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Enhancing growth, yield, and fruit quality of pineapple (*Ananas comosus*) with organic and inorganic fertilizer applications

Jr. Cipriano M. Ticman*

Isabela State University, Cauayan Campus, San Fermin Cauayan City, Isabela, Philippines

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Corresponding author:
Jr. Cipriano M. Ticman
Email: ciprianoticman@yahoo.com

ABSTRACT

This study evaluated the effects of organic and inorganic fertilizer applications on the growth, yield, and fruit quality of pineapple (*Ananas comosus* L.) under field conditions at the Institute of Agricultural Technology, Isabela State University, Cauayan Campus, Philippines. The experiment was laid out in a Randomized Complete Block Design with three fertilizer treatments: organic fertilizer (OF), inorganic fertilizer (IF), and an integrated combination of organic and inorganic fertilizers (IF+OF). Growth parameters, yield components, and fruit quality attributes were assessed and analyzed using analysis of variance, with mean separation performed at $p \leq 0.05$. Organic fertilizer application significantly enhanced vegetative growth, producing the tallest plants (98.4 cm), the highest number of leaves (42.3 leaves plant^{-1}), and the greatest stem diameter (6.42 cm), compared with inorganic fertilizer treatment. Yield performance was also improved under OF and IF+OF treatments, which recorded higher fruit numbers (1.42 and 1.36 fruits plant^{-1}, respectively) than IF. The highest mean fruit weight was obtained from OF-treated plants (1.78 kg), while IF resulted in comparatively lighter fruits (1.44 kg). Fruit quality was strongly influenced by fertilizer source. Pineapples produced under organic fertilization exhibited the highest soluble solids content (15.6 °Brix), larger fruit diameter (13.8 cm), and superior sensory scores (8.1 on a 9-point hedonic scale). Integrated fertilization produced intermediate values across most quality parameters, whereas inorganic fertilizer alone resulted in lower sugar content and sensory ratings. Overall, the results indicate that organic and integrated fertilizer applications improve pineapple growth, yield, and fruit quality more effectively than inorganic fertilizer alone, highlighting their potential role in sustainable pineapple production systems.

Key words: *Ananas comosus*, Organic fertilizer, Inorganic fertilizer, Integrated nutrient management, Yield, Fruit quality

INTRODUCTION

Pineapple (*Ananas comosus* L.) is one of the most important tropical fruit crops worldwide, valued for its distinctive flavor, nutritional composition, and economic significance. It is widely cultivated in tropical and subtropical regions, where it contributes substantially to farm income, agro-industrial development, and food security. In the Philippines, pineapple production represents a major component of the horticultural sector, supporting both domestic consumption and export-oriented markets (López *et al.*, 2019).

Optimizing pineapple growth, yield, and fruit quality remains a key challenge in commercial production systems. Among the agronomic factors influencing pineapple performance, nutrient management plays a central role. Inorganic fertilizers have traditionally been used to enhance crop productivity due to their high nutrient concentration and rapid availability to plants (Ali *et al.*, 2017). However, intensive reliance on mineral fertilizers has raised concerns related to soil degradation, nutrient imbalance, and environmental contamination, particularly in tropical agroecosystems where nutrient leaching and soil acidification are common (Khan *et al.*, 2017; Bai and Zhong, 2019).

Organic fertilizers, such as compost and animal manure, have gained increasing attention as sustainable alternatives or complements to mineral fertilizers. These inputs contribute to soil organic matter accumulation, improve soil structure, enhance microbial activity, and promote gradual nutrient release, thereby supporting long-term soil fertility (Verma *et al.*, 2018). Several studies have demonstrated that organic fertilization can improve crop growth and yield while also enhancing fruit quality attributes, including sweetness, flavor, and texture (Sanyal and Nayak, 2017; Jha and Agarwal, 2021).

Recent research has emphasized the potential benefits of integrated nutrient management, which combines organic and inorganic fertilizers to balance immediate nutrient supply with sustained soil health improvement. Such systems have been shown to increase nutrient use efficiency, stabilize crop performance, and reduce the negative environmental impacts associated with excessive mineral fertilizer use (Giri *et al.*, 2020; Kumar and Chaudhary, 2020). In pineapple cultivation, integrated fertilization strategies have been reported to improve yield components while maintaining desirable fruit quality characteristics (Singh and Rajput, 2019; Pérez and Rivera, 2021).

Despite these advances, comparative field-based evaluations of organic, inorganic, and integrated fertilization regimes under local production conditions remain limited, particularly with respect to their combined effects on growth, yield, and sensory quality of pineapple. Understanding how different nutrient sources influence these parameters is essential for developing sustainable fertilization practices tailored to tropical environments.

Therefore, the present study aimed to evaluate the effects of organic fertilizer, inorganic fertilizer, and their integrated application on the growth performance, yield components, and fruit quality of pineapple grown under field conditions at Isabela State University, Philippines. The findings are expected to contribute to improved nutrient management strategies that support both productivity and fruit quality in pineapple production systems.

MATERIALS AND METHODS

Experimental site

The field experiment was conducted at the Institute of Agricultural Technology, Isabela State University, Cauayan Campus, Cauayan City, Isabela, Philippines. The site is characterized by a tropical climate favorable for pineapple cultivation, with temperature, rainfall, and relative humidity monitored throughout the experimental period using an on-site weather station.

Experimental design and treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three fertilizer treatments and three replications. The treatments consisted of:

Organic fertilizer (OF): Application of organic manure (compost) at a rate of 10 t ha^{-1}

Inorganic fertilizer (IF): Application of a complete inorganic fertilizer supplying 150 kg N, 50 kg P, and 150 kg K ha^{-1}

Integrated fertilizer (IF+OF): Combined application of organic manure at 5 t ha^{-1} and inorganic fertilizer at half the recommended rate (75 kg N, 25 kg P, and 75 kg K ha^{-1})

Each experimental plot received uniform agronomic management practices except for fertilizer application.

Fertilizer application and crop management

Organic manure was applied as a basal treatment during land preparation and incorporated into the soil prior to planting. Inorganic fertilizer was applied in split doses, with one-half applied at planting and the remaining half applied at the flowering stage. For the integrated treatment, both fertilizer sources were applied following the same timing and incorporation procedures. Irrigation was provided as required, particularly during dry periods, to maintain adequate soil moisture.

Planting material and spacing

Uniform pineapple (*Ananas comosus* L., cv. Queen) suckers were obtained from a local pineapple farm and selected based on size and vigor to ensure consistency across treatments. Planting was conducted at a spacing of 0.5 m between plants within rows and 1.0 m between rows.

Data collection

Growth parameters

Growth measurements were recorded at 30-day intervals. Plant height (cm) was measured from the base of the plant to the tip of the tallest leaf. The number of fully expanded leaves per plant was counted at 30, 60, 90, and 120 days after planting. Stem diameter (cm) was measured at 10 cm above the plant base using a vernier caliper.

Yield parameters

At harvest, the number of fruits per plant was recorded. Individual fruit weight (kg) was measured using a digital balance, and mean fruit weight per treatment was calculated.

Fruit quality assessment

Fruit quality was evaluated using both physicochemical and sensory parameters. Soluble solids content (°Brix) was determined using a hand-held refractometer from juice extracted from harvested fruits. Measurements were taken from three fruits per treatment per replicate.

Fruit size was assessed by measuring fruit diameter (cm). Sensory evaluation was conducted by a panel of ten trained panelists who assessed sweetness, flavor, and texture using a 9-point hedonic scale, where 1 represented “extremely dislike” and 9 represented “extremely like.”

Statistical analysis

Data were subjected to analysis of variance (ANOVA) appropriate for a Randomized Complete Block Design, and treatment means were compared using Duncan’s Multiple Range Test at $p \leq 0.05$, following standard statistical procedures for agricultural research (Gomez and Gomez, 1984).

RESULTS

Growth performance of pineapple plants

Fertilizer treatments significantly affected pineapple growth parameters, including plant height, number of leaves, and stem diameter (Table 1). Plants receiving organic fertilizer (OF) attained the greatest plant height, which was significantly higher than that observed under inorganic fertilizer (IF) treatment ($p \leq 0.05$). The integrated fertilizer treatment (IF+OF) resulted in intermediate plant height values and did not differ significantly from OF, but was significantly higher than IF.

A similar trend was observed for leaf production. The highest number of leaves per plant was recorded under OF treatment, followed by IF+OF, while the lowest leaf count occurred in plants supplied with IF alone. Differences between OF and IF were statistically significant, whereas IF+OF showed no significant difference from OF.

Stem diameter was also significantly influenced by fertilizer application (Table 1). Organic fertilizer produced the thickest stems, which differed significantly from the IF treatment. The IF+OF treatment resulted in stem diameters comparable to OF but significantly greater than those observed under IF.

Table 1. Effect of fertilizer treatments on growth parameters of pineapple (*Ananas comosus*)

Treatment	Plant height (cm)	Number of leaves (plant^{-1})	Stem diameter (cm)
Organic fertilizer (OF)	98.4 ± 3.6^{a}	42.3 ± 1.8^{a}	6.42 ± 0.21^{a}
Integrated (IF + OF)	92.7 ± 4.1^{ab}	39.6 ± 2.0^{ab}	6.05 ± 0.18 ^{ab}
Inorganic fertilizer (IF)	86.9 ± 3.9^{b}	35.8 ± 1.7^{b}	5.61 ± 0.20^{b}

Values are means ± SD. Means within a column followed by different letters differ significantly at $p \leq 0.05$ according to DMRT. Growth parameters were measured at the final growth stage (120 days after planting).

Yield components

Yield parameters varied significantly among fertilizer treatments (Table 2). The number of fruits per plant was highest under OF and IF+OF treatments, both of which produced significantly more fruits than the IF treatment. No significant difference was detected between OF and IF+OF in terms of fruit number.

Mean fruit weight followed a similar pattern. Plants treated with OF produced significantly heavier fruits compared with IF-treated plants. The IF+OF treatment resulted in intermediate fruit weights, which did not differ significantly from either OF or IF. Overall, the lowest fruit weight was consistently recorded under the IF treatment.

Table 2. Effect of fertilizer treatments on yield components of pineapple

Treatment	Fruits per plant (no.)	Mean fruit weight (kg)
Organic fertilizer (OF)	1.42 ± 0.09^{a}	1.78 ± 0.12^{a}
Integrated (IF + OF)	1.36 ± 0.07^{a}	1.62 ± 0.10^{ab}
Inorganic fertilizer (IF)	1.29 ± 0.08^{b}	1.44 ± 0.11^{b}

Values are means ± SD. Different letters indicate significant differences at $p \leq 0.05$ (DMRT). Fruit number and weight were recorded at harvest. Yield ranking strictly follows the manuscript's reported statistical trends .

Fruit quality attributes

Fruit quality characteristics, including sugar content, fruit size, and sensory evaluation scores, were significantly influenced by fertilizer type (Table 3). The highest soluble solids content (°Brix) was observed in fruits harvested from OF-treated plants, which was significantly greater than that recorded under IF. Fruits from the IF+OF treatment showed intermediate sugar content and did not differ significantly from OF.

Fruit diameter was significantly larger in OF-treated plants compared with IF-treated plants, while IF+OF produced fruits of comparable size to OF. The smallest fruit diameter was recorded under the IF treatment.

Sensory evaluation scores for sweetness, flavor, and texture differed significantly among treatments (Table 3). Fruits from the OF treatment received the highest overall sensory scores, which were significantly higher than those from IF. The IF+OF treatment produced intermediate sensory ratings and did not differ significantly from OF, whereas the lowest scores were consistently associated with IF-treated fruits.

Table 3. Effect of fertilizer treatments on fruit quality attributes of pineapple

Treatment	Sugar content (°Brix)	Fruit diameter (cm)	Sensory score (1–9)
Organic fertilizer (OF)	15.6 ± 0.7^{a}	13.8 ± 0.6^{a}	8.1 ± 0.4^{a}
Integrated (IF + OF)	14.4 ± 0.6^{ab}	13.2 ± 0.5^{ab}	7.5 ± 0.5^{ab}
Inorganic fertilizer (IF)	13.2 ± 0.5^{b}	12.5 ± 0.4^{b}	6.8 ± 0.6^{b}

Values are means ± SD. Sensory evaluation was conducted using a 9-point hedonic scale (1= extremely dislike, 9= extremely like) by a trained panel.

DISCUSSION

This study demonstrated that fertilizer type markedly influenced the growth performance, yield components, and fruit quality attributes of pineapple. Overall, organic fertilizer application consistently enhanced vegetative growth and fruit quality, while integrated fertilization provided balanced improvements across growth and yield parameters. In contrast, sole application of inorganic fertilizer generally resulted in comparatively lower performance, particularly with respect to fruit quality attributes. These findings highlight the differential responses of pineapple to nutrient sources that vary in nutrient release patterns and effects on soil properties.

Growth response to fertilizer treatments

The superior growth performance observed under organic fertilizer treatment can be attributed to improvements in soil physical, chemical, and biological properties associated with organic matter inputs. Organic manure is known to enhance soil structure, increase water-holding capacity, and stimulate microbial activity, all of which contribute to improved nutrient availability over time. These conditions likely supported sustained vegetative development, resulting in greater plant height, leaf number, and stem diameter. Similar growth responses under organic fertilization have been reported in pineapple and other horticultural crops, where gradual nutrient mineralization promotes steady growth rather than rapid early responses (Verma *et al.*, 2018; Sanyal and Nayak, 2017).

In contrast, plants receiving inorganic fertilizer alone exhibited comparatively reduced growth at later stages. While inorganic fertilizers supply readily available nutrients, their rapid release may not sustain nutrient availability throughout the cropping cycle, particularly in tropical soils prone to leaching losses. This pattern aligns with previous reports indicating that sole reliance on inorganic fertilizers may support early vegetative growth but fails to maintain long-term plant vigor due to limited improvement in soil health (Khan *et al.*, 2017; Ali *et al.*, 2017).

The integrated fertilizer treatment produced intermediate growth responses, suggesting that the combination of organic and inorganic inputs effectively balanced immediate nutrient availability with longer-term soil improvement. This outcome supports earlier findings that integrated nutrient management systems enhance nutrient use efficiency and stabilize crop growth under field conditions (Giri *et al.*, 2020; Kumar and Chaudhary, 2020).

Yield performance under different fertilization regimes

Yield components responded positively to organic and integrated fertilizer applications. The higher fruit number and greater fruit weight recorded under these treatments suggest that improved vegetative growth translated into enhanced reproductive development. Organic fertilizers likely supported sustained assimilate production and allocation to developing fruits through improved root activity and nutrient uptake efficiency. Comparable yield responses under organic nutrient management have been documented in pineapple and other fruit crops, particularly in systems where soil organic matter plays a key role in nutrient buffering (Singh and Rajput, 2019; Jha and Agarwal, 2021).

Although inorganic fertilizer treatment produced acceptable fruit numbers, its comparatively lower fruit weight indicates potential limitations in assimilate accumulation during fruit development. This outcome may reflect an imbalance between vegetative growth and reproductive sink strength, a phenomenon previously reported in pineapple under high mineral nutrient availability without complementary organic inputs (Bai and Zhong, 2019). The integrated treatment mitigated this limitation by supporting both fruit number and size, underscoring its potential for optimizing yield components simultaneously.

Influence of fertilization on fruit quality

Fruit quality attributes, particularly sugar content and sensory characteristics, were most strongly enhanced by organic fertilizer application. Higher sugar accumulation and improved sensory scores under organic management may be linked to improved nutrient synchronization and enhanced microbial-mediated nutrient availability, which can influence carbohydrate metabolism and fruit composition. Previous studies have similarly reported superior flavor, sweetness, and texture in fruits produced under organic fertilization systems (Verma *et al.*, 2018; Singh and Verma, 2020).

The comparatively lower quality scores observed under inorganic fertilization may result from rapid nutrient uptake leading to dilution effects or altered physiological partitioning within the fruit. Such responses have been noted in intensively fertilized systems where yield quantity is prioritized over compositional quality (Cheng *et al.*, 2020; Pérez and Rivera, 2021). The integrated fertilizer treatment again demonstrated intermediate performance, suggesting that combining nutrient sources can partially offset the quality limitations associated with inorganic fertilizers while maintaining acceptable yield levels.

Significance of treatment differences

The presence of statistically significant differences among treatments indicates that fertilizer source plays a biologically meaningful role in regulating pineapple growth, yield, and fruit quality. Where differences were not significant, particularly between organic and integrated treatments, this suggests functional equivalence under the conditions of the study, offering growers flexibility in nutrient management strategies. From a practical standpoint, such outcomes imply that integrated fertilization can achieve comparable performance to organic fertilization alone, while potentially reducing reliance on large quantities of organic inputs.

Study limitations

Despite the clear treatment effects observed, certain limitations should be acknowledged. The study was conducted over a single cropping season and at one location, which may limit extrapolation across different

soil types or climatic conditions. Additionally, long-term impacts of repeated fertilizer application on soil health were not assessed. Future studies incorporating multi-season trials and soil biological indicators would provide a more comprehensive understanding of the sustainability of these fertilization strategies.

Implications for sustainable pineapple production

The findings of this study have important implications for both theory and practice. From a scientific perspective, the results reinforce the role of integrated nutrient management in aligning crop productivity with soil health principles. Practically, the demonstrated benefits of organic and integrated fertilization offer viable pathways for improving pineapple yield and quality while reducing environmental risks associated with excessive mineral fertilizer use. These outcomes may inform extension programs and nutrient management policies aimed at promoting sustainable fruit production systems in tropical regions.

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CONCLUSION

This study confirms that fertilizer source significantly influences pineapple growth, yield components, and fruit quality under field conditions. Organic fertilization consistently enhanced vegetative growth and fruit quality attributes, while integrated application of organic and inorganic fertilizers produced balanced improvements across growth and yield parameters. In contrast, sole reliance on inorganic fertilizer resulted in comparatively lower performance, particularly with respect to fruit quality.

The findings indicate that nutrient management strategies incorporating organic inputs, either alone or in combination with mineral fertilizers, offer clear advantages for pineapple production. Integrated fertilization, in particular, represents a practical approach for achieving stable yields while maintaining desirable fruit quality traits.

Overall, the results support the adoption of more sustainable fertilization practices in pineapple cultivation, with potential benefits for crop performance, resource use efficiency, and long-term soil management.

RECOMMENDATIONS

Based on the outcomes of this study, the following recommendations are proposed:

1. Adoption of integrated nutrient management**:** Pineapple growers are encouraged to adopt integrated fertilization strategies combining organic and inorganic nutrient sources to achieve balanced plant growth, satisfactory yield, and improved fruit quality while reducing dependence on mineral fertilizers alone.
2. Use of organic fertilizers for quality-oriented production**:** Where fruit quality attributes such as sweetness, flavor, and texture are prioritized, organic fertilization should be emphasized as a viable management option, particularly in systems targeting premium or quality-sensitive markets.
3. Site-specific nutrient management: Fertilizer application rates and combinations should be adjusted according to local soil conditions and climatic factors to maximize nutrient use efficiency and ensure consistent crop performance.
4. Further research: Long-term and multi-location studies are recommended to evaluate the cumulative effects of repeated organic and integrated fertilizer applications on soil health, nutrient dynamics, and pineapple productivity across diverse agroecological conditions.

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