



Agronomic and Yield Assessment of High-Yielding Sugarcane Varieties (Phil 99-1793 and Phil 2004-1011) in Response to Integrated Nutrient Management

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ABSTRACT

Sugarcane farming plays a vital role in rural livelihoods, agro-industrial development, and national economic growth. Evaluation of two high-yielding sugarcane varieties: Phil 99-1793 and Phil 2004-1011 under different nutrient management strategies: full recommended inorganic fertilizer (70-140-260 kg NPK ha⁻¹), mud press at 10 t ha⁻¹, and an integrated nutrient management (INM) approach consisting of 50% recommended inorganic fertilizer (35-70-130 kg NPK ha⁻¹) combined with 5 t ha⁻¹ mud press. The experiment was arranged in a Factorial Randomized Complete Block Design with three replications in Kabankalan City, Negros Occidental, Philippines, from June 2021 to April 2022. Standard cultural management practices were employed. Agronomic and juice quality parameters were analysed at the 5% threshold level. Nutrient treatments did not differ significantly in stalk diameter, number of nodes, or number of internodes. Phil 2004-1011 outperformed Phil 99-1793 in plant height (149.89 cm), stalk length (198.84 cm), plot weight (111.44 kg), cane yield (30.89 t ha⁻¹), sucrose yield (2.06 LKg TC⁻¹), and sugar yield (1.63 LKg ha⁻¹), demonstrating superior genetic potential. Full inorganic fertilizer (IF) positively increased tiller count, Brix, sucrose yield, and sugar yield. INM application enhanced the number of millable canes and produced comparable cane yield (30 t ha⁻¹), indicating potential as a cost-efficient and sustainable alternative. Combination of high-performing varieties with optimized nutrient management strategies can improve productivity, resource-use efficiency, and sustainable sugarcane production. Findings recommended exploring root architecture, physiological responses to stress conditions, nutrient dynamics, soil microbial interactions, and molecular characterization under diverse environmental conditions.

ARTICLE INFO

Received: Mar. 12, 2026

Revised: Sept. 9, 2026

Accepted: Sept. 16, 2026

KEYWORDS

Integrated nutrient management, Kabankalan City, Mud press, Phil 99-1793, Phil 2004-1011, Sugarcane productivity

Suggested Citation (APA Style 7th Edition):

Torteo, E.G. & Lumba, A.R.L. (2026). Agronomic and yield assessment of high-yielding sugarcane varieties (Phil 99-1793 and Phil 2004-1011) in response to integrated nutrient management. *International Research Journal of Science, Technology, Education, and Management*. 6(3), 1-10.
<https://doi.org/10.5281/zenodo.23032203>

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is one of the most economically important cash crops worldwide and a source of sugar, bioethanol, and agro-industrial by-products that support the food, energy, and manufacturing sectors (Solomon & Misra, 2024). In the Philippines, sugarcane remains a significant driver of agricultural growth and a source of employment in rural communities. Statistically, approximately 65% of sugarcane production is attributed to Pampanga, Mindanao, and Western Visayas (Oñal et al., 2021). To sustain the growth demand, the Sugar Regulatory Administration (SRA) is mandated to promote varietal development, improved cultural practices, and technological innovations that benefit small to marginalized sugarcane farmers and agro-industrial stakeholders (Republic Act No. 10659 | GOVPH, 2015). Physiologically, sugarcane growth, development, yield, and income are influenced by a complex interaction of environmental, genetic, and management factors, including climate, soil characteristics, topographic location, irrigation, pest and disease pressure, variety, and nutrient management (Mehdi et al., 2024; Verma et al., 2024). Nutrient availability, timing, and application rates are particularly critical factors in crop production, especially in sugarcane, which requires a balanced supply of macro- and micronutrients to support photosynthesis, enzyme activity, structural development, and sucrose accumulation (Kumar et al., 2021; Johnson & Mirza, 2020).

Currently, the overreliance on inorganic fertilizers has led to declining soil fertility and degradation, lower nutrient-use efficiency (NUE), increased production costs, and environmental stress and health concerns, prompting the need for more sustainable nutrient management strategies (Pang et al., 2021; Banerjee et al., 2018). Organic amendments serve as a better solution to address soil problems because they enhance soil fertility through their ability to boost soil microorganism populations, improve water retention, and promote deeper root systems that can endure extreme weather conditions, including strong winds, typhoons, and lodging (Singh et al., 2022; Abbasi, 2025). Among the environmentally friendly organic amendments that provide budget-friendly solutions, sugarcane press mud (SPM) serves as one option because it contains essential nutrients as a by-product from the sugarcane juice clarification process used in refined sugar production. SPM serves as a soil amendment that promotes nutrient retention and soil aeration to support crop development while being environmentally safe for restoring degraded soils that suffered from prolonged chemical fertilizer use (Venkatakrishnan & Manimaran, 2020; Jha et al., 2019; Zhao et al., 2020).

The scientific evidence demonstrates that SPM provides agricultural advantages. The application of the product results in better seed germination, increased tillering, taller plants, an increased number of millable cane, heavier stalks, higher sucrose content, and greater total yield, especially when NPK rates are applied as recommended (Kumar et al., 2017; Chattha et al., 2019). The use of press mud has increased sugarcane yields while also boosting turmeric production by 22.7% when SPM and NPK were used together (Bairagi, 2022). The practice of Integrated Nutrient Management (INM), which combines organic amendments like SPM with inorganic fertilizers, enables more effective nutrient usage while enhancing soil quality to achieve sustainable agricultural output (Priyadarshi et al., 2021; Sarimong et al., 2017; Ranjan et al., 2020; Darandale, 2016). The understanding of SPM interactions with high-yielding sugarcane varieties at different fertilizer levels becomes crucial because SPM serves as a secondary nutrient source.

Objectives of the Study

This study aimed to identify the optimal sugarcane variety, nutrient management approach, and their combination that maximize growth, yield, and juice quality under local conditions. Specifically, it seeks to evaluate the performance of different sugarcane varieties under three nutrient management strategies—inorganic, organic (SPM), and integrated—to determine which treatment or combination produces the most favorable agronomic and quality outcomes.

METHODOLOGY

The field experiment was conducted at the Central Philippines State University (CPSU) Experimental Research Area, Barangay Camingawan, Kabankalan City, Negros Occidental, Philippines (Figure 1), spanning one cropping cycle from June 2021 to 2022. The area is characterized by distinct wet and dry seasons and is a typical sugarcane-producing region in the province. Standard agronomic and cultural practices recommended for commercial sugarcane production were followed throughout the experimental period to ensure optimal crop growth. The experiment was arranged in a factorial design using a Randomized Complete Block Design (RCBD) with three replications. The sugarcane varieties Phil 99-1793 & Phil 2004-1011 were utilized, and integrated nutrient management (INM) was used, which included the full recommended rate (RR) of inorganic fertilizer (70-140-260 kg NPK ha⁻¹), 10 t ha⁻¹ mud press (organic fertilizer), and 50% RR of inorganic fertilizer (35-70-130 kg NPK ha⁻¹) combined with 5 t ha⁻¹ mud press. Each treatment combination was randomly assigned within each block to minimize experimental error arising from field variability. Each plot measured 36 m², with plant spacing of 25 cm × 120 cm, 1-meter alleys between treatments, and 2-meter buffer zones between blocks.

A total of 120 healthy and uniform planting materials were used for crop establishment. Land preparation included plowing and harrowing to achieve a fine seedbed. Fertilizer treatments were applied according to the designated levels, with inorganic fertilizers applied in split applications and mud press incorporated before planting. Uniform cultural management practices, including irrigation, weeding, hilling-up, and pest and disease control, were consistently implemented. The researchers measured sugarcane growth parameters, including the number of tillers, plant height, number of nodes and internodes, stalk length, and diameter. On the yield and juice quality at harvest evaluated the number of millable canes per plot, plot weight, cane yield, Brix percentage, sucrose yield, and sugar yield. Juice quality analyses were conducted at the Research Laboratory Services Office of the Sugar Regulatory Administration, La Granja, La Carlota City, Philippines, following established procedures for sugar extraction and analysis.

All collected data were encoded judiciously and subjected to Analysis of Variance (ANOVA) to evaluate the effects of sugarcane variety, integrated nutrient management, and their interaction on growth, yield, and juice quality parameters. Prior to ANOVA, data normality and homogeneity of variance were assessed using the Shapiro–Wilk and Levene’s tests, respectively. When significant differences were detected at the 5% level, treatment means were compared using Tukey’s Honest Significant Difference (HSD) test at 5% probability. Interaction effects between sugarcane varieties and nutrient management treatments were specifically examined to identify differential varietal responses to fertilizer strategies. All data were analysed using the RStudio software program.

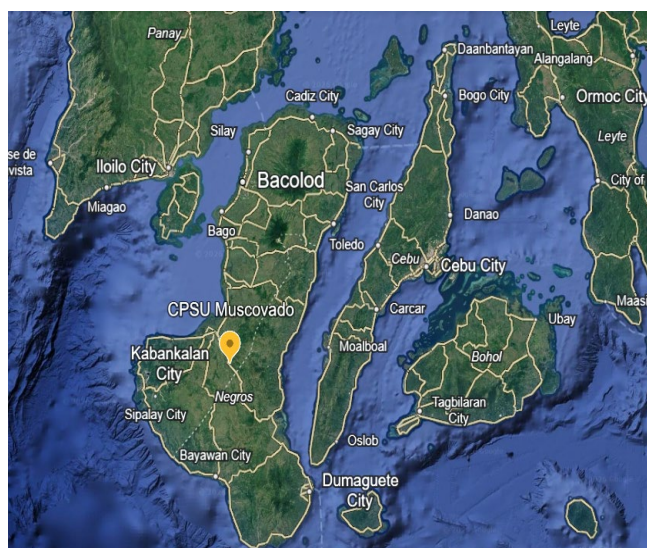


Figure 1. Location of the Experimental Area

RESULTS AND DISCUSSION

The results showed that both sugarcane variety and integrated nutrient management contributed to differences in agronomic and sugar yield performance. The two varieties exhibited distinct growth and productivity characteristics, while nutrient management treatments produced varying responses across the measured parameters. These results provide a basis for assessing the relative performance of Phil 99-1793 and Phil 2004-1011 and determining suitable nutrient management strategies to improve sugarcane production.

Agronomic Response

Table 1. Growth response of sugarcane varieties to integrated nutrient management.

Sugarcane Varieties	Tiller/ Plant	Plant Height	Stalk Length	No. of Nodes	No. of Internodes	Stalk Diameter
Phil 99 - 1793	5.75	110.83 ^b	162.63 ^b	24.10 ^b	23.10 ^b	86.76 ^a
Phil 2004-1011	6.25	149.88 ^a	198.94 ^a	26.23 ^a	25.33 ^a	77.89 ^b
Integrated Nutrient Management						
Full IF (70-140-260 NPK)	7.05 ^a	145.73	191.85	23.47	83.34	24.42
10 tons/ha Mudpress	4.70 ^b	131.07	172.43	24.43	81.39	25.93
50% RR + 5 tons/ha Mudpress	6.25 ^a	114.27	178.08	24.25	82.11	25.25
Sugarcane Varieties * INM	-	-	-	-	-	-
CV% p > 0.05	16.08	19.98	9.54	6.93	6.39	5.63

Tillering is one of the most important traits in sugarcane because it directly affects the number of canes that can be harvested per area, overall yield, and ratooning success (Ranjan et al., 2020). There was no significant difference in tiller numbers between the two sugarcane varieties. However, Phil 2004-1011 produced a numerically higher tiller count than Phil 99-1793, indicating a stronger genetic potential for shoot growth. In contrast, integrated nutrient management had a significant effect on tillering. The full recommended rate of inorganic fertilizer (70-140-260 kg NPK ha⁻¹) produced the highest tiller count (7.05), significantly exceeding the results of sole mud press application and the integrated treatment. This finding supports the work of Bhatt et al. (2024), who noted that balanced NPK fertilization improves shoot emergence and lowers incidences of withered heart, enhancing stand establishment.

Plant height is an important measure of crop health, biomass accumulation, and potential yield (Wang et al., 2018). Phil 2004-1011 exhibited significantly greater plant height (149.88 cm) than Phil 99-1793, highlighting the substantial influence of genetic factors on plant growth. This finding is consistent with Arefin et al. (2022), who reported that differences in plant height are primarily associated with genetic factors, reflecting the inherent capacity of genotypes to express distinct growth characteristics. Although plants receiving the full recommended fertilizer rate tended to be taller than those under other nutrient management strategies, the differences among fertilizer treatments were not statistically significant. The observed variation in plant height was more strongly associated with genotypic differences than with nutrient management under the conditions.

Stalk elongation is crucial for sugarcane productivity since it relates closely to sucrose storage and final yield. Physiologically, the shift from vegetative growth to sucrose storage is shown by increased stalk length and the development of more nodes and internodes. Significant differences were noted in stalk length, node number, and internode count. Phil 2004-1011 had longer stalks (198.94 cm) with more nodes (26.23) and internodes (25.33) than Phil 99-1793, suggesting better structural growth and storage capacity. These results are further supported by

Arefin et al. (2022), who highlighted the genetic role in stalk growth. However, nutrient management treatments did not significantly affect these traits, indicating that genetic factors mainly influenced stalk elongation.

Stem diameter is another key growth trait, reflecting structural strength and potential sugar storage. Zhao et al. (2020) reported that larger stem diameters result from tissue growth and are linked to higher sugar content. In this study, significant differences in stalk diameter emerged, with Phil 99-1793 having thicker stalks (86.76 mm) than Phil 2004-1011, aligning with its classification as a medium-thick type. This observation is consistent with Arefin et al. (2022), who noted that stem thickness largely depends on genotype. In contrast, integrated nutrient management treatments did not significantly affect stalk diameter, suggesting that fertilizer variation had a limited impact on this growth trait.

Yield Assessment Performance

Table 2. Yield and juice quality of sugarcane varieties under integrated nutrient management.

Sugarcane Varieties	No. Millable Canes/Plot	Plot Weight (kg)	Brix %	Cane Yield (tons/ha)	Sucrose Yield (Lkg/TC)	Sugar Yield (LKg/ha)
Phil 99 - 1793	106.89 ^b	95.10 ^b	18.43	26.33 ^b	1.95 ^b	1.54 ^b
Phil 2004-1011	164.44 ^a	111.44 ^a	18.88	30.89 ^a	2.06 ^a	1.63 ^a
Integrated Nutrient Management						
Full IF (70-140-260 NPK)	110.17	97.49	18.99 ^a	27.17	2.09 ^a	1.65 ^a
10 tons/ha Mudpress	118.34	103.50	18.22 ^b	28.67	1.92 ^b	1.52 ^b
50% RR + 5 tons/ha Mudpress	178.50	108.83	18.77 ^{ab}	30.00	2.01 ^b	1.59 ^b
Sugarcane Varieties	-	-	-	-	*	*
* INM	-	-	-	-	-	-
CV%	9.58	6.78	2.51	7.41	3.69	3.75

The number of millable canes per plot is a key factor in field productivity. It directly affects the amount of harvestable biomass and economic return. Phil 2004-1011 produced significantly more millable canes per plot than Phil 99-1793. This difference may be due to its better tillering capability and genetic potential. Zhao et al. (2022) noted that a variety's genetic makeup is crucial in determining stalk population and final yield. Among the nutrient management treatments, using 50% of the recommended NPK (35-70-130 kg ha⁻¹) along with 5 t ha⁻¹ mud press resulted in the highest number of millable canes (178.50 canes plot⁻¹) and outperformed both sole inorganic and sole organic applications. Bhatt et al. (2024) found that integrated nutrient management improves stalk population by enhancing nutrient availability and soil condition. A notable difference in plot weight was observed; Phil 2004-1011 exceeded Phil 99-1793 by 16.04 kg. The greater number of millable canes, longer stalks, and overall better growth likely contributed to this increase. This finding supports Jha et al. (2019), as mentioned by Arefin et al. (2022), indicating that yield-related traits are closely linked to the inherent genetic traits. On the other hand, integrated nutrient management did not significantly affect plot weight, yet the combination of inorganic and organic treatment produced the highest plot weight, suggesting synergistic effects from balanced nutrient supply and better soil properties.

Brix percentage indicates soluble solids concentration and juice quality and was not greatly influenced by the variety. However, nutrient management showed a positive trend. The full recommended inorganic fertilizer rate resulted in the highest Brix value (18.99%), which is comparable to the integrated treatment (18.77%). This supports Bekheet et al. (2018), who found that phosphorus and well-balanced fertilization boost sucrose accumulation and storage during cane maturation. In terms of cane yield, Phil 2004-1011 significantly outperformed Phil 99-1793, with a yield of 30.89 t ha⁻¹ compared to 26.33 t ha⁻¹. This highlights the role of genetic

potential in yield determination. While environmental factors, such as temperature and rainfall, can greatly affect sugarcane productivity (Dotaniya et al., 2016), the yield advantage noted in this study was primarily linked to varietal traits under the current conditions.

Nutrient management treatments did not significantly impact cane yield. Varietal performance had a stronger influence than fertilizer variation, as emphasized by Bhatt et al. (2024); proper selection of genotypes in crop production establishment is vital to maintain productivity. Sucrose and sugar yields were greatly influenced by the interaction of sugarcane variety and integrated nutrient management (INM). Among the varieties, Phil 2004-1011 produced a much higher sucrose yield of 2.06 Lkg TC⁻¹ and a sugar yield of 1.63 Lkg ha⁻¹ compared to Phil 99-1793, which recorded 1.95 Lkg TC⁻¹ and 1.54 Lkg ha⁻¹, respectively. In terms of nutrient management, using the full recommended inorganic fertilizer rate of 70-140-260 kg NPK ha⁻¹ resulted in the highest sucrose yield of 2.09 Lkg TC⁻¹ and sugar yield of 1.65 Lkg ha⁻¹. These figures were significantly better than those from the sole mud press application of 10 t ha⁻¹, which produced 1.92 Lkg TC⁻¹ and 1.52 Lkg ha⁻¹, respectively.

The integrated treatment of 50% recommended NPK and 5 t ha⁻¹ mud press generated intermediate values of 2.01 Lkg TC⁻¹ for sucrose yield and 1.59 Lkg ha⁻¹ for sugar yield. Sucrose yield plays a key role in sugar recovery during milling. If harvested cane is not processed quickly, sucrose degrades rapidly (Kumat et al., 2021). The strong performance of Phil 2004-1011 in both sucrose and sugar yield highlights how much genetic potential affects economic productivity. This supports findings from Cervi et al. (2018) and Kumar et al. (2021), who noted that improving genetics is crucial for boosting sucrose levels and overall crop profits. The significant rise in sucrose and sugar yield under the full recommended NPK treatment suggests that a balanced and adequate nutrient supply improves photosynthetic activity, assimilate movement, and sucrose processing.

Mehdi et al. (2020) and Sasy et al. (2021) found that proper NPK fertilization positively affects enzymes involved in sucrose production and storage in sugarcane. The significant interaction effect further shows that the performance of varieties is affected by nutrient availability. Phil 2004-1011 responded better to higher NPK levels, leading to better sugar recovery. On the other hand, the integrated nutrient management treatment offered competitive yields. This demonstrates that partially replacing inorganic fertilizer with mud press can maintain productivity while also improving soil health and long-term sustainability, in line with findings from Arefin et al. (2020). The results highlight the importance of choosing high-performing varieties and pairing them with the right nutrient management strategies to maximize sugarcane productivity and economic returns.

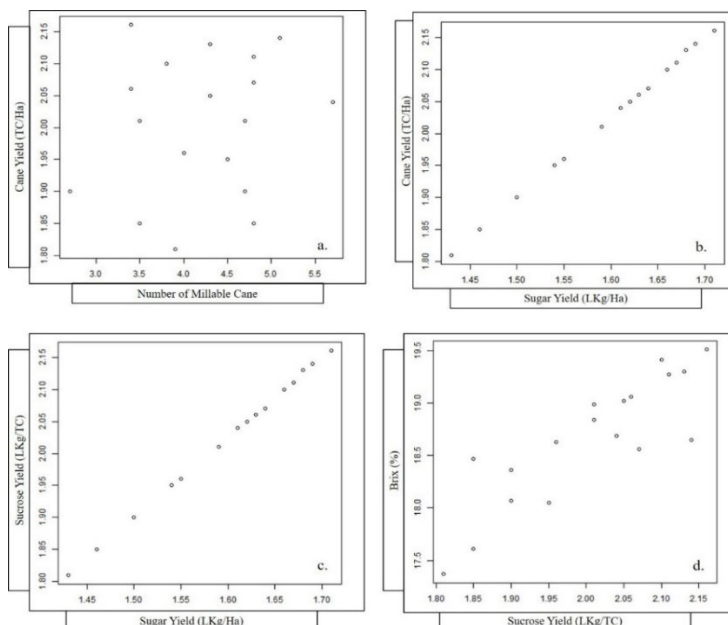


Figure 2. Correlation analysis illustrating, via scatter plots, results showing the relationships between (a) cane yield and number of millable stalks, (b) cane yield and sugar yield, (c) sucrose yield and sugar yield, and (d) Brix (%) and sugar yield.

Among sugarcane growth, yield, and quality parameters. Vegetative traits such as tiller number, stalk diameter, plant height, number of millable canes, and number of internodes generally showed weak correlations with yield and juice quality. For example, tiller number versus cane yield ($r = 0.364$, $p = 0.138$), stalk diameter versus cane yield ($r = -0.348$, $p = 0.157$), plant height versus plot weight ($r = 0.319$, $p = 0.198$), plant height versus sugar yield ($r = 0.285$, $p = 0.252$), and stalk diameter versus Brix ($r = -0.100$, $p = 0.693$) were all not statistically significant. In contrast, the number of millable canes was moderately and significantly correlated with cane yield ($r = 0.480$, $p = 0.044$), indicating that increased cane density enhances productivity. Strong positive correlations were found between cane yield and sugar yield ($r = 0.610$, $p = 0.007$) and between sucrose yield and sugar yield ($r = 0.9998$, $p < 0.001$), demonstrating a close association between total cane production and sugar output. Furthermore, sucrose yield was strongly correlated with Brix ($r = 0.858$, $p < 0.001$), indicating that higher sugar concentration aligns with greater sucrose accumulation.

The weak correlations observed between vegetative traits and yield parameters suggest that morphological characteristics alone are insufficient predictors of sugarcane productivity. This finding is consistent with previous research highlighting the greater influence of environmental conditions and integrated crop management compared to plant morphology in determining yield (Arefin et al., 2022; Mehdi et al., 2024; Venkatakrishnan and Manimaran, 2020). The significant positive correlation between the number of millable canes and cane yield emphasizes the importance of optimizing cane density, in agreement with studies demonstrating the benefits of integrated nutrient management for sugarcane growth and productivity (Banerjee et al., 2018; Bhatt et al., 2024). Strong associations between cane yield and sugar yield, as well as between sucrose yield and both sugar yield and Brix, indicate that biomass accumulation directly affects sugar production and quality. This supports previous reports on the role of sucrose mobilization in sugar accumulation (Ranjan et al., 2020; Sasy and Abu-Ellail, 2021; Pérez-Contreras et al., 2025). The results further highlight the advantages of integrating organic and inorganic nutrient sources, such as composted press mud and green manures, to improve soil fertility, yield, and juice quality (Darandale, 2016; Chattha et al., 2019; Kumar et al., 2017; Priyadarshi et al., 2021). Optimizing cane density, implementing effective nutrient management, and monitoring sucrose accumulation are essential strategies for maximizing both sugarcane yield and sugar quality within sustainable cultivation systems (Abbasi, 2025; de Oliveira et al., 2023; Oñal et al., 2021).

Treatment Influence

Regression analysis indicates the positive influence of the number of tillers on the cane weight and cane yield per hectare, although its effect on juice quality was not significant. Plant height and stalk length had no significant impact on yield and quality traits, while node and internode counts showed marginal positive effects on pol percentage and cane yield. Stalk diameter, a significant negative predictor of millable cane, indicates that thicker stalks may reduce cane harvestability due to reduced stalk population density and increased competition for space and nutrients within the crop stand. The Brix % and sucrose yield were largely unaffected by growth parameters, except for a slight positive influence of node count on pol content. Although not statistically significant, tiller number can influence yield potential by determining the number of millable canes per plot (Oñal et al., 2021), indicating that management practices promoting tillering may still enhance productivity. The lack of significant effects of plant height and stalk length traits is less critical for sucrose accumulation than stalk thickness and biomass (Mehdi et al., 2024; Zhao et al., 2020). Marginal positive effects of node and internode counts on pol content suggest that nodal development slightly enhances sugar storage through improved vascular transport and translocation (Johnson & Mirza, 2020; Kumar et al., 2017). The negative impact of thicker stalks on millable cane supports physiological expectations that denser tissue reduces harvestable stalk numbers (Zhao et al., 2020). Meanwhile, the strong positive influence of tiller number on single cane weight and cane yield confirms its key role

in biomass accumulation and sugar productivity (Arefin et al., 2022; Bhatt et al., 2024). Optimizing growth traits through integrated nutrient management and organic amendments can improve stalk robustness and yield efficiency (Banerjee et al., 2018; Jha et al., 2019; Priyadarshi et al., 2021). Most growth traits had a limited effect on Brix and sucrose yield, suggesting that juice quality is more dependent on soil fertility, nutrient management, and environmental conditions (Abbasi, 2025; Dotaniya et al., 2016; Mehdi et al., 2024).

CONCLUSION

Sugarcane growth, yield, and juice quality depended more on varietal performance than on nutrient management methods. Phil 2004-1011 demonstrated superior agronomic traits to Phil 99-1793, with higher tiller number, plant height, stalk length, number of nodes, and internodes, resulting in better cane yield, sucrose yield, and sugar yield. Integrated nutrient management (INM) produced positive effects on selected growth and juice quality parameters. The full recommended rate of inorganic fertilizer (RR of IF) led to better results in tiller production, Brix, sucrose yield, and sugar yield, whereas the partial use of inorganic fertilizer with mud press (50% NPK + 5 t ha⁻¹ mud press) resulted in millable canes and cane yield that matched the outcomes of complete inorganic fertilization. The results demonstrate that INM has the ability to maintain agricultural output while enhancing soil quality and enabling effective use of agro-industrial waste materials. The research indicates that sugarcane productivity and quality can be improved through the combination of high-performing varieties and effective nutrient management methods, which include Phil 2004-1011 as a promising base cultivar for commercial production.

RECOMMENDATIONS

The study results demonstrate that Phil 2004-1011 produces better growth performance, yield and yield components, ideal choice for commercial sugarcane farming. Sugarcane growers should apply complete fertilizer recommendations based on the recommended analysis to achieve optimal plant growth and sugar revenues. The utilization of the integrated nutrient management system of inorganic fertilizer and sugarcane by-products can enhance cane output without losing total yield. The multi-location trials at diverse farmer-managed conditions will outline the performance of the varieties together with their nutrient management strategies. The researchers recommended further investigating root architecture, physiological responses, pest and disease dynamics, and soil-plant-microbe interactions to find the best ways to boost sugarcane growth in different environmental situations. Also, it is encouraged to preserve genetic resources for sustainable production and to support future breeding initiatives.

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Acknowledgment

The researchers wish to express their sincere gratitude to the Office of the Research and Development Services of the Central Philippines State University, Kabankalan City, for their invaluable support in crop establishment, data monitoring, and collection, which greatly contributed to the successful completion of this study.