Influence of inorganic fertilization on production parameters of two varieties of sweet potato

Influencia de la fertilización inorgánica sobre parametros productivos de dos variedades de camote

Influência da adubação inorgânica nos parâmetros de produção de duas variedades de batata doce

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Abstract

In order to determine the effect of inorganic fertilization treatments on the productive behavior of the sweetpotato varieties “INIAP-Toquecita” and “INIAP-Buena Vista”, this research was carried out during the dry season (June–December 2022) at the Portoviejo Experimental Station of the National Institute of Agricultural Research-INIAP, in the Colón parish, canton Portoviejo, province of Manabí, Ecuador. A randomized complete block design was used with three replications, and the following variables were analyzed: percent yield, total number of guides per plant, length of guides, mass of 100 guides, foliage yield, and number and yield of commercial roots. The inorganic fertilization treatments under study were: 1. $N+P_2O_5+K_2O+S+Mg+B$; 2. $N+P_2O_5+K_2O+S+Mg+B+Zn+Mn+Fe$; 3. 50 % more $N+P_2O_5+K_2O+S+Mg+B$ with respect to treatment 1; 4. $N+P_2O_5+K_2O$; and 5. no fertilizers (control). It was evidenced that the inorganic fertilization treatments implemented on the variety “INIAP-Buena Vista” outperformed the results of the control, while treatments 1 and 2 of inorganic fertilization implemented on the variety “INIAP-Toquecita” outperformed the control. It was observed that the most favorable scenario for maximizing the yield of commercial tuberous roots in the variety “INIAP-Buena Vista” was treatment 3, which had 50 % more macro and micronutrients per hectare added to the soil with respect to treatment 1. The varieties evaluated did not show nutritional deficiencies during the production cycle (120 days).

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Resumen

Con la finalidad de determinar el efecto de los tratamientos de fertilización inorgánica, en el comportamiento productivo de las variedades de camote "INIAP-Toquecita" e "INIAP-Buena Vista", se realizó la presente investigación en la época seca (junio-diciembre 2022) en la Estación Experimental Portoviejo del Instituto Nacional de Investigaciones Agropecuarias-INIAP, en la parroquia Colón, cantón Portoviejo, provincia de Manabí, Ecuador. Se utilizó un diseño de bloques completos al azar, con tres repeticiones y se analizaron las variables: porcentaje de prendimiento, número total de guías por planta, longitud de guías, masa de 100 guías, rendimiento de follaje, número y rendimiento de raíces comerciales. Los tratamientos de fertilización inorgánica en estudio fueron: 1. $N+P_2O_5+K_2O+S+Mg+B$; 2. $N+P_2O_5+K_2O+S+Mg+B+Zn+Mn+Fe$; 3. 50 % más de $N+P_2O_5+K_2O+S+Mg+B$ con respecto al tratamiento 1; 4. $N+P_2O_5+K_2O$ y 5. sin fertilizantes (testigo). Se evidenció que los tratamientos de fertilización inorgánica implementados en la variedad "INIAP-Buena Vista" superaron a los resultados del testigo, mientras que los tratamientos 1 y 2 de fertilización inorgánica implementados en la variedad "INIAP-Toquecita" superaron al testigo. Se observó que el escenario más propicio para maximizar el rendimiento de raíces tuberosas comerciales en la variedad "INIAP-Buena Vista" fue el tratamiento 3, el cual tuvo 50 % más cantidad de macro y micronutrientes por hectárea adicionadas al suelo con respecto al tratamiento 1. Las variedades evaluadas no mostraron deficiencia nutricional durante el ciclo productivo (120 días).

Palabras clave: tratamiento, rendimiento, raíces tuberosas comerciales, INIAP-Toquecita, INIAP-Buena Vista.

Resumo

Com o objetivo de determinar o efeito dos tratamentos de fertilização inorgânica no comportamento produtivo das variedades de batata-doce "INIAP-Toquecita" e "INIAP-Buena Vista", a presente investigação foi realizada durante a estação seca (junho-dezembro de 2022) na Estación Experimental Portoviejo del Instituto Nacional de Investigaciones Agropecuarias-INIAP, na freguesia de Colón, cantão de Portoviejo, província de Manabí, Equador. Utilizou-se um delineamento em blocos completos casualizados com três repetições e foram analisadas as seguintes variáveis: rendimento percentual, número total de guias por planta, comprimento das guias, massa de 100 guias, rendimento foliar, número e rendimento de raízes comerciais. $N+P_2O_5+K_2O+S+Mg+B$; 2. $N+P_2O_5+K_2O+S+Mg+B+Zn+Mn+Fe$; 3. 50 % a mais de $N+P_2O_5+K_2O+S+Mg+B$ em relação ao tratamento 1; 4. $N+P_2O_5+K_2O$ e 5. sem adubação (testemunha). Foi demonstrado que os tratamentos de fertilização inorgânica implementados na variedade "INIAP-Buena Vista" superaram os resultados da testemunha, enquanto os tratamentos 1 e 2 de fertilização inorgânica implementados na variedade "INIAP-Toquecita" superaram a testemunha. Observou-se que o cenário mais favorável para maximizar o rendimento de raízes tuberosas comerciais na variedade "INIAP-Buena Vista" foi o tratamento 3, que teve 50 % a mais de macro e micronutrientes por hectare adicionados ao solo em relação ao tratamento 1. As variedades avaliadas não apresentaram deficiência nutricional durante o ciclo produtivo (120 dias).

Palavras-chave: tratamento, rendimento, raízes tuberosas comerciais, INIAP-Toquecita, INIAP-Buena Vista.

Introduction

The sweetpotato *Ipomoea batatas* L. (Convolvulaceae) is characterized by being creeping and rustic in terms of care (CIP *et al*., 1991). The different agroclimatic conditions of Ecuador allow it to be cultivated in the Coast or Littoral; sheltered valleys of the highlands or andean region and in the east or Amazon. For a long time it has been considered a marginal or subsistence crop, so the development of technology for its management, including fertilization, weed control and irrigation, has not been widely studied in the country (Cobeña *et al*., 2017). However, in provinces such as Manabí, Loja and in certain localities of Guayas, it represents a significant guarantee for the food security and sovereignty of rural farmers, as well as for activating their economic synergy.

As in all crops, sweetpotato fertilization should be controlled according to the plant's demand (table 1), so knowing its requirements based on the interpretation of soil analysis allows maintaining an optimum level of concentration of nutritional elements throughout the crop cycle (Padilla, 1979). Excess nitrogen favors the development of the aerial part, and decreases sweetpotato plant yield (Martí, 2018).

Table 1. Nutritional requirements of sweetpotato (*Ipomoea batatas* L.) according to soil analysis interpretation performed by the National Institute of Agricultural Research-Ecuador (INIAP-Ecuador) during 2022.

Interpretation of soil analysis	Requirement $kg.ha^{-1}$		
	N	P_2O_5	K_2O
Low	80	80	120
Medium	60	40	60
High	40	20	20

Source: Authors.

Roots and tubers require less nitrogen and more potassium; in tuberous roots, the role of potassium is related to formation, growth and development (Rodríguez Soto *et al*., 2023). Phosphorus, as a mineral, is part of many organic compounds, is fundamental in the metabolism, flower development and morphology of tuberous roots, in addition, the increase of phosphorus in the soil does not increase the leaf area in sweetpotato crops (Kareem, 2013). Fertilizers are important inputs to increase productivity (Ali *et al*., 2005).

The soil analysis laboratory of the Pichilingue-INIAP Experimental Station, Los Ríos, Ecuador, conducted soil analysis in five cantons of the province of Manabí, Ecuador, in 2022. This laboratory reported soils with low nitrogen and organic matter content, both concomitant characteristics. Nitrogen content was from 6.71 to 16.93 ppm and organic matter from 0.9 to 1.8 %, values compared with acceptable levels for sweetpotato cultivation referred by Martí (2018) which are between 3.3 and 4.5 %. With respect to phosphorus determined in the soils analyzed (22 to154 ppm) and potassium (0.57 to 2.81 $meq.100\ mL^{-1}$), the INIAP report considers them high.

In Manabí, Ecuador, there is no updated information available to provide a recommendation on the inorganic fertilizers to be used to increase sweetpotato crop yields. The objective of this study was to determine the effect of treatments with different doses of inorganic fertilizers on the productive behavior of two sweetpotato varieties.

Materials and methods

The research was conducted between June and December 2022 (dry season), at the Portoviejo Experimental Station, Colón parish, Portoviejo canton, Manabí province, Ecuador (Latitude 1°09’52.1” S; Longitude 80°23’18.3” W, 44 m a.s.l.). The study site has temperatures between 21 and 31 °C, mean relative humidity of 82 %, mean annual rainfall of 672.7 mm and a heliophany of 1,394.7 daylight hours (DATA, 2022), as well as flat topography soils, with a loam-clay texture (43 % clay).

The study factor was inorganic fertilization with four levels of inorganic fertilization treatment and the control treatment without fertilization. The control treatment responded to the traditional way sweet potato (*Ipomoea batatas* L.) is grown in Manabí, Ecuador. The treatments were designed based on the results of the soil analysis of five cantons in the province of Manabí, Ecuador, performed in 2022 by the soil laboratory of the Pichilingue-INIAP Experimental Station, Los Ríos, Ecuador, as well as the needs of the crop described for the conditions of the Ecuadorian countryside as described by INIAP-Ecuador (Padilla, 1979).

Fertilizers were (table 2) inorganic source and consisted in treatment 1, in the application of complete fertilizer (15-15-15), urea (46-0-0), ammonium sulfate (21-0-0-24S) and an inorganic fertilizer (Fertiboro®) with boron content (disodium tetraborate pentahydrate 99.0 %, Boron element 14.9 %). This combination was the same for treatment 2, except that other microelements were added. Treatment 3 consisted of applying 50 % more fertilizers than treatment 1, treatment 4 consisted of applying urea, ammonium sulfate and potassium muriate® (0-0-60) and treatment 5 was the control without fertilization.

A randomized complete block design (RCBD) with three replications was used, forming 15 experimental units for the two varieties evaluated.

Table 2. Inorganic fertilization treatments of the varieties “INIAP-Toquecita” and “INIAP-Buena Vista”.

Treatment	N	P_2O_5	K_2O	S	Mg	B	Zn	Mn	Fe
	kg.ha^{-1}								
1	80	10	10	25	2.4	1.6			
2	80	10	10	25	2.4	1.6	3.0	1.5	1.5
3	120	15	15	37	4.8	3.2			
4	80	10	10						
5 (T)	0	0	0	0	0	0	0	0	0

The plant material used was the “INIAP-Toquecita” and “INIAP-Buena Vista” varieties, from which vegetative seed (40 cm long guides) was extracted from the distal part of the 2-month-old plant, free of pests and diseases, supplied by the Portoviejo Experimental Station of INIAP-Ecuador.

The soil was prepared mechanically, with deep plowing and two passes of heavy disc harrow (romplow). Each plot consisted of three planting furrows 5.1 m long and 0.80 m between furrows. Prior to planting, irrigation was carried out to maintain soil moisture. A vegetative seed was sown with at least five buds per planting point, every 0.30 m and at a depth of 0.10 m, leaving 25 % of the guide exposed in the soil for a population of 41,667 sweetpotato guides per hectare. After planting, irrigation was carried out to avoid dehydration of the plant material. From the central furrow of each replicate, 10 plants were selected for the respective evaluation, without considering the border plants. The drip irrigation system was used with applicators of 1.6 L.hour^{-1}, spaced 0.20 m apart. Two hours of irrigation were applied daily until 90 dap.

Table 3 details the application of inorganic fertilizers during the first 40 dds, each dose was incorporated into the soil next to the planting point.

Table 3. Frequency of application and fractionation of doses of nutrients applied to the soil according to the treatments studied.

Treatment	Days	N	P_2O_5	K_2O	S	Mg	B	Zn	Mn	Fe
		kg.ha^{-1}								
T1	0	26.67	10	10	0	0	0	0	0	0
	20	26.67	0	0	25	2.4	1.6	0	0	0
	40	26.67	0	0	0	0	0	0	0	0
T2	0	26.67	10	10	0	0	0	0	0	0
	20	26.67	0	0	25	2.4	1.6	3	1.5	1.5
	40	26.67	0	0	0	0	0	0	0	0
T3	0	40.00	15	15	0	0	0	0	0	0
	20	40.00	0	0	37	4.8	3.2	0	0	0
	40	40.00	0	0	0	0	0	0	0	0
T4	0	26.67	10	10	0	0	0	0	0	0
	20	26.67	0	0	0	0	0	0	0	0
	40	26.67	0	0	0	0	0	0	0	0
T5	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0

T5: control without fertilizer application.

Data were recorded using the sweet potato descriptors implemented by the International Potato Center (CIP *et al*., 1991). The variable yield was evaluated at 15 dap, and the number of guides set out of the total number of guides planted was counted and multiplied by 100 to express it as a percentage. Through this variable, the initial state of the crop and the influence of treatments according to the variety were evidenced.

The mass of 100 guides was obtained by cutting 0.40 m long guides from the distal part of the plant, and was expressed in kg. Total guides per plant were counted according to the number of guides on each plant. The evaluation of the length of the main guide per plant was made by measuring from the base of the plant to its distal part, whose values were expressed in meters.

Harvesting was carried out at 120 dap, data was taken for foliage yield, for which all the foliage extracted from the neck of the plant was weighed and the total number of commercial tuberous roots harvested in the useful plot was counted, discarding the tuberous roots that showed physical damage and those of masses less than 100 g, the values were expressed in units per hectare. For root yield, the total number of commercial roots was weighed and expressed in $t.ha^{-1}$.

The chlorophyll index was recorded every 30 days over a four months period, in three plants per treatment, from which 10 leaves were taken from the middle third of the main guide. The SPAD-502 Plus chlorophyll meter (Konica Minolta, Japan) was used. For leaf analysis, 1 kg samples of each inorganic fertilization treatment were taken at 120 dap, identified and sent to the soil, plant and water analysis laboratory of the Santa Catalina Experimental Station, Quito, Ecuador.

Before submitting the data to the analysis of variance, the assumptions of normality by Shapiro-Wilks and homogeneity of variances by Bartlett were checked. Regarding the statistical significance of averages, a Tukey mean comparison test analysis was generated ($p<0.05$) and the coefficient of variation was calculated. InfoStat v.2020 software was used for this data evaluation.

Results and discussion

The percentage of lodging in the variety "INIAP-Buena Vista" (table 4) showed statistical differences ($p<0.05$). Treatment 5 presented the highest percentage of lodging in comparison with the other treatments. On the other hand, the treatments applied to the variety "INIAP-Toquecita" did not present statistical significance; however, treatment 3 presented the highest percentage of sprouting. The results found in this study are superior to those obtained by Quispe (2017), who recorded an average value of 91.53 % of sprouting obtained from the study of 20 sweetpotato clones, who stated that this percentage of sprouting is a variable that reflects the good initial state of the guide.

The inorganic fertilization treatments did not show statistical significance ($p>0.05$) for the total number of guides per plant, guide length and mass of 100 guides (Table 5). Numerical differences were recorded, where the variety "INIAP-Toquecita" with treatment 3, showed the highest total number of guides, guide length and mass of 100 guides. This result could be due to the higher amount of N in treatment 3 compared to the other treatments, which agrees with Darko *et al*. (2020), who stated that the higher the amount of N, the higher the shoot growth.

Table 4. Average yield in the "INIAP-Toquecita" and "INIAP-Buena Vista" varieties at 15 dap.

Treatment	"INIAP-Toquecita"	"INIAP-Buena Vista"
	Sprouting (%)	
1	95	98 ab
2	95	97 ab
3	97	98 ab
4	92	93 b
5 (T)	94	99 a
X̄	94.60	97.00
CV (%)	2.50	2.06
p	ns	*

p: probability, ns: not significant, *: significant (Tukey, $p<0.05$).

The results indicated that the maximum yield potential was achieved with adequate fertilization, information that is similar to that reported by Xiangbei *et al*. (2019), who indicated that the fractional application of N at the beginning of planting and 30 dap, produced high tuberous root yields. Regarding the high coefficient of variation, Piepho (1998) indicated that the higher the CV value, the lower the yield stability. The CV obtained for commercial tuberous foliage and root yields was in agreement with that found by Darko *et al*. (2020), where a CV of 36.6 % for biomass and 51.9 % for root yield in $t.ha^{-1}$ was found.

Table 5. Total number, length and mass of 100 guides of the varieties "INIAP-Toquecita" and "INIAP-Buena Vista".

Treatment	"INIAP-Toquecita"			"INIAP-Buena Vista"		
	Total number of guides per plant	Guide length (m)	Mass of 100 guides (kg)	Total number of guides per plant	Guide length (m)	Mass of 100 guides (kg)
1	17	2.51	1.4	6	3.10	1.3
2	20	2.71	1.8	7	3.33	1.1
3	25	2.72	2.0	6	3.51	1.9
4	18	2.65	1.6	6	3.26	2.0
5 (T)	15	2.67	1.7	5	2.68	1.8
X̄	19	2.65	1.7	6	3.18	1.62
CV (%)	22.78	16.36	25.05	24.38	21.79	19.52
p	ns	ns	ns	ns	ns	ns

p: probability, ns: not significant.

Table 6. Yields and number of commercial tuberous roots of the variety "INIAP-Toquecita".

Treatament	Foliage yield (t.ha^{-1})	Number of commercial tuberous roots (ha)	Yield of commercial tuberous roots (t.ha^{-1})
1	37.64	79.167	28.19
2	31.67	90.279	26.53
3	33.47	61.112	19.30
4	32.78	76.390	20.83
5 (T)	36.39	88.890	25.83
X	34.39	79.168	24.14
CV (%)	14.57	39.62	42.81
p	n.s	n.s	n.s

p: probability, ns: not significant.

Table 7 shows that the inorganic fertilization treatments, in the variety "INIAP-Buena Vista", presented statistical significance ($p<0.05$) for commercial root yield, being treatment 3 the one that reached the highest value. The increase in inorganic fertilization described in treatment 3, influenced the production of commercial roots, results in agreement with those found by Darko *et al*. (2020), who indicated that chemical fertilization influenced the increase in root yield. However, Relente and Asio (2020) reported that amounts higher than 160 kg.ha^{-1} of nitrogen resulted in a decrease in root yield.

Table 7. Yield data and number of commercial tuberous roots of the variety "INIAP-Buena Vista".

Treatment	Foliage yield (t.ha^{-1})	Number of commercial roots (ha)	Commercial root yields (t.ha^{-1})
1	14.07	88.890	15.27 ab
2	17.27	94.445	18.77 ab
3	14.60	100.001	22.37 a
4	15.30	104.168	20.13 ab
5 (T)	10.53	75.001	8.60 b
$\bar{X}$	14.35	92.501	17.03
CV (%)	21.49	14.89	28.46
p	n.s	n.s	*

p: probability, ns: not significant, *: significant (Tukey, $p<0.05$).

Treatment 2, achieved the highest results for foliage yield, these results indicated that the addition of minor elements such as zinc, iron and manganese, increased foliage yield, which is similar to that reported by Fernandes *et al*. (2020), who showed that N fertilization increased the absorption of P, K, Ca and Mg and micronutrients, which influenced the growth of sweetpotato plants. Treatment 4 showed the highest number of commercial tuber roots per hectare, data in agreement with those reported by Relente and Asio (2020), who indicated that applications of 80 kg.ha^{-1} of nitrogen produced the best number of commercial roots.

The chlorophyll index recorded with the SPAD-502 Plus meter made it possible to determine the intensity of the green color of the sweetpotato plant leaves. Figure 1 shows that the inorganic fertilization treatments in the variety "INIAP-Toquecita" presented increases in SPAD units during the 120-day study period, with treatment 3 standing out with the greatest intensity of green in the leaf, although it shows the lowest yield per hectare of tuberous roots, except for the control which registered a decrease in the chlorophyll index from 90 to 120 days; the foliage presented yellow tones as an indicator of tuberous root maturity.

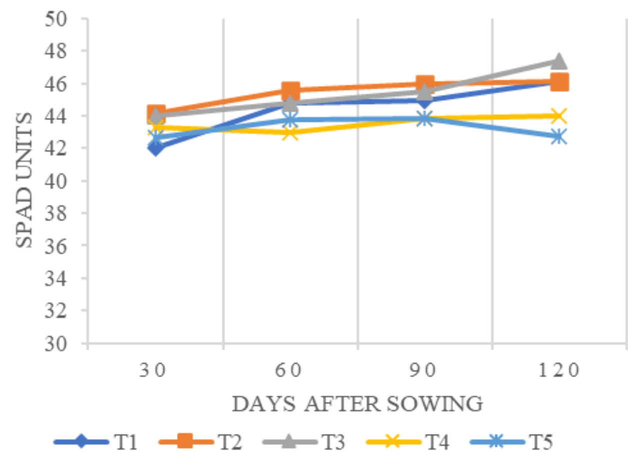

Figure 1. Chlorophyll index of sweetpotato (*Ipomoea batatas* L.) var. "INIAP-Toquecita".

Figure 2, shows that treatments 2, 3 and 4 of inorganic fertilization in the INIAP-Buena Vista variety, increased the chlorophyll index gradually until 90 dap, from which the SPAD index stabilized until 120 dap. Results in agreement with those expressed by Cunha *et al*. (2015) who stated that the increase in the SPAD index is related to the increase in nitrogen.

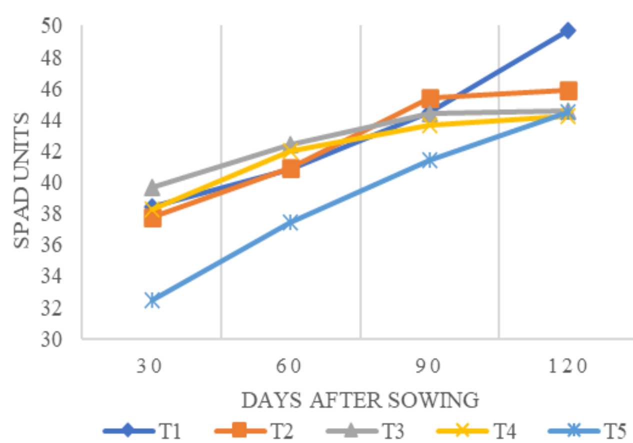

Figure 2. Chlorophyll index of sweetpotato (*Ipomoea batatas* L.) var. "INIAP-Buena Vista".

The results of the chemical analysis of sweetpotato foliage are shown in table 8, where it is observed that all the elements analyzed in each of the treatments under study exceeded the deficiency levels as cited by Méndez *et al*. (1987), where he describes the levels of N 1.5; P 0.1; K 0.5; Ca 0.2; Mg 0.05 and S 0.08, as deficient.

Table 8. Macro and micro element content determined in the foliage of the varieties "INIAP-Toquecita" and "INIAP-Buena Vista" at 120 dap.

Treatment	Variety	N	P	K	Ca	Mg	S	B	Zn	Cu	Fe	Mn
		%						mg.kg^{-1}				
1	"INIAP-Toquecita"	2.51	0.33	3.64	1.81	0.44	0.26	34.29	23.70	12.13	721.71	36.12
2		2.42	0.37	3.73	2.12	0.44	0.25	39.56	30.65	10.05	598.08	26.63
3		2.70	0.36	3.74	1.79	0.44	0.24	30.20	34.17	13.84	883.01	42.86
4		2.31	0.38	3.47	2.17	0.44	0.24	39.62	28.02	10.78	577.50	27.02
5 (T)		2.57	0.40	3.66	2.25	0.50	0.28	40.71	34.42	14.17	1,072.61	46.83
1	"INIAP-Buena Vista"	2.74	0.43	3.48	2.17	0.51	0.25	37.48	27.14	16.44	344.49	13.26
2		2.86	0.47	3.77	1.98	0.49	0.27	37.92	38.48	20.40	478.09	28.65
3		2.44	0.42	3.45	2.05	0.49	0.26	44.09	31.77	16.71	488.89	37.29
4		3.00	0.43	3.70	1.86	0.47	0.26	38.60	35.05	17.56	445.74	41.74
5 (T)		2.81	0.45	3.77	1.74	0.49	0.26	37.05	41.14	17.38	642.09	38.62

Source: Soil, plant and water analysis laboratory report. Santa Catalina Experimental Station, 2023. Quito, Ecuador.

Conclusions

The inorganic fertilization treatments implemented in the variety "INIAP-Buena Vista" surpassed the results of the control, while treatments 1 and 2 in the variety "INIAP-Toquecita".

It was observed that the most favorable scenario for maximizing the yield of commercial tuberous roots in the variety "INIAP-Buena Vista" was treatment 3, which registered 50% more macro and micronutrient content per hectare added to the soil with respect to treatment 1.

The varieties evaluated did not show nutritional deficiencies during the production cycle (120 days).

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Literature cited

Ali, H., SHakeel, A., Ali, H., & Sohail Hassan, F. (2005). Impact of nitrogen application on growth and productivity of wheat (*Triticum aestivum* L .). *Journal of Agriculture & Social Science, 1*, 216–218. https://www.fspublishers.org/published_papers/62378_..pdf

CIP, AVRDC, & IBPGR. (1991). Descriptores de la batata (Z. Huamán (ed.); International Board). International Board for Plant Genetic Resources. https://cropgenebank.sgrp.cgiar.org/images/file/learning_space/descrip_sweet_potato_spa_jpg.pdf

Cobeña, G., Cañarte, E., Mendoza, A., Cárdenas, F., & Ángel, G. (2017). Manual técnico del cultivo del cultivo de camote. In E. S. P. A. de M. "Manuel F. López" (Ed.), Editorial Humus (1st ed., Vol. 1). Editorial Humus. https://doi.org/978-9942-8595-9-4

Cunha, Antonio Ribeiro da, Katz, Ieoschua, Sousa, Antônio de Pádua, & Martinez Uribe, R. A. (2015). SPAD index according growth and development of lisianthus plants in relation to different nitrogen levels under protected environment. Idesia (Arica), 33(2), 97–105. http://dx.doi.org/10.4067/S0718-34292015000200012

Darko, C., Yeboah, S., Amoah, A., Opoku, A., & Berchie, J. N. (2020). Productivity of sweet potato (*Ipomoea batatas* (L.) Lam) as influenced by fertilizer application in different agro-ecologies in Ghana. Scientific African, 10, e00560. https://doi.org/10.1016/j.sciaf.2020.e00560

DATA, C. (2022). Cantón Portoviejo. Climate-Data.Org. https://en.climate-data.org/south-america/ecuador/provincia-de-manabi/portoviejo-2974/#climate-graph

Duan, W., Zhang, H., Xie, B., Wang, B., & Zhang, L. (2019). Impacts of nitrogen fertilization rate on the root yield, starch yield and starch physicochemical properties of the sweet potato cultivar Jishu 25. *PLoS ONE, 14*(8), 1–11. https://doi.org/10.1371/journal.pone.0221351

Fernandes, A. M., Assunção, N. S., Ribeiro, N. P., Gazola, B., & da Silva, R. M. (2020). Nutrient uptake and removal by sweet potato fertilized with green manure and nitrogen on sandy soil. *Revista Brasileira de Ciencia Do Solo, 44*, 1–25. https://doi.org/10.36783/18069657RBCS20190127

Kareem, I. (2013). Growth, yield and phosphorus uptake of sweet potato (Ipomoea batatas) under the influence phosphorus fertilizers. *Research Journal of Chemistry and Environment, 16*(3), 1-12. https://doi.org/10.9734/JAERI/2018/15004

Martí, H. (2018). Producción de batata. Ediciones INTA. https://www.academia.edu/93661305/Gu%C3%ADa_para_la_producci%C3%B3n_de_batata_en_Corrientes

Méndez, C. H., Moreira, M. A., & Bertsch, F. (1987). Absorción y contenido de nutrimentos durante el ciclo de la planta de dos cultivares de camote (*Ipomoea batatas* L.), en Alajuela. Boletín Técnico Estación Experimental Fabio Baudrit, 20(1), 1–10. https://www.kerwa.ucr.ac.cr/handle/10669/78663

Padilla, W. (1979). Guía de recomendaciones de fertilización para los principales cultivos del Ecuador. Instituto Nacional De Investigaciones Agropecuarias, 1. http://181.112.143.123/bitstream/41000/2827/1/iniapsc322est.pdf

Piepho, H. P. (1998). Methods for comparing the yield stability of cropping systems - A review. *Journal of Agronomy and Crop Science, 180*(4), 193–213. https://doi.org/10.1111/j.1439-037X.1998.tb00526.x

Quispe, A. (2017). Adaptación y rendimiento de 20 clones de camote (Ipomoea batatas L.) de doble propósito en el ecosistema de bosque seco, Piura. *Ciencia y Desarrollo, 20*(1). https://doi.org/http://dx.doi.org/10.21503/cyd.v20i1.1407

Relente, F.A., & Asio, L. (2020). Nitrogen application improved the growth and yield performance of sweetpotato (*lpomoea batatas* (L.) Lam.). Annals of Tropical Research, May, 45–55. https://doi.org/10.32945/atr4214.2020

Rodríguez Soto, G., Pinedo-Taco, R., & Culqui Gaslac, C. (2023). Dosis de fertilización y densidad de siembra en clones avanzados de camote (*Ipomoea batatas* L.). *Revista de Investigación e Innovación Agropecuaria y de Recursos Naturales, 10*(1), 7–15. https://doi.org/10.53287/AQWB5429IT60E

Xiangbei, D., Lingcong, K., Min, X., & Xinyue, Z. (2019). Split application improving sweetpotato yield by enhancing photosynthetic and sink capacity under reduced nitrogen condition. *Field Crops Research, 238*(May), 56–63. https://doi.org/10.1016/j.fcr.2019.04.021