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Growth Response of Sugarcane Seedlings (*Saccharum officinarum* L. cv. Kidang Kencana) to NPK Fertilizer Doses and Gibberellin Application in Bud-Based Seedling

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Abstract*. Sugarcane cultivation often faces productivity losses due to poor sprouting and non-uniform initial growth. In bud-based nursery systems, seedling quality is heavily constrained by limited media volume and low buffering capacity. This study aimed to evaluate the synergistic effects of NPK fertilizer dosages and Gibberellic Acid (GA) concentrations on the growth and physiological vigor of sugarcane seedlings. The experiment was conducted using a Completely Randomized Design featuring nine treatment combinations with four replications. Parameters measured included plant height, stem diameter, the number of tillers, the number of leaves, and the chlorophyll index. The results demonstrated that the application of the NPK 150 kg ha^{-1} + GA 50 ppm treatment significantly enhanced plant height, stem diameter, number of shoots, and the number of leaves compared to the control treatment. Statistical analysis revealed a significant interaction between nutrient availability and hormonal stimulation in overcoming the constraints of limited rooting environments. These findings suggest that precise integration of chemical fertilization and exogenous growth regulators is essential for producing high-quality planting material, potentially reducing losses in the subsequent planting cycle. In the future, it is necessary to confirm the use of a combination of NPK fertilizer with gibberellin during the vegetative period of plants so that the information obtained is comprehensive.*

Keywords: *Gibberellic acid, NPK fertilizer, Plant growth regulator, Seedling quality, Sugarcane seedlings*

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INTRODUCTION

Sugarcane is a strategic industrial crop, yet yield realization in farmers’ fields is frequently constrained by the quality of planting material and the success of early stand establishment. Weak sprouting and non-uniform initial growth can reduce stand density, delay canopy closure, and depress productivity through cumulative effects throughout the crop cycle. In response to these constraints, modern seedcane systems, such as pre-sprouted seedlings, have been promoted to improve establishment efficiency and reduce the amount of stalk material required for planting (Otto et al., 2022).

Nevertheless, the successful implementation of these systems still depends on producing vigorous seedlings during the nursery phase, where confined rooting conditions can amplify management-related variability. Evidence from controlled studies indicates that pre-germinated or nursery-raised propagules may provide neutral to positive effects on early growth and stand establishment, but outcomes can differ across environments and management intensity (Madala et al., 2023).

The hypothesis of this study is that there is a significant interaction between NPK fertilizer dose and gibberellin concentration on the growth of bud-chip sugarcane seedlings. The optimal combination of NPK doses and gibberellin concentrations will provide the best growth response compared to either single treatment. Therefore, interventions that improve seedling vigor and uniformity before transplanting remain agronomically relevant. Recent work on improved planting material handling, including bud-based technologies, reinforces that better quality propagules can enhance establishment and yield-related components under appropriate production schedules (Ajribzadeh et al., 2025).

LITERATURE REVIEW

Seedling quality in bud-based or nursery systems is strongly influenced by the rooting environment, particularly because growth occurs in a limited media volume with restricted buffering capacity. Substrate composition, moisture regime, and nutrient availability can jointly shape seedling morphology and vigor, resulting in variable growth responses among management settings. For example, studies on pre-sprouted sugarcane seedlings demonstrate that substrate characteristics and nursery conditions can substantially affect seedling performance and quality attributes (Costa et al., 2021).

Macronutrient management is a key determinant of early physiological development because nitrogen (N), phosphorus (P), and potassium (K) regulate complementary processes underlying seedling growth. Nitrogen supports chlorophyll formation and biomass accumulation in sugarcane growth, which is directly linked to canopy development and early vigor (Zeng et al., 2020). Phosphorus is essential for metabolic energy transfer and contributes to the formation of a vigorous root system and tillering-related performance, with genotypic differences reported under contrasting P availability (Tarumoto et al., 2022). Potassium further supports osmotic regulation and physiological stability through effects on leaf gas exchange and water relations, thereby strengthening photosynthetic performance under stress variability (Lavres et al., 2025).

In nursery or polybag-based seedling production, fertilization practices are often empirical, creating risks of underdose or excessive salt load that reduce nutrient-use efficiency and seedling uniformity. Dose calibration is therefore critical, and specific recommendations for fertilization management in pre-sprouted seedling production have been proposed under controlled subirrigation systems, indicating that seedling fertilization requires nursery-oriented optimization rather than direct adoption of field fertilizer logic (Macan et al., 2020). Beyond mineral nutrition, gibberellic acid (GA) is widely reported to regulate developmental processes associated with shoot and tiller dynamics; transcriptome-scale evidence in sugarcane supports GA-mediated regulation linked with tiller development (Luo et al., 2023). There is a positive correlation between GA treatment and photosynthesis efficiency, which helps plants produce more assimilates for initial growth. GA may also interact with nutrient acquisition and nitrogen metabolism under limiting conditions, reinforcing the biological plausibility of combining nutritional and hormonal management during early growth (Zhang et al., 2024). Importantly, GA responses commonly follow an optimum dose window rather than a strictly linear pattern, supporting the need for dose-specific evaluation when GA is integrated into seedling management (Muharram et al., 2021).

RESEARCH METHODS

The experiment was conducted in the Plososari village, Grati District, Pasuruan, East Java, Indonesia, from March to June 2025. Plososari Village is located at an altitude of about 700 meters above sea level, has relatively high rainfall, with an average monthly rainfall of about 21-50 mm, and an average annual temperature of between 32-36°C.

1. Materials and Tools

Planting materials consisted of single-bud sugarcane setts (*Saccharum officinarum* L.) cv. Kidang Kencana was collected from mature basal stalk sections. Polybags (20 cm × 20 cm), topsoil, goat manure, water, NPK compound fertilizer, and a commercial gibberellin product (Gibgro, 20% active gibberellin) were used. Supporting tools included a digital balance, measuring tape, digital caliper, SPAD meter (chlorophyll index), and a hand sprayer.

2. Experimental Design and Treatments

The experiment was arranged in a Completely Randomized Design (CRD) with nine treatments and four replications, resulting in 36 experimental units. Each experimental unit has 3 cuttings in a polybag, for a total of 108 cuttings. Treatments were designed to evaluate the response of sugarcane seedlings to different NPK fertilizer doses and GA concentrations, including single and combined applications. The control received zero NPK and zero GA, while the remaining treatments consisted of NPK at 100 and 150 kg ha^{-1}, GA at 50 and 75 ppm, and their combinations (NPK 100 kg ha^{-1} + GA 50 ppm; NPK 100 kg ha^{-1} + GA 75 ppm; NPK 150 kg ha^{-1} + GA 50 ppm; and NPK 150 kg ha^{-1} + GA 75 ppm).

3. Experimental Procedures

The growing medium was prepared by mixing topsoil and goat manure at a 1:1 ratio (v/v), thoroughly homogenized, and moistened before planting. Single-bud sugarcane setts were planted horizontally in each polybag with buds oriented upward and positioned near the media surface to facilitate sprouting. NPK fertilizer was applied once, 2 weeks after planting (WAP), using the pocket placement method by inserting the fertilizer into a small hole near the plant base and covering it with soil. Gibberellic acid (GA) was prepared from a commercial product (Gibgro, 20% active ingredient) and applied as a foliar spray at concentrations of 50 and 75 ppm after bud emergence, followed by a second application at 2 WAP. Seedlings were maintained under standard nursery management, including twice daily irrigation (morning and afternoon), manual weeding as required, and soil loosening when necessary to maintain aeration and support root development.

4. Cultivation

Sugarcane seedling care includes watering, weeding, and tilling. Watering is done daily in the morning and evening. Watering is done as needed to meet the water needs of the sugarcane seedlings. This ensures that the plants do not experience either under- or over-watering. Weeding is carried out manually by hand if weeds are present in the sugarcane seedling polybags. This is done to prevent weeds from becoming a source of competition for the sugarcane seedlings. Weeds can include nutsedge. Tillage is the process of loosening the soil in the polybags using simple tools or, in this study, by hand. Tillage is carried out to maintain soil aeration and porosity, which support the growth of sugarcane seedlings. Tillage is carried out as needed if the soil appears compacted**.**

5. Observed Variables and Measurement

Growth observations were carried out at 32, 54, and 75 days after planting (DAP), except for the chlorophyll index, which was measured at 54 DAP. Plant height was measured from the soil surface to the tip of the longest leaf. Stem diameter was measured at the basal stem portion using a digital caliper. The number of tillers was recorded as the number of basal shoots produced per experimental unit. The number of leaves was counted as fully expanded green leaves per unit, while shoot emergence was recorded as the total newly emerged shoots originating from the planted setts in each unit. Chlorophyll index was determined using a SPAD meter on a fully expanded, photosynthetically active leaf and expressed as SPAD units.

6. Data Analysis

The observation data were then analyzed using analysis of variance (ANOVA) and tested using the F-test with a 5% error rate to determine whether the treatment had an effect on the data produced. If there was a significant effect, a Least Significant Difference (LSD) test was performed at a 5% confidence level.

RESULTS AND DISCUSSION

Kidang Kencana is an improved variety that is tolerant to extreme climates and suitable for intensive cropping systems. Characteristics: Yellowish-green stems, resistant to lodging, and a medium harvest period. Observations show that Kidang Kencana is more adaptive to light-textured soils with good drainage and sufficient nitrogen (N) availability. The Kidang Kencana variety indicates a need for adequate soil moisture conditions with good drainage. This variety's growth preference is higher on light to medium-textured soils compared to heavy-textured soils. The following are the results obtained for the Kidang Kencana variety treated with NPK fertilizer and gibberellin.

1. Plant height

Plant height responded to the NPK and GA treatments at all observation times. At 32 DAP, the NPK 100 kg ha^{-1} + GA 75 ppm treatment produced the tallest seedlings (33.20 cm), which was significantly higher than the control (26.70 cm). Under single-input treatments, NPK 100 kg ha^{-1} and GA 75 ppm resulted in plant heights of 28.35 cm and 30.87 cm, respectively, indicating that the combined treatment enhanced early elongation relative to either input alone. At 54 DAP, NPK 150 kg ha^{-1} + GA 50 ppm recorded the greatest plant height (69.58 cm), exceeding NPK 150 kg ha^{-1} (59.20 cm) and GA 50 ppm (62.42 cm). A similar pattern was observed at 75 DAP, where the same combination maintained the highest plant height (81.75 cm) compared with NPK 150 kg ha^{-1} (72.85 cm) and GA 50 ppm (73.45 cm). Increasing GA to 75 ppm under the higher NPK rate did not further improve plant height, as NPK 150 kg ha^{-1} + GA 75 ppm produced lower values at 54 DAP (60.85 cm) and 75 DAP (71.40 cm).

Table 1. Sugarcane plant height based on the effects of NPK fertilizer dosage and gibberellin concentration

Treatments	Plant height (cm) at observation time (DAP)		
	32	54	75
Control	26,70 a	57, 18 a	67,18 a
NPK 100 kg ha^{-1}	28,35 abc	60,20 bc	70,15 ab
NPK 150 kg ha^{-1}	29,00 bcd	59,20 ab	72,85 bc
GA 50 ppm	29,85 cde	62,42 cd	73,45 bc
GA 75 ppm	30,87 e	63,43 d	74,48 c
NPK 100 kg ha^{-1} + GA 50 ppm	28,95 bcd	67,40 e	78,3 de
NPK 100 kg ha^{-1} + GA 75 ppm	33,20 f	61,25 bcd	75,00 cd
NPK 150 kg ha^{-1} + GA 50 ppm	30,35 de	69,58 e	81,75 e
NPK 150 kg ha^{-1} + GA 75 ppm	27,22 ab	60,85 bcd	71,40 bc
LSD 5%	1,84	2,95	3,73
CV (%)	4,31	3,27	3,49

Note: Numbers followed by different letters indicate significant differences based on the LSD 0.05 test; LSD: Least Significant Difference; CV: Coefficient of Variation

Plant height can be used as one of the characteristics of plants that can be observed, where plant height has a positive correlation with sugarcane production (Tena et al., 2012). Gibberellin itself is a plant hormone that can be applied in the form of a plant growth regulator. One of the functions of gibberellin is to stimulate plant stem elongation.

In addition, the application of gibberellin can encourage root formation in sugarcane, where the roots will help the plant to absorb nutrients in the soil, which can support plant elongation (Kumar et al., 2023). Giberelin application can also increase the absorption of nutrients such as nitrogen, potassium, and phosphorus compared to sugarcane plants that are not given giberelin (Ghodke et al., 2022). The increase in plant length also indicates that the plants are absorbing the nutrients that have been applied. Therefore, with the application of gibberellin, the length of sugarcane plants will also increase.

2. Stem diameter

Stem diameter showed a stronger response under specific combined treatments than under single-input applications. At 32 DAP, NPK 150 kg ha^{-1} + GA 50 ppm produced the largest stem diameter (0.78 cm), higher than the control (0.40 cm), NPK 150 kg ha^{-1} (0.45 cm), and GA 50 ppm (0.50 cm). This superiority was maintained at 54 DAP (1.13 cm) and further increased at 75 DAP (1.46 cm). In comparison, single-input treatments resulted in smaller diameters at 75 DAP, including NPK 150 kg ha^{-1} (1.07 cm) and GA 25 ppm (1.12 cm). The NPK 100 kg ha^{-1} + GA 75 ppm treatment also produced a relatively large diameter at 75 DAP (1.39 cm), but remained below NPK 150 kg ha^{-1} + GA 50 ppm.

Table 2. Sugarcane stem diameter based on the effects of NPK fertilizer dosage and gibberellin concentration

Treatments	Stem diameter (cm) at observation time (DAP)		
	32	54	75
Control	0,40 a	0,88 a	1,00 a
NPK 100 kg ha^{-1}	0,48 abc	0,95 ab	1,11 ab
NPK 150 kg ha^{-1}	0,45 ab	0,88 a	1,07 ab
GA 50 ppm	0,50 abcd	0,90 a	1,12 ab
GA 75 ppm	0,58 cd	0,90 a	1,13 ab
NPK 100 kg ha^{-1} + GA 50 ppm	0,53 bcd	0,93 ab	1,23 bc
NPK 100 kg ha^{-1} + GA 75 ppm	0,60 d	1,08 bc	1,39 cd
NPK 150 kg ha^{-1} + GA 50 ppm	0,78 e	1,13 c	1,46 d
NPK 150 kg ha^{-1} + GA 75 ppm	0,50 abcd	0,87 a	1,05 ab
LSD 5%	0,11	0,16	0,19
CV (%)	14,43	11,79	11,37

Note: Numbers followed by different letters indicate significant differences based on the LSD 0.05 test; LSD: Least Significant Difference; CV: Coefficient of Variation

The application of GA without optimal NPK supplementation actually risks reducing the diameter of sugarcane stems due to a lack of energy to fill the rapidly growing biomass. Gibberellin stimulates cell division and elongation in the stem nodes (internodes) (Marschner, 2011). Since sugar is stored in the stems, longer stems mean greater storage space (sink). Potassium from NPK helps regulate osmotic pressure when cells elongate due to the influence of gibberellin, preventing the stems from becoming brittle or easily falling over.

3. Number of tillers

The number of tillers differed mainly at the early observation stage. At 32 DAP, NPK 150 kg ha^{-1} + GA 50 ppm produced the highest tiller number (2.75), whereas NPK 150 kg ha^{-1} alone resulted in the lowest value (1.25). Among single-input treatments, GA 50 ppm produced 2.50 tillers, which was higher than NPK 100 kg ha^{-1} (2.00). At 54 and 75 DAP, tiller number did not differ significantly among treatments, although the highest means were still observed under NPK 150 kg ha^{-1} + GA 50 ppm at 54 DAP (3.25) and 75 DAP (3.75).

Table 3. Sugarcane number of tillers based on the effects of NPK fertilizer dosage and gibberellin concentration

Treatments	Number of tillers at observation time (DAP)		
	32	54	75
Control	1,50 ab	1,75	2,50
NPK 100 kg ha^{-1}	2,00 abc	2,50	2,75
NPK 150 kg ha^{-1}	1,25 a	1,50	2,00
GA 50 ppm	2,50 bc	2,75	3,00
GA 75 ppm	2,00 abc	2,25	2,75
NPK 100 kg ha^{-1} + GA 50 ppm	1,75 abc	2,00	2,50
NPK 100 kg ha^{-1} + GA 75 ppm	2,25 abc	2,50	3,00
NPK 150 kg ha^{-1} + GA 50 ppm	2,75 c	3,25	3,75
NPK 150 kg ha^{-1} + GA 75 ppm	1,75 abc	2,00	2,50
LSD 5%	38,72	35,84	27,33
CV (%)	0,11	ns	ns

Note: Numbers followed by different letters indicate significant differences based on the LSD 0.05 test; ns: not significant; LSD: Least Significant Difference; CV: Coefficient of Variation

Sugarcane tiller growth is a crucial phase that determines the number of stems per hectare and the final sugar yield. The relationship between nutrients (NPK) and growth regulators (Gibberellin) works through the mechanisms of energy supply and cell division stimulation. Phosphorus is very important in the early stages for root development and energy transfer. Strong roots enable plants to absorb more nutrients to support the growth of multiple tillers. Potassium plays a role in enzyme activation and carbohydrate translocation from leaves to tiller growth points (Anam et al., 2025). Without sufficient NPK, Gibberellin stimulation will result in weak and easily dying tillers. Conversely, without sufficient hormone stimulation, high-dose NPK application often only enlarges the main stem without maximizing the potential number of tillers.

4. Number of leaves

Leaf number increased with plant age and was consistently enhanced by the combined treatments. NPK 150 kg ha^{-1} + GA 50 ppm produced the highest leaf numbers at 32 DAP (4.30 leaves), 54 DAP (5.72 leaves), and 75 DAP (6.88 leaves). These values exceeded those of the single-input treatments, including NPK 150 kg ha^{-1} at 32 DAP (3.32 leaves), 54 DAP (4.42 leaves), and 75 DAP (5.30 leaves), as well as GA 50 ppm at 32 DAP (3.30 leaves), 54 DAP (4.28 leaves), and 75 DAP (5.50 leaves). The GA 75 ppm treatment also maintained relatively high leaf numbers across observations, while NPK 100 kg ha^{-1} + GA 50 ppm showed strong leaf development at 32 DAP (4.05 leaves), 54 DAP (5.33 leaves), and 75 DAP (6.27 leaves), but remained below NPK 150 kg ha^{-1} + GA 75 ppm.

Table 3. Sugarcane number of leaves based on the effects of NPK fertilizer dosage and gibberellin concentration

Treatments	Number of leaves at observation time (DAP)		
	32	54	75
Control	2,35 a	3,07 a	4,55 a
NPK 100 kg ha^{-1}	3,05 b	3,68 ab	5,00 ab
NPK 150 kg ha^{-1}	3,32 bc	4,42 bc	5,30 abc
GA 50 ppm	3,30 bc	4,28 bc	5,50 bcd
GA 75 ppm	3,82 cd	4,97 de	6,05 cd
NPK 100 kg ha^{-1} + GA 50 ppm	3,15 b	4,15 bc	5,28 abc
NPK 100 kg ha^{-1} + GA 75 ppm	4,05 d	5,33 ef	6,27 de
NPK 150 kg ha^{-1} + GA 50 ppm	4,30 d	5,72 f	6,88 e
NPK 150 kg ha^{-1} + GA 75 ppm	3,15 b	4,62 cd	5,77 bcd
LSD 5%	0,61	0,65	0,77
CV (%)	12,42	10,10	9,51

Note: Numbers followed by different letters indicate significant differences based on the LSD 0.05 test; LSD: Least Significant Difference; CV: Coefficient of Variation

The application of NPK fertilizer can be beneficial in enhancing the vegetative growth of sugarcane plants. Based on research (Kandhro et al., 2021), NPK fertilizer can have a positive impact on the growth and development of sugarcane leaves. NPK fertilizer is one of the fertilizers that can supply the macro nutrients that are important for plants. One of these nutrients is nitrogen. Nitrogen itself is one of the nutrients that is very important in the vegetative growth of plants. According to (Oktaviona & Hartini, 2021), Plants need nitrogen to form important compounds such as chlorophyll, nucleic acids, and growth enzymes. In addition, this nutrient is needed by plants in large quantities during the vegetative growth phase. Thus, with the addition of NPK fertilizer, plants will experience increased vegetative growth.

5. Number of shoots

Shoot number showed the clearest and most consistent response under the combined management, particularly at the higher NPK rate with GA 50 ppm. NPK 150 kg ha^{-1} + GA 50 ppm produced the highest shoot number at 32 DAP (4.10 shoots), 54 DAP (14.55 shoots), and 75 DAP (22.60 shoots), and differed from the control. This treatment also exceeded NPK 150 kg ha^{-1} alone at 32 DAP (3.45 shoots), 54 DAP (13.80 shoots), and 75 DAP (20.12 shoots). GA 50 ppm alone resulted in a high shoot number at 75 DAP (21.60 shoots), yet remained below the combined treatment. Under the lower NPK rate, NPK 100 kg ha^{-1} + GA 75 ppm reached 75 DAP (20.87 shoots), higher than NPK 100 kg ha^{-1} alone (18.90 shoots), indicating that combination effects were also present at the moderate nutrient level.

Table 5. Sugarcane number of shoots based on the effects of NPK fertilizer dosage and gibberellin concentration

Treatments	Number of shoots at observation time (DAP)		
	32	54	75
Control	3,07 ab	13,42 a	17,80 a
NPK 100 kg ha^{-1}	3,20 ab	13,27 a	18,90 ab
NPK 150 kg ha^{-1}	3,45 abc	13,80 ab	20,12 cde
GA 50 ppm	3,15 ab	13,22 a	21,60 fg
GA 75 ppm	3,00 a	13,87 ab	20,35 de
NPK 100 kg ha^{-1} + GA 50 ppm	3,52 bc	14,45 bc	19,48 bcd
NPK 100 kg ha^{-1} + GA 75 ppm	3,37 abc	14,13 bc	20,87 ef
NPK 150 kg ha^{-1} + GA 50 ppm	4,10 d	14,55 c	22,60 g
NPK 150 kg ha^{-1} + GA 75 ppm	3,82 cd	13,80 ab	19,12 bc
LSD 5%	0,45	0,67	1,10
CV (%)	9,14	3,33	3,77

Note: Numbers followed by different letters indicate significant differences based on the LSD 0.05 test; LSD: Least Significant Difference; CV: Coefficient of Variation

Shoots are one of the most important organs in sugarcane plantations. The higher the number of healthy shoots produced by sugarcane, the higher the sugar production will be (Hussain et al., 2017). NPK fertilization is one way to increase sugarcane production. Meanwhile, nitrogen is one of the nutrients that can greatly limit the number of shoots produced. This can be caused by nitrogen, which has various functions in plants, such as supporting the rate of plant photosynthesis to an optimal. A deficiency in nitrogen nutrients will affect the rate of photosynthesis, which will in turn affect the number of shoots produced. Adding N nutrients to sugarcane can increase the number of shoots compared to sugarcane that is not given nitrogen nutrients.

6. Clorophyll Index

Chlorophyll index measured at 54 DAP did not differ significantly among treatments, although numerical variation was observed. The highest SPAD value was recorded under NPK 100 kg ha^{-1} (181.34), whereas GA 50 ppm produced a lower value (129.74). Across combined treatments, SPAD values generally ranged from 138.64 to 145.97, and the lowest value was observed under NPK 150 kg ha^{-1} + GA 50 ppm (127.53).

Table 6. Sugarcane chlorophyll index based on the effects of NPK fertilizer dosage and gibberellin concentration

Treatments	Chlorophyll index at 54 DAP
Control	164.28
NPK 100 kg ha^{-1}	181.34
NPK 150 kg ha^{-1}	158.65
GA 50 ppm	144.47
GA 75 ppm	129.74
NPK 100 kg ha^{-1} + GA 50 ppm	145.97
NPK 100 kg ha^{-1} + GA 75 ppm	141.9
NPK 150 kg ha^{-1} + GA 50 ppm	138.64
NPK 150 kg ha^{-1} + GA 75 ppm	127.53
LSD 5%	ns
CV (%)	15.03

Note: ns: not significant; Least Significant Difference; CV: Coefficient of Variation

The chlorophyll index of plants can be used as an indicator to calculate plant production and biomass (Liu et al., 2019). The chlorophyll index itself is an indicator that shows how green the leaves of a plant are, which is closely related to the chlorophyll content or nitrogen in the plant (Ali et al., 2017). A higher chlorophyll index can be caused by the application of NPK fertilizer. NPK fertilization of sugarcane plants can increase the nitrogen nutrients that can be absorbed by the plants, thereby increasing the chlorophyll index.

CONCLUSION

The study showed that sugarcane seedling growth was strongly influenced by the interaction between NPK fertilization and gibberellic acid application. The combination of NPK 150 kg ha^{-1} + GA 50 ppm consistently produced the best results in plant height, stem diameter, number of leaves, number of tillers, and number of shoots, indicating a synergistic effect between nutrient availability and moderate hormonal stimulation. Single applications of NPK or GA improved growth compared to the control but were less effective than combined treatments, while a higher GA concentration did not provide additional benefits. Chlorophyll index was not significantly affected by treatments. Overall, the integrated application of NPK 150 kg ha^{-1} and GA 50 ppm is recommended to produce uniform and vigorous sugarcane seedlings in bud-based nursery systems. Suggestions for further research are to conduct observations in the vegetative phase with a combination of NPK fertilizer and gibberellin treatment.

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