al. (2006), who evaluated the effect of N fertilization on the same species and edaphoclimatic conditions, reported lower ash contents (0.79 and 0.82%) compared to those found in the present study at the same harvest time (seven months). Corroborating this, Senanayake et al. (2013) analyzed the physicochemical composition of three species of *Dioscorea* spp. and observed high K contents in all ash samples, which was attributed to the use of K-rich fertilizers. Based on this, the interaction of the nutritional factors evaluated may also have contributed to the increase in ash content since nitrogen in the nitrate form ($NH3^-$) can favor K^+ absorption, increasing its concentrations in different plant organs (Coskun et al., 2017).

The better result of the SPAD index under N fertilization was obtained possibly because it influences the chlorophyll content of the plant, as described by Silva et al. (2011). Takada et al. (2018) reported that the SPAD index (<40) was higher in yam treated with N, in the period of greatest growth of the aerial part. Thus, it is suggested that the SPAD index may be influenced by N fertilization and vary due to both cultivation factors (species, cultivar and environment) and plant development stage.

The N contents as a function of the use of N and K_2O are within the range from 30 to 48 g kg^{-1}, considered normal for tuber vegetables (Prezotti and Martins, 2013). Similarly, Dantas et al. (2013) and Santos et al. (2015) also obtained contents within the standard, 34.5 and 36.5 g kg^{-1}, respectively, evaluating N doses in the same species and edaphoclimatic conditions. The higher leaf N content at the maximum dose of N may indicate that the plant did not reach saturation with respect to this nutrient, due to a possible constant absorption influenced by soil moisture. Mirzakhani and Sajedi (2015) reported that plants in the absence of water stress absorb more N, which influences leaf N accumulation and chlorophyll synthesis. Regarding fertilization with K_2O, there is a negative influence on leaf N accumulation with the increase of its doses, attributed to the excess of K fertilizer, which inhibits the absorption of other nutrients, such as N or magnesium, because of competition for root absorption mechanisms, as described by Sardans and Peñuelas (2021).

The P content is below the common values in tuberous species, from 2.5 to 5.0 g kg^{-1} (Prezotti and Martins, 2013), possibly because high concentrations of K inhibit inorganic P uptake and negatively regulate phosphate uptake genes (Ródenas et al., 2019). Likewise, N at high doses in the soil can cause disorder in the allocation and absorption of phosphorus by plants. The interaction of these nutrients also promoted adverse effects on the accumulation of foliar P. However, the mechanisms of this interaction that trigger such effects still need further studies at the molecular level.

The leaf K content is within the average range for agricultural plants (4 to 43 g kg^{-1}), according to Batista et al. (2018). Oliveira et al. (2013), evaluating K_2O doses in the same species, also obtained results within the appropriate concentration range (22.3 g kg^{-1}). The interaction between nitrogen and potassium on the accumulation of K leaf content probably occurred due to the nitrogen effect, as it turns into different forms in the soil that affect the absorption of potassium and other nutrients, such as sulfur and boron. Senanayake et al. (2022) also observed that nitrogen influenced potassium accumulation in Dioscorea spp. plants. Therefore, the decrease in the K content in leaves as a function of N doses is related to the marked inhibition effect by NH_4^+ on the high-affinity K^+ absorption system, occurring under low and high K^+ conditions, due to a hyperpolarization of the electrical potential of the plasma membrane (Coskun et al., 2017).

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