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Agronomic and productive efficiency of the blackberry crop (*Rubus glaucus* Benth.) with the application of nitrogen and potassium in subtropical conditions of Ecuador

Eficiencia agronómica y productiva del cultivo mora (*Rubus glaucus* Benth.) con la aplicación de nitrógeno y potasio en condiciones subtropicales de Ecuador

Alex Enrique Salazar-Saltos [1*]; Cristian Rene Chusin-Ayala [1]

[1]Facultad de Ciencias Agrarias, Universidad Estatal Península de Santa Elena, Manglar Alto, Ecuador
[2]Independent Researcher, Ecuador

ABSTRACT

Nitrogen (N) is essential for optimal crop development, while potassium (K) plays a key role in protein synthesis and the water and ion balance of plants, influencing their productivity. This study evaluated the effectiveness of N and K application in blackberry (*Rubus glaucus* Benth.) cultivation under subtropical conditions. Five treatments with four replicates were implemented in a randomized block design (RBD), and the results were statistically analyzed using Tukey's test ($p<0.05$). Fertilization was applied to the soil, and agronomic variables such as the number of main and secondary shoots, productive and unproductive branches, flowers, fruit weight and size, yields, and associated costs were measured. Treatments T1 (210 kg of N ha^{-1}+ 165 kg of K_2O ha^{-1}) and T3 (350 kg of N ha^{-1} + 165 kg of K_2O ha^{-1}) increased unproductive branches, showing lower overall performance. In contrast, T2 (210 kg of N ha^{-1} + 275 kg of K_2O ha^{-1}) optimized shoots, productive branches, and flowers, while T4 (350 kg of N ha^{-1} + 275 kg of K_2O ha^{-1}) improved fruit size and weight. However, T2 stood out with a yield of 11,039.53 kg ha^{-1} (11.04 t) and profitability of 110.28 %, offering significant economic benefits for farmers.

Keywords: soil fertility; fruit trees; plant nutrition; subtropical crops

RESUMEN

El nitrógeno (N) es fundamental para el desarrollo óptimo de los cultivos, mientras que el potasio (K) desempeña un rol clave en la síntesis de proteínas y en el equilibrio hídrico e iónico de las plantas, lo que influye en su productividad. Este estudio evaluó la eficacia de la aplicación de N y K en el cultivo de mora (*Rubus glaucus* Benth.), bajo condiciones subtropicales. Se implementaron cinco tratamientos con cuatro repeticiones en un diseño de bloques al azar (DBCA), y se analizaron estadísticamente los resultados mediante la prueba de Tukey ($p<0.05$). La fertilización se aplicó de forma forma edáfica y se midieron variables agronómicas como el número de brotes principales y secundarios, ramas productivas e improductivas, flores, peso y tamaño de los frutos, rendimientos y costos asociados. Los tratamientos T1 (210 kg de N ha^{-1} + 165 kg de K_2O ha^{-1}) y T3 (350 kg de N ha^{-1} + 165 kg de K_2O ha^{-1}) incrementaron ramas improductivas, mostrando menor desempeño general. En contraste, T2 (210 kg de N ha^{-1}+ 275 kg de K_2O ha^{-1}) optimizó brotes, ramas productivas y flores, mientras que T4 (350 kg de N ha^{-1} + 275 kg de K_2O ha^{-1}) mejoró el tamaño y el peso de los frutos. Sin embargo, T2 destacó con un rendimiento de 11,039.53 kg ha^{-1} (11.04 t) y rentabilidad del 110.28 %, ofreciendo beneficios económicos significativos para agricultores.

Palabras clave: fertilidad del suelo; frutales; nutrición vegetal; subtropicales

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* alex.salazar5584@utc.edu.ec (corresponding author)

1. INTRODUCTION

Blackberry (*Rubus glaucus* Benth) is an important crop in Ecuador, with production spanning approximately 4,046 hectares, primarily in the inter-Andean corridor provinces such as Tungurahua, Bolívar, Chimborazo, Cotopaxi, Carchi, and Imbabura (C. Liu et al., 2023). Key varieties like Castilla, INIAP, Colombian, and Brazo demonstrate adaptability to local subtropical conditions and contribute to the sector's economic potential (X.-M. Liu et al., 2022). However, climate variability disrupts soil nutrient dynamics—intense rainfall increases nitrogen leaching, while drought reduces soil moisture, restricting potassium uptake. These factors impact blackberry productivity and highlight the need for improved nutritional management to stabilize yields in the region.

According to Ministerio de Agricultura y Ganadería (2022), yields vary: Cotopaxi (10.15 t ha^{-1}), Tungurahua (9.89 t ha^{-1}), and Bolívar (9.01 t ha^{-1}) outperform Chimborazo (5.27 t ha^{-1}) and Imbabura (3.58 t ha^{-1}). This reflects how local conditions drive efficiency, making Cotopaxi an economic benchmark despite less cultivation (E. Liu et al., 2023). These disparities suggest a need for strategies that optimize local resources (Pilco, 2023).

Blackberry is an iconic Ecuadorian fruit that generates about 1.8 direct jobs per hectare and supports rural family farming (Latchem et al., 2021). Market prices in Sarahuasi, Guarumal, and Galápagos ($0.70–1.10/kg) contrast with intermediary margins ($1/kg), exposing value chain inefficiencies that lower producer profits (Sandhu et al., 2021). This highlights the need for equitable and productivity-focused interventions (Song et al., 2025).

This study was conducted in Chiquinquirá, Chugchilán, Sigchos, Cotopaxi (1,650 m ASL). The region's acidic subtropical soils and limited research on nitrogen and potassium fertilization at this altitude create a need for evidence-based fertilization recommendations (Cerda & Cifuentes, 2012; X.-M. Liu et al., 2022). By validating adapted nutrient doses for local conditions, this research aims to improve resilience and productivity for blackberry growers.

The objective is to identify optimal nitrogen and potassium doses that improve blackberry yield and farmer profitability under the target region's subtropical conditions (C. Liu et al., 2023). The hypothesis is that balanced, moderate N and K applications will sustain higher yields and returns than more extreme rates, supporting sustainable agricultural practice (Véliz & Seni, 2022).

2. MATERIALS AND METHODS

2.1. Location and duration of the experiment

The present research project was conducted in the Chiquinquirá sector, Chugchilán parish, Sigchos canton, Cotopaxi, Ecuador. The geographical location corresponds to the coordinates latitude x = 9902427 and longitude y = 717584, at an altitude of 1650 m ASL. The study lasted 150 days. A randomized complete block design (RCBD) was used, with five treatments and four replicates. Agronomic and economic variables were evaluated, and statistical differences were determined using Tukey's test ($p<0.05$).

2.2. Plant material

The study used the Colombian blackberry variety (*Rubus glaucus* Benth.), chosen for its rusticity and thornlessness, which ease agricultural management (E. Liu et al., 2023). Its lack of thorns reduces worker risk and shortens the harvesting process. Phenologically, it develops early, enabling earlier production. The fruit's higher firmness and adequate soluble solids (10.09 °Brix) enable faster returns on investment, reduced postharvest losses, and greater acceptance in local markets and agroindustrial uses.

2.3 Mineral sources used in the study

Urea (46% N, amide nitrogen) and potassium chloride (60% K_2O) were the main nitrogen and potassium sources for blackberry (*Rubus glaucus* Benth). Diammonium phosphate (DAP; 18% N, 46% P_2O_5) was used for nutritional maintenance, as soil tests showed no phosphorus deficiency. Fertilizer doses were based on soil analysis and crop needs, prioritizing nitrogen and potassium as detailed in Table 1. Fertilizers were incorporated into the soil every 15 days. Urea and DAP were applied through flowering, while potassium chloride was applied until harvest to meet the higher potassium demand during fruit fill and ripening.

Table 1.
Nutritional requirements of Colombian blackberry (Rubus glaucus Benth.).

Sources	Dosage based on crop needs (kg/ha/year)				
	T1: 210 ^{N} +165^{K_2O}	T2: 210 ^{N} + 275^{K_2O}	T3: 350 ^{N} + 165^{K_2O}	T4: 350 ^{N} +275^{K_2O}	T5: Testigo
Urea	440	440	740	740	0
Potassium chloride	230	380	230	380	0
DAP	50	50	50	50	0

Soil analysis identified a boron deficiency, evidenced by incomplete drupe formation, which was corrected through soil applications of boron (10%) and foliar micronutrient applications at uniform doses to prevent boron from acting as a yield-limiting factor (E. Liu et al., 2023). Once this imbalance was corrected across all experimental units, the study focused on nitrogen and potassium fertilization, as these macronutrients are critical for key physiological processes in blackberry (*Rubus glaucus* Benth.), including floral differentiation, fruit set, assimilate transport, and fruit filling. The persistence of incomplete drupe formation and poor fruit filling observed in the field indicated that productivity limitations were not solely due to micronutrient deficiencies, but also to the need to optimize nitrogen and potassium nutrition. Therefore, mineral sources of nitrogen and potassium were used to evaluate their effect on fruit uniformity and yield once the boron factor had been controlled.

2.4. Experimental design

The experiment was established in a randomized complete block design (RCBD), with five treatments (Table 2) and four replicates per treatment, for a total of 20 experimental units. Each experimental unit covered an area of 147.20 m² and consisted of 20 blackberry plants, arranged in three rows, with a spacing of 3.30 m between rows and 2.30 m between plants. For the evaluation of agronomic variables, central plants were selected as sampling units in order to minimize border effects. Statistical analysis was performed using Tukey's multiple-range test at the 5% significance level, using InfoStat.

Table 2.
Experiment diagram.

Treatment	Description	Dose
T1	Low nitrogen + Low potassium	210 kg of N ha^{-1} +165 kg of K_2O ha^{-1}
T2	Low nitrogen + High potassium	210 kg of N ha^{-1} + 275 kg of K_2O ha^{-1}
T3	High nitrogen + Low potassium	350 kg of N ha^{-1} + 165 kg of K_2O ha^{-1}
T4	High nitrogen + High potassium	350 kg of N ha^{-1} +275 kg of K_2O ha^{-1}
T5	Absolute Control	

2.5. Evaluated variables

In this study, six plants per treatment were evaluated, and several variables were measured. The number of main and secondary shoots was recorded at 15 and 43 days after fertilization, while productive and unproductive branches were counted at 30 and 57 days after pruning. At 45 days, the number of flowers was recorded from six selected plants. At 85 days, the weight, diameter, and length of 15 randomly selected fruits per experimental unit were measured. Finally, yield was calculated in kg/ha based on the total weight of harvested fruits using the following formula:

$$\text{kg/ha} = (\text{yield per net plot (kg)} \times 10000\ m^2) / (\text{net plot area } m^2)$$

2.6. Cost and income analysis of treatments

The economic analysis of treatments considered yield (kg/ha), sales revenue, and fixed and variable costs. Net benefit (NB) was calculated by subtracting total costs (TC) from gross income (GI). Profitability was determined using the cost–benefit ratio (B/C) and return on investment (ROI). The formulas used were as follows: TC = X + PX; IG = Y x PY; NB = GI – TC; B/C = NB/TC; and ROI = (NB/TC) x 100.

3. RESULTS AND DISCUSSION

The observed response of the blackberry crop to nitrogen fertilization can be attributed to increased soil-assimilable nitrogen availability, which promotes key physiological processes such as chlorophyll formation and enhanced photosynthetic activity. This effect translates into greater vegetative growth and improved differentiation of reproductive structures, consistent with previous reports highlighting the close relationship between nitrogen nutrition and biomass accumulation in fruit crops (Cerda & Cifuentes, 2012).

Additionally, the combined soil applications likely improved nitrogen uptake efficiency by synchronizing nutrient supply with crop demand, thereby minimizing losses due to volatilization or leaching. This behavior has been documented by Tang et al. (2025), who found that such fertilization strategies effectively optimize nitrogen use efficiency in intensive agricultural systems.

Regarding potassium, the results demonstrate its critical role in both yield and fruit quality. This can be explained by its involvement in regulating water balance, carbohydrate transport, and overall metabolic efficiency in plants. Adequate potassium nutrition also enhances tolerance to water stress conditions, a key factor in fruit production systems, as reported by Véliz & Seni (2022).

Soil application of potassium ensured sustained nutrient availability in the root zone, promoting its uptake and agronomic efficiency. This finding is consistent with recent studies emphasizing the importance of soil-based potassium fertilization to maximize crop productivity (Song et al., 2025).

At the end of the experiment, organic matter increased across all treatments: T1 (5.6%), T2 (5.5%), T3 (5.3%), T4 (6.1%), and control (5.4%). Soil pH remained acidic in T1, T2, and T3, while it was moderately acidic in T4 and the control. Nitrogen levels reached high values in T2, T3, and T4, phosphorus remained elevated, and potassium increased to 1.22, 1.75, 1.15, and 1.38 meq/100 g in T1, T2, T3, and T4, respectively, contributing to the correction of nutritional imbalances.

The presence of nitrogen in ammonium form (NH_4^+) modified soil pH by nitrifying to nitrate (NO_3^-), releasing protons (H^+) that acidified the soil and affected microbial activity and organic matter decomposition (Tang et al., 2025).

Before fertilization, nitrogen levels were low; however, after treatment T5, an increase was observed, likely influenced by topographical characteristics and environmental factors, such as soil moisture.

Table 3.
Comparison of soil analysis.

Parameters	O.M (%)	pH	NH_4 (ppm)	P (ppm)	K (meq/100 g)	B (ppm)
Initial	4.9 m	6.3 ac	10 b	77 a	0.40 m	0.47 b
Final T1	5.6 a	5.2 ac	18 b	64 a	1.22 a	0.27 b
Final T2	5.5 a	5.2 ac	57 a	65 a	1.75 a	0.58 m
Final T3	5.3 a	5.1 ac	67 a	53 a	1.15 a	0.53 m
Final T4	6.1 a	5.8 me	161 a	95 a	1.38 a	0.47 b
Testigo	5.4 a	5.9 me-ac	22 m	73 a	0.35 m	0.25 b

* High (a), medium (m), moderately acidic (ma), acidic (ac), low (b).

3.1. Number of primary shoots

Table 4 shows that treatment T2 was significantly superior to the other treatments in terms of the number of primary shoots at both 15 and 43 days, recording averages of 4 and 7 shoots, respectively. This result indicates a vigorous crop response to balanced nutrition. This effect is consistent with the findings of Bautista-Montealegre et al. (2021), who reported that applying nitrogen, phosphorus, potassium, and calcium to *R. glaucus* significantly increased shoot production and improved physiological responses to anthracnose. Similarly, Zhao et al. (2023) reported that treatment three, based on combined drench and soil applications, achieved an average of 10.98 primary shoots. This treatment included ammonium nitrate (4 L per plant), Yaramila (25 g per plant), potassium nitrate (2 L per plant), urea (50 g per plant), calcium nitrate (4 L per plant), and DAP (100 g per plant). These findings confirm that adequate nitrogen availability promotes early shoot development, establishing the foundation for higher productive potential in *R. glaucus*.

Statistical analysis indicates that the differences observed under T2 were not only numerical but also significant, as determined by the experimental design and multiple-comparison test ($p>0.05$ for means sharing the same letter). This reinforces the importance of balanced nutrient management at optimal doses. From a practical perspective, higher doses of N and K_2O can accelerate crop establishment, promote healthy shoot development, and potentially increase total yield, provided that integrated soil and water management practices are maintained to avoid negative effects such as salt accumulation.

3.2. Number of secondary shoots

Table 4 shows that the number of secondary shoots varied significantly with the applied fertilization dose. At 15 days, treatment T2 (low N + high K_2O) recorded the highest average with 83.25 shoots, highlighting the key role of potassium in the early induction of lateral buds. In contrast, at 43 days, treatment T3 (high N + low K_2O) showed the highest number of shoots (118.5), indicating that nitrogen becomes more relevant during later stages of vegetative development. This behavior suggests that the interaction between nitrogen and potassium is dynamic and dependent on the plant's phenological stage, promoting initial shoot emergence and subsequently sustaining vegetative growth. According to Ayala-Sánchez et al. (2015), balanced nutrition in blackberries promotes the vigor of young tissues and bud differentiation, which supports the results of this study.

Complementary research has confirmed that combined nutrient application enhances vegetative development in perennial species. Song et al. (2025) reported that the joint application of NPK significantly increases the formation and persistence of vegetative structures, highlighting the role of potassium in early shoot development and nitrogen in shoot elongation and maintenance. Likewise, Bautista-Montealegre et al. (2021) demonstrated that fertilization with N, P, K, and Ca in *R. glaucus* not only improves vegetative growth but also enhances resistance to diseases, ensuring the survival of secondary shoots throughout the crop cycle. In this context, the results of the present study confirm that designing fertilization programs according to the phenological stage is essential to maximize productivity and ensure agroproductive sustainability in the highlands of La Maná canton.

Table 4.
Number of primary and secondary shoots under N and K fertilization in blackberry cultivation.

Treatments	Primary shoots		Secondary shoots	
	15 days	43 days	15 days	43 days
T2: Low N + High K_2O	4 a	7 a	83.25 a	105.25 ab
T4: High N + High K_2O	2.75 b	6 ab	62.75 ab	91.25 b
T3: High N + Low K_2O	2.5 b	5 bc	63 ab	118.5 a
T1: Low N + Low K_2O	2.5 b	4 c	50 b	64 c

T5: Absolute Testigo	1.5 c	2.75 d	42 b	59.75 c
C.V.%	**11.93**	**12.52**	**16.39**	**9.36**

* Means sharing a common letter are not significantly different ($p > 0.05$).

3.3. Number of productive branches

Table 5 shows the effect of treatments on the number of productive branches, highlighting T2 as the most effective in both evaluations, with 13 branches at 30 days and 22 branches at 57 days (Sánchez et al., 2020). This response is attributed to the combined application of nitrogen and potassium, which optimized vegetative growth (Tang et al., 2025).

Statistical analysis confirmed that T2, outperformed the other treatments, showing significantly higher averages ($p<0.05$) (X.-M. Liu et al., 2022). Nitrogen availability, together with adequate water supply and proper pruning, stimulated branch production, consistent with studies linking these factors to foliar development (Sandhu et al., 2021).

Compared with previous data, the 13 and 22 branches observed under T2 exceeded the 5.6 and 7 branches reported by Guamán (2023) using 300 kg ha^{-1} of ammonium nitrate, suggesting that balanced N and K doses are more efficient than high nitrogen-only applications (Pilco, 2023). This superiority reinforces the hypothesis of optimized fertilization (Véliz & Seni, 2022).

Table 5.
Number of productive branches under N and K fertilization in blackberry cultivation.

Treatments	**Productive branches**	
	30 days	**57 days**
T2: Low N + High K_2O	13 a	22 a
T1: High N + Low K_2O	10 b	13 d
T3: High N + High K_2O	8.25 bc	15 c
T4: Low N + Low K_2O	7.5 c	17.75 b
T5: Absolute Testigo	4.5 d	8 e
C.V.%	**11.07**	**3.51**

* Means sharing a common letter are not significantly different ($p > 0.05$).

3.4. Number of flowers

Table 6 illustrates the effect of treatments on the number of flowers at 45 days, with T2 (low nitrogen + high potassium) reaching 941.25 flowers, demonstrating that balanced fertilization accelerates floral bud emergence and enhances flowering (Boonterm et al., 2013). This superiority highlights the role of potassium in sugar translocation toward reproductive organs (G. Liu et al., 2023).

Compared with previous studies, the number of flowers recorded in this study far exceeds the values of 4.6 and 3 flowers reported by Sandhu et al. (2021) under organic fertilization schemes with biols (1.25–3.75 cm^3/L), indicating that balanced chemical fertilization—particularly nitrogen and potassium—is more effective in inducing flowering in *R. glaucus* (Ye et al., 2025).

These findings reinforce the importance of fertilization during key growth stages. Plants under T2 not only increased flower production but also accelerated reproductive maturity, aligning with studies in Andean crops where potassium mitigates nitrogen deficiencies (Manokieng & Jampeetong, 2025). The observed variability (CV = 9.97%) indicates robustness of the experimental design (Li et al., 2022).

3.5. Fruit weight (g)

Treatments T4 and T2 showed the highest fruit weight, with averages of 6.15 g and 5.93 g, respectively ($p<0.05$, Tukey), indicating that high potassium combined with moderate to high nitrogen optimizes fruit development (G. Liu et al., 2023). This effect suggests improved nutrient balance and enhanced accumulation of solids in the fruit (Ye et al., 2025).

Statistical analysis confirmed the superiority of T4, followed by T2, surpassing values reported in previous studies using commercial fertilization plus organic amendments (Boonterm et al., 2013). Nitrogen's contribution to fruit weight was enhanced by potassium, outperforming approaches based solely on nitrogen (Manokieng & Jampeetong, 2025).

Compared with previous findings, T4 and T2 exceeded results reported by Pilco (2023), highlighting the advantage of optimized N and K combinations in subtropical soils (Li et al., 2022). This difference highlights the importance of adjusting fertilization according to varieties and cycles, adapting to subtropical soils (Luo et al., 2015).

3.6. Fruit length (cm)

Table 6 shows the effect of treatments on fruit length, with T4 and T2 presenting the highest values, 2.48 and 2.38 cm, respectively ($p<0.05$, Tukey). These results suggest that high potassium combined with moderate-to-high nitrogen promotes fruit elongation (Li et al., 2022). This trend reflects the influence of nutritional management in subtropical varieties (Ye et al., 2025).

Statistical analysis confirmed the superiority of these treatments, aligning with previous findings that highlight the influence of soil type and fertilization strategies (Manokieng & Jampeetong, 2025). Compared with Saito et al. (2020), who reported values of 2.57-2.68 cm, the results obtained are competitive, demonstrating the adaptability of the Colombian blackberry variety (Luo et al., 2015).

Table 6 presents mean with common letters that are not significantly different ($p>0.05$), which reinforces the consistency of T4 and T2, indicating that potassium optimizes cell growth, while nitrogen sustains biomass (Boonterm et al., 2013). These findings open new perspectives for standardizing fertilization in acidic soils of Cotopaxi (G. Liu et al., 2023)

3.7. Yield (kg/ha)

Table 6 shows the effect of the treatments on production yield at 85 days, with T2 (210 N + 275 K_2O kg/ha) reaching 11,039.53 kg/ha (11.04 t ha^{-1}), the highest among all treatments ($p<0.05$, Tukey), highlighting the efficiency of a moderate nitrogen dose combined with high potassium under subtropical conditions (C. Liu et al., 2023). This yield reflects nutritional optimization that helps mitigate climatic limitations (E. Liu et al., 2023).

Statistical analysis confirmed significant differences, with T2 outperforming T4 (9,713.04 kg ha^{-1}), T3 (8,177 kg ha^{-1}), T1 (5,447.26 kg ha^{-1}), and the control (4,499.4 kg ha^{-1}), consistent with reported yield ranges of 6–16 t ha^{-1} in conventional crops and up to 30 t ha^{-1} in technified systems (Latchem et al., 2021). Compared with the 10.15 t ha^{-1} reported for Cotopaxi (Ministerio de Agricultura y Ganadería, 2022), T2 represents a practical improvement for inter-Andean regions (Pilco, 2023).

These results differ from previous reports such as 23.93 kg/plant (E. Liu et al., 2023), but they exceed averages observed in trials with imbalanced fertilization, where low temperatures reduced fruit size and yield (X.-M. Liu et al., 2022). The superiority of T2 suggests that factors such as climate and genetic management do influence productivity, but balanced fertilization can raise yields to 11 t ha^{-1} in acidic soils (Sandhu et al., 2021).

Table 6.
Effect of nitrogen (N) and potassium (K) application on productive variables of blackberry (Rubus glaucus Benth).

Treatments	Number of flowers	Fruit weight (g)	Fruit length (cm)	Fruit length (cm)	Yield (kg/ha)
	45 days	**85 days**	**85 days**	**85 days**	**85 days**
T2: Low N dose + High K dose	941.25 a	6.15 a	2.38 a	2.38 a	11,039.53 a
T4: High N dose + High K dose	824.5 ab	824.5 ab	2.48 a	2.48 a	9,713.04 a
T3: High N dose + Low K dose	756 bc	4.80 b	1.85 b	1.85 b	8,177 b
T1: Low N dose + Low K dose	658 c	4,58 b	1.85 b	1.85 b	5,447.26 b
T5: Absolute Control	431 d	3.65 c	1.38 c	1.38 c	1,449.94 c
C.V.%	**9.97**	**4.94**	**3.47**	**3.47**	**10.45**

* Means sharing a common letter are not significantly different (p>0.05).

3.8. Economic analysis

The economic analysis evaluated annual costs for materials, equipment, labor, fertilizers (per kg/ha), and fungicides (ha year^{-1}) against income from the sale of 1 kg of blackberry in the Quito market, highlighting T2, which achieved a production of 11,039.53 kg ha^{-1} and generated total income of USD 17,663.25 ($p<0.05$, ANOVA). This performance reflected a profitability of 110.28 %, surpassing the other treatments. T2 optimized costs by aligning fertilization with soil nutritional analysis, thereby avoiding the economic losses observed in T1, T3, and T4, where nutrient imbalances reduced yields. Compared with generic fertilization approaches, this specific strategy increased profit margins, supporting its economic viability in the acidic soils of Cotopaxi.

The profitability of T2 contrasts with less efficient treatments, in which excessive fungicide and fertilizer use increased costs without a proportional rise in income. These results underscore that management based on crop nutrient requirements and soil monitoring maximizes economic returns, offering a replicable model for local farmers.

CONCLUSIONS

Treatment T2 showed superior agronomic performance, with higher numbers of primary and secondary shoots, productive branches, and flowers, highlighting its effectiveness in optimizing both vegetative and reproductive development. In contrast, T4 stood out in terms of fruit weight, diameter, and length, demonstrating that higher nitrogen doses enhance fruit size.

Conversely, T1 and T3 showed increased unproductive branches and lower overall performance, reflecting nutritional imbalances. Although T4 produced larger and heavier fruits, its yield (9,713.04 kg ha^{-1}) was lower than that of T2 (11,039.53 kg ha^{-1}), suggesting that excessive nitrogen application does not necessarily result in higher yields.

While no significant differences were observed between T2 and T4 in terms of fruit size and weight, the results indicate that moderate nitrogen levels combined with high potassium are sufficient to maximize yield, while reducing production costs and environmental risks. The highest yield was achieved with T2, reaching 11,039.53 kg/ha (11.04 t ha^{-1}) using 210 kg of N ha^{-1} and 275 kg of K_2O ha^{-1}, clearly outperforming the other treatments, where N/K imbalances limited productivity.

From an agronomic perspective, the study achieved its objective by demonstrating that blackberry (*Rubus glaucus* Benth.) response to N and K fertilization is not determined by excessive nitrogen application, but rather by an appropriate nutrient balance. Treatment T2 confirmed that moderate nitrogen levels, combined with high potassium doses, promote both vegetative and reproductive development, increase yield, and contribute to more efficient and sustainable production under subtropical conditions.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to the subject of this work.

AUTHOR CONTRIBUTIONS

Conceptualization and formal analysis: Salazar-Saltos, A. E.

Investigation: Salazar-Saltos, A. E. and Chusin-Ayala, C.R.

Methodology, project administration, and supervision: Salazar-Saltos, A. E.

Validation: Chusin-Ayala, C.R.

Visualization: Salazar-Saltos, A. E.

Writing – original draft and writing – review & editing: Salazar-Saltos, A. E. and Chusin-Ayala, C.R.

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