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Seed tuber size, staking practices and fertilization on purple yam productivity

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Abstract – The objective of this work was to evaluate the effects of seed tuber weight, staking system, and planting fertilization on the purple yam (*Dioscorea trifida*) crop. The experiment was conducted in the municipality of Caapiranga, in the state of Amazonas, Brazil. A randomized complete block design was used in a 3x2x5 factorial arrangement with four replicates. Three staking systems (intercropping with cassava, smooth wire espalier, and wooden stakes), two seed tuber weights (100 and 300 g), and five fertilization practices [no fertilization or soil correction, poultry manure (PM), triple superphosphate (TS), PM + TS, and PM + TS + dolomitic limestone] were evaluated. The assessed traits were number of tubers per plant, tuber weight (g), and tuber yield (Mg ha^{-1}). The treatments containing PM yielded superior results for all evaluated traits. The highest mean values for number of tubers and total tuber yield are obtained in the espalier and wooden stake systems. In addition, 300 g seed tubers produce a significantly higher tuber number and total yield.

Index terms: *Dioscorea trifida*, Amazon region, crop science, poultry manure, tuber yield.

Tamanho de tubérculo, práticas de estaqueamento e adubação sobre a produtividade de inhame-roxo

Resumo – O objetivo deste trabalho foi avaliar os efeitos do tamanho de tubérculo-semente, do sistema de tutoramento e da adubação de plantio no cultivo de inhame-roxo (*Dioscorea trifida*). O experimento foi conduzido no município de Caapiranga, no estado do Amazonas, Brasil. Utilizou-se delineamento experimental de blocos ao acaso, em arranjo fatorial 3x2x5 com quatro repetições. Foram avaliados: três sistemas de tutoramento (consórcio com mandioca, espaldeira e estaca), dois pesos de tubérculos-semente (100 e 300 g), e cinco tipos de adubação [sem adubação ou correção do solo, esterco de aves (EA), superfosfato triplo (ST), EA + ST e EA + ST + calcário dolomítico]. As características analizadas foram número de tubérculos por planta, peso de tubérculo (g) e produtividade de tubérculos (Mg ha^{-1}). Os tratamentos contendo EA apresentaram os melhores resultados para todas as características. As maiores médias para número e produtividade de tubérculos são obtidos nos sistemas de tutoramento em espaldeira e em estaca. Além disso, o tubérculo de semente de 300 g apresenta médias significativamente maiores para número e produtividade de tubérculos.

Termos para indexação: *Dioscorea trifida*, região Amazônica, fitotecnia, esterco de aves, produtividade de tubérculos.

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Introduction

In the Amazon region, purple yam (*Dioscorea trifida* L.f.) is commonly consumed at breakfast or during main meals because it has high levels of energetic value (365 kcal 100 g^{-1}), carbohydrates (87.42 g 100 g^{-1}), and potassium (981 mg 100 g^{-1}) alongside a low total fat content at 0.26 g 100 g^{-1} (Rosas et al., 2024; Ferrari & Ferrari, 2025). Although the Amazon's climate is favorable for its cultivation, local production is hindered by logistical challenges and a notable lack crop-specific scientific research (Ferrari & Ferrari, 2025).

Shifting cultivation is still practiced on family farms, and involves clearing new areas and frequently employs slash-and-burn techniques, which leads to soil depletion (Bieluczyk et al., 2025). Nevertheless, appropriate management techniques can maintain high yam yield levels over time while preserving soil quality (Oshunsanya et al., 2022; Chen et al., 2023). For instance, implementing a staking system increases yields by expanding the plant's photosynthetic area (Oshunsanya et al., 2022). The most common staking method uses a wooden stake to prevent direct contact between the plant and the soil, typically placed beside the plant at the time of planting or upon emergence (Oshunsanya et al., 2022). However, reliance on wooden stakes cut from native forests raises significant environmental concerns, contributing to deforestation and biodiversity loss (Bertino et al., 2022; Abrell et al., 2024).

In the Amazon, organic fertilizers are more used than mineral fertilizers due to their lower cost and local availability (Mendonça et al., 2024). Although soils in the Amazon region are generally clayey with good permeability indices, they are characterized by high aluminum content, dystrophic conditions, and low phosphorus concentration. Under such conditions, the combined or isolated use of organic and chemical fertilizers can contribute to higher yield (Abrell et al., 2024). Among the organic options available in the region, poultry manure (PM) stands out because its application improves soil fertility by increasing cation exchange capacity and nutrient release, thereby enhancing the physical, chemical, and biological properties of the soil (Ning et al., 2022; Minkina et al., 2023; Mendonça et al., 2024).

Ultimately, increased yam yields can ultimately be achieved through a combination of proper staking, optimal fertilizer selection, and the correct choice of seed tuber weight (Hamaoka et al., 2022; Chen et al., 2023; Pelemo et al., 2025). Because all these factors can significantly affect crop production, characterizing their influence and recommending the best combination for yam cultivation in the Amazon region is of paramount importance.

The objective of this work was to evaluate the effects of seed tuber weight, staking system, and planting fertilization on the purple yam crop.

Materials and Methods

The experiment was conducted in a dryland area in the municipality of Caapiranga, in the state of Amazonas, Brazil (03º11'57"S, 61º10'33"W, at 39 m of altitude) between October 2016 and September 2017. The climate is classified as humid tropical climate, with a mean annual temperature of 27°C, and the soil is classified as a Latossolo Amarelo, according to Brazilian Soil Classification System (Santos et al., 2025), equivalent to an Oxisol. A local *D. trifida* variety, maintained by the producers, was used. The meteorological data recorded during the experiment are shown in Figure 1 (Sparks, 2018), and the soil chemical characteristics in the 0-20 cm soil layer is provided in Table 1.

The experiment was arranged in a 3x2x5 factorial arrangement in a randomized complete block design with four replicates. The study factors were three different staking systems (S): intercropping with cassava, smooth wire espalier, and wooden stakes; two seed tuber weights (W): 100 g and 300 g; and five distinct planting fertilization techniques (F): no soil amendment or fertilization as a control treatment, 10 Mg ha^{-1} PM, 60 kg ha^{-1} triple superfosfate (TS), 10 Mg ha^{-1} PM + 60 kg ha^{-1} TS, 10 Mg ha^{-1} PM + 60 kg ha^{-1} TS + 3 kg dolomitic limestone (LI) per plot.

Each experimental plot consisted of a 13 m^2 bed measuring 10 linear meters in length by 1.30 m in width, with a height of 0.25 m and linear spacing of 0.35 m. The spacing between plant rows was 1.65 m, and the spacing within rows was 1.30 m, totaling 11 yam plants per plot and 6,734 plants ha^{-1}. The espalier height was 1.50 m, constructed using stakes and a single wire. The staking system height was also 1.50 m, with a tie used on each plant to direct growth. Due to their similar growth cycles, cassava and yam were planted

simultaneously. However, cassava showed greater initial development, allowing it to serve as a support for the yam. In the intercropping system, the yam plant density was maintained, with cassava planted 0.45 m from each yam hill, occupying the midpoint between two yam hills.

Conventional soil preparation was performed, and the seedbeds were raised using a rotary tiller. Manual fertilization of the plots consisted of 60 kg ha^{-1} TS, 10 Mg ha^{-1} PM, and 3 kg of limestone per plot, applied according to each treatment. Following application, the rotary tiller was used again to incorporate the fertilizer into the soil. Planting was carried out in a row of holes dug along the center of the seedbed, with three seed tubers per hole spaced 0.20 m apart. Forty days after emergence of the seed tuber shoots, topdressing was manually applied to all experimental plots, except the control. This consisted of 45 kg ha^{-1} of nitrogen and 80 kg ha^{-1} of K_2O. The nitrogen, phosphorus, and potassium fertilization recommendations for planting and topdressing were adapted from Dias et al., (2004).

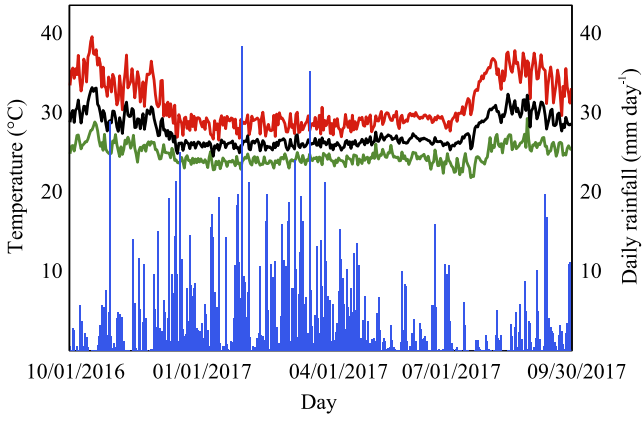


Figure 1. Meteorological data graph for mean temperature values in the black line, minimum temperature in the green line, maximum temperature in the red line, and precipitation in the blue column during the experiment performed from October 2016 to September 2017, in the municipality of Caapiranga, in the state of Amazonas, Brazil.

No diseases or pests were observed during visual inspections throughout the experiment. Weeds were controlled by manual weeding for the first 150 days of cultivation. Due to the favorable rainfall distribution during the cultivation period (Figure 1), supplemental irrigation was not required. The crop was harvested 10 months after planting, allowing for a single harvest carried out manually with the aid of a hoe.

The evaluated traits were mean number of tubers $plant^{-1}$ (NTP), tuber weight (TW) in g $tuber^{-1}$, and tuber yield (TY) in Mg ha^{-1}. The number of tubers was evaluated by counting all tubers harvested from each plot, as the local market absorbs them regardless of size. Tuber weight was calculated as the mean tuber weight for the plot, and tuber yield was obtained by extrapolating the plot yield to a per hectare basis.

The data were subjected to analysis of variance (ANOVA), and mean comparisons were performed using Tukey's test when significant differences were observed. The statistical model used for the analysis of variance was:

$$y_{ijkl} = \mu + \omega_l + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + \varepsilon_{ijkl},$$

where y_{ijkl} is the observed trait value, μ is the overall mean effect, ω_l is the effect of the l-th block (l = 1, 2, 3 and 4), α_i is the effect of the i-th staking system (i = 1, 2, and 3), β_j is the effect of the j-th seed tuber weight (j = 1, and 2), γ_k is the effect of the k-th fertilization concentration (k = 1, 2, 3, 4 and 5), $\alpha\beta_{ij}$ is the two-way interaction between S and W, $\alpha\gamma_{ik}$ is the two-way interaction between S and F, $\beta\gamma_{jk}$ is the two-way interaction between W and F, $\alpha\beta\gamma_{ijk}$ is the three-way interaction between the three factors, and ε_{ijkl} is the random error. All statistical analyses and graphs were performed using R software version 4.3.2 (R Core Team, 2023).

Table 1. Physical and chemical soil characteristics recorded in the experimental area at a depth of 0 to 20 cm for the experiment performed in 2016 and 2017, in the municipality of Caapiranga, in the state of Amazonas, Brazil.

pH	Na^+	$H^+ + Al^{+3}$	Al^{+3}	Ca^{+2}	Mg^{+2}	SB	T	K^+	P	OM
Water	($cmol_c\ dm^{-3}$)							($mg\ dm^{-3}$)		($g\ kg^{-1}$)
4.43	3.0	4.8	3.74	0.46	0.32	0.85	5.65	22.0	1.0	32.08

Results and Discussion

Overall, mean values were 15.54 tubers per plant for NTP, 148.21 g tuber^{-1} for TW, and 14.88 Mg ha^{-1} for TY (Table 2). The coefficients of variation of the experiment ranged from 24.84% for NTP to 34.68% for TY (Table 2). In the analysis of variance, the three-way interaction was not significant for any of the evaluated traits with p-values of 0.3604, 0.3627, and 0.4190 for NTP, TW and TY, respectively. Given the absence of significant three-way interactions, the significant two-way interactions were evaluated. For NTP, the significant two-way interactions were between S x W ($p = 0.0009$), and S x F ($p = 0.0308$). TW presented no significant two-way interactions between S x W ($p = 0.6058$), S x F ($p = 0.2275$), and F x W ($p = 0.6365$), with only the main effect of fertilization showing significance ($p<0.0001$). For TY, significant two-way interactions occurred between S x F ($p = 0.0369$) and S x W ($p = 0.0476$).

For NTP, analysis of the S × F interaction showed that espalier and wooden stake systems produced the highest mean values under three specific fertilization treatments (Figure 2 A). With PM application, espalier and wooden stake yielded 20.32 and 18.45 tubers per plant, respectively. Under PM + TS, values reached 18.43 tubers per plant for espalier and 20.31 tubers per plant for wooden stake, whereas under PM + TS + LI, tuber numbers rose to 21.54 tubers per plant for espalier and 21.15 tubers per plant for wooden stake.

Analysis of the two-way interaction between S and W for NTP showed that the staking system showed a significant effect only when using the 300 g seed tuber. Conversely, the seed tuber weight significantly influenced NTP only under the espalier and wooden stake systems (Figure 2 B). Within this seed weight and specific staking systems, the espalier and wooden stake systems presented the highest means at 18.17 and 20.27 tubers per plant, respectively.

For TW, only the main effect of fertilization was significant (Table 2 and Figure 3). The fertilization types yielding the highest TW values were PM + TS + LI at 170.93 g tuber^{-1}, PM + TS at 161.42 g tuber^{-1}, and PM at 160.88 g tuber^{-1}.

For TY, within the espalier and wooden stake systems, the highest means were recorded under PM (19.20 and 20.44 Mg ha^{-1}, respectively), PM + TS (18.18 and 20.31 Mg ha^{-1}) and PM + TS + LI (24.40 and 22.28 Mg ha^{-1}) as seen in Figure 4 A. In the intercropping system, the highest TY means were obtained with PM at 14.77 Mg ha^{-1}, TS at 11.28 Mg ha^{-1}, PM + TS at 15.41 Mg ha^{-1} and PM + TS + LI at 13.85 Mg ha^{-1}.

Within the S x W interaction, seed tuber weight showed a significant effect only in the wooden stake system (Figure 4 B). Specifically, using 300 g seed tuber resulted in the highest mean of TY mean at 19.30 Mg ha^{-1}. When comparing staking systems, a significant effect was observed only when the 300 g

Table 2. Analysis of variance for the mean number of tubers per plant (NTP), mean tuber weight (TW), and total tuber yield (TY) of purple yam (*Dioscorea trifida*), as a function of the staking system, fertilizer, tuber size and their interactions.

Source of Variation	Degree of freedom (DF)	p-value		
		NTP	TW	TY
Block	3	0.1100	0.4373	0.0596
Staking system (S)	2	0.0003	0.7708	0.0041
Fertilizer (F)	4	<0.0001	<0.0001	<0.0001
Seed tuber weight (W)	1	<0.0001	0.5317	0.0008
S x F	8	0.0308	0.2275	0.0369
S x W	2	0.0009	0.6058	0.0476
F x W	4	0.1460	0.6365	0.4175
S x F x W	8	0.3604	0.3627	0.4190
Coefficient of variation (CV, %)	-	24.84	25.40	34.68
Maximum	-	30.70	364.96	32.95
Mean	-	15.54	148.21	14.88
Minimum	-	0.91	20.27	0.57

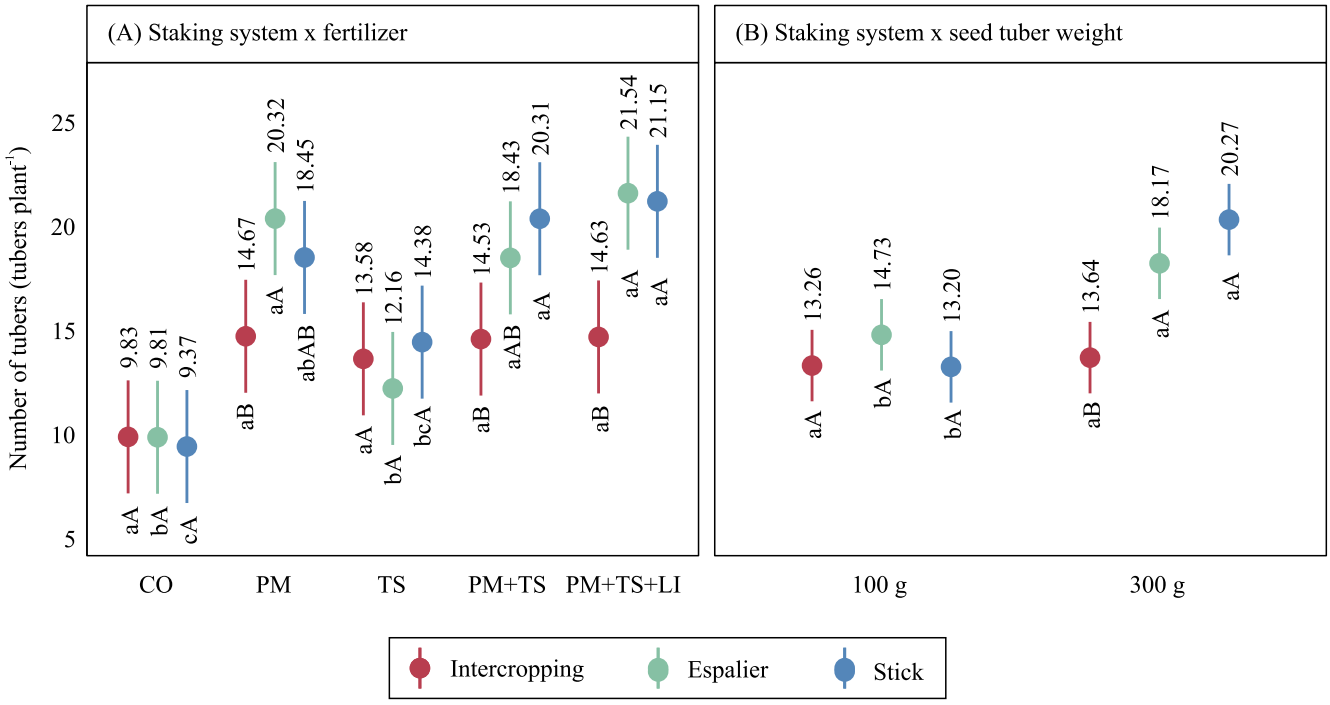


Figure 2. Number of tubers per plant of of purple yam (*Dioscorea trifida*) as a function of the two-way interaction between staking system x fertilization (A), and staking system x seed tuber weight (B). The fertilization techniques evaluated were no fertilization as control (CO), poultry manure (PM), triple superphosphate (TS), poultry manure + triple superphosphate (PM+TS), and poultry manure + triple superphosphate + limestone (PM+TS+LI). In A, lowercase letters compare fertilizer type with each staking system, while uppercase letters compare staking system with each fertilizer type by Tukey's test ($p \leq 0.05$). In B, lowercase letters compare seed tuber weight with each staking system, while uppercase letters compare staking system with each seed tuber weight by Tukey's test ($p \leq 0.05$).

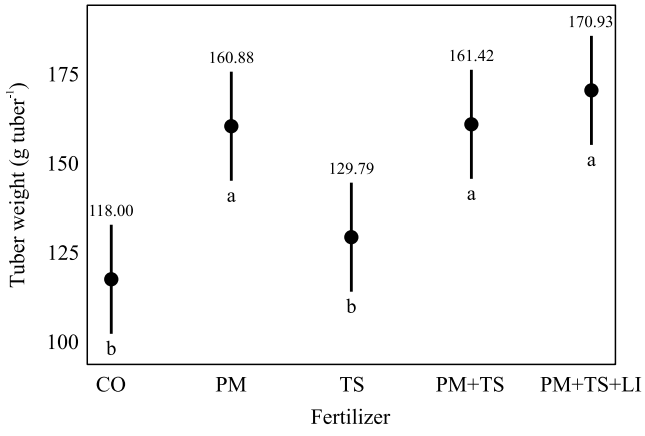


Figure 3. Tuber weight of purple yam (*Dioscorea trifida*) according to fertilization type. The fertilization techniques evaluated were no fertilization as control (CO), poultry manure (PM), triple superphosphate (TS), poultry manure + triple superphosphate (PM+TS), and poultry manure + triple superphosphate + limestone (PM+TS+LI). Means followed by different letters differ from each other by Tukey's test ($p \leq 0.05$).

seed tuber was used. Under this seed tuber, the espalier and wooden stake systems yielded the highest mean values, reaching 17.29 and 19.30 Mg ha^{-1}, respectively (Figure 3 B).

Considering both NTP and TY, the use of espalier or wooden stake systems produced the highest means compared to intercropping in most evaluated scenarios (Figures 2 and 4). This aligns with the findings of Bertino et al. (2022), who observed that implementing a staking system increased yam yields compared to cultivation without staking. Staking is essential because it guides the yam, and prevents direct contact between the apical meristem and the soil, thereby avoiding leaf burn, a condition that would compromise plant and tuber development due to the lack of assimilates for storage (Oshunsanya et al., 2022). Furthermore, the absence of staking causes self-shading, which hinders the plant's ability to utilize solar radiation and creates a microclimate that favors fungal diseases, both of

which indirectly affect tuber growth (Oshunsanya et al., 2022). Nevertheless, it must be considered that intercropping makes better use of natural resources compared to monoculture (Fedeli & Leibler, 2024).

Fertilization with PM, applied either alone or combined with chemical fertilizers, increased yam yield compared with the control (Figure 4 A). Fertilization with PM, PM + TS, and PM + TS + LI resulted in the highest means across most evaluated scenarios (Figures 2, 3, and 4). Notably, TS alone achieved the highest means only in the intercropping system for the number of tubers per plant (Figure 2 A). The use of PM is advantageous as it can be produced on-farm, and increases tuber yield without relying on chemical fertilizers. Additionally, PM improves the chemical, physical, and microbiological properties of the soil (Bhunia et al., 2021).

The results obtained in this study demonstrate that applying 10 Mg ha^{-1} of poultry manure alone achieved a tuber yield of nearly 20 Mg ha^{-1} (Figure 4 A). In comparison, fertilization at planting with PM + TS + LI yielded 24 Mg ha^{-1}. Adjei et al. (2022) observed a comparable yam yield of approximately 18.4 Mg ha^{-1} when evaluating different genotypes across six locations in Uganda. Similarly, Neina (2021) observed satisfactory yields for *Dioscorea alata* L., *Dioscorea cayenensis* Lam., and *Dioscorea rotundata* Poir. when evaluating various organic fertilizers in Ghana, noting that tuber yield did not decline over time with organic inputs. In that study, the author achieved up to 42.5 Mg ha^{-1} when using oil palm bunch ash combined with PM, while PM alone obtained the maximum value of 32.5 Mg ha^{-1}. Other studies also report favorable outcomes from the use of PM for

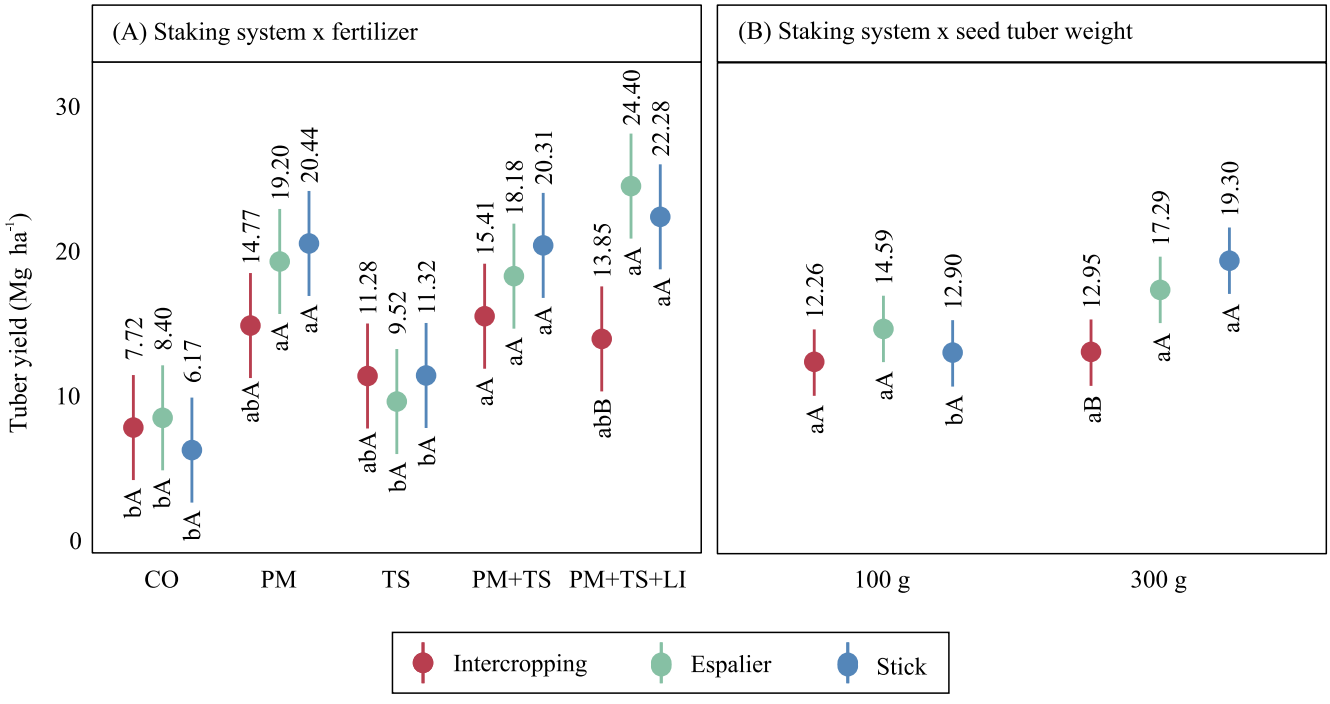


Figure 4. Tuber yield of purple yam (*Dioscorea trifida*) as a function of the two-way interaction between staking system x fertilizer type (A) and staking system x seed tuber weight (B). The fertilization techniques evaluated were no fertilization as control (CO), poultry manure (PM), triple superphosphate (TS), poultry manure + triple superphosphate (PM+TS), and poultry manure + triple superphosphate + limestone (PM+TS+LI). In A, lowercase letters compare fertilizer type with each staking system, while uppercase letters compare staking system with each fertilizer type by Tukey's test ($p \leq 0.05$). In B, lowercase letters compare seed tuber weight with each staking system, while uppercase letters compare staking system with each seed tuber weight by Tukey's test ($p \leq 0.05$).

various crops (Agbede & Oyewumi, 2022; Asfaw, 2022; Bilong et al., 2022).

Seed tuber quality and weight determine uniform emergence and rapid crop establishment, playing a fundamental role in final yield while preventing uneven stand establishment that can compromise crop development (Norman et al., 2021). In this study, 300 g seed tubers led to an increased number of tubers when combined with TS, PM + TS, and PM + TS + LI fertilizers (Figure 2 B). This heavier seed tuber weight also enhanced total tuber yield within the wooden stake staking system (Figure 4 B). The favorable result of the heavier seed tuber may be attributed to the greater initial rhizome production, which positively influences final yield. However, using 300 g seed tubers increases production costs due to the higher volume of planting material required. Consequently, the practical adoption of heavier seed tubers requires careful evaluation, as their yield gains were less pronounced than those achieved through adequate fertilization.

Conclusions

1. Fertilization with poultry manure (PM) alone, PM + triple superfosfate (TS), and PM + TS + limestone yields superior results for the evaluated traits of purple yam (*Dioscorea trifida*).

2. The espalier and wooden stake systems achieve the highest means for the number of tubers per plant and total tuber yield of purple yam.

3. Planting 300 g seed tubers produces the highest mean values for the number of tubers per plant and total tuber yield of purple yam compared to 100 g seed tubers.

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No generative artificial intelligence (AI) was used in this study.

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