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RESPONSE OF RICE GROWTH AND YIELD UNDER DIFFERENT TIMING OF NPK-BASE FERTILIZERS APPLICATION IN THE SALIBU SYSTEM

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Abstract. In the Salibu system (SS), rice plants have a shorter growth cycle than their parent plants. Applying NPK-base fertilizer can promote optimal vegetative growth and yield. This study aimed to determine the optimal timing of NPK-base fertilizer application to enhance rice yield in the SS. The experiment was arranged in a randomized complete block design (RCBD) with three replications, where each replication acted as a block. The timing of NPK-base fertilizers application included four treatments: no application (control), at harvest, stem cuttings (seven days after harvest, or 7 DAH), and seven days after stem cuttings (7 DAC). The results indicated that the application of NPK-base fertilizers could significantly increase the shoot dry weight clump^{-1} and 1000-filled grains. The Application of NPK-base fertilizer at stem cuttings enhanced plant height at 28 DAC, with no significant difference compared to harvest. Furthermore, this treatment resulted in a higher grains dry weight clump^{-1} (15.3 g) than the control (13.2 g), and was not significantly different from the treatments at harvest (13.9 g) or 7 DAC (14.6 g). No significant differences were observed among the treatments at harvest, 7 DAC, and the control. The conclusion shows that applying NPK-base fertilizer at stem cuttings of the parent plants optimally enhances the rice yield in the SS. Future research should recommend determining the optimal dosage of NPK-base fertilizer to maximize rice growth and yield.
Keywords: *harvest, main stem, parent plant, ratoon, stem cutting*

Introduction

As Indonesia's population grows, the demand for food, particularly rice, is increasing. Various measures have been implemented to achieve national rice self-sufficiency, including adapting the SS. The term of Salibu is derived from the Indonesian phrase "Salin ibu", which translates to "change of the parent plants" in English.

The ratoon rice technique is a rice cultivation method that utilizes the rice stems remaining after harvest (ratoon) to regrow and produce the next rice crop. After the main harvest, the remaining rice stems are left to regenerate, and new roots and shoots develop to make rice in a shorter time frame. In the SS, after the main rice harvest, the remaining stems are not regenerated as in the conventional ratoon technique but also undergo special management practices such as cutting the main stems, fertilization, weed control, and others to ensure higher and more stable yields.

The SS features a shorter life cycle than parent plants, enabling increased productivity by applying NPK-base fertilizer. Furthermore, using NPK-base fertilizer can accelerate the growth of rice shoots during the early stages, thereby enhancing the potential for higher yields.

The SS is a rice cultivation method based on local wisdom, originally implemented in West Sumatra, Indonesia. The technology has been tested in various regions across Indonesia. Although farmers have not widely adopted it due to perceptions of lower yields, this technology can enhance rice harvests and improve land-use efficiency with proper management. According to Abdulrachman et al. (2015), the SS offers advantages such as faster harvest times, more efficient water usage, and reduced production costs by up to 45% compared to the transplanting method. This method reduces land preparation, seedling production, and planting expenses. Therefore, the SS has the potential to improve the welfare of farmers.

The success of the SS technology is influenced by various factors, one of which is the timing of NPK-base fertilizer application. The NPK fertilizer plays a crucial role in supporting the growth of the new shoots after the parent plants are cut. Applying the fertilizer can provide the essential nutrients the new shoots need and promotes their development. Since the SS has a shorter harvest cycle than its parent plants, it is important to determine the optimal fertilizer application timing to accelerate the growth of the new shoots. However, research on the timing of NPK-base fertilizer in the SS remains limited. Therefore, further studies are necessary to identify the optimal timing for fertilizer application in the SS.

In Indonesia, rice cultivation in irrigated land typically occurs one to three times annually, depending on the irrigation system employed. In rainfed fields, rice can be planted only once a year, while fully irrigated fields can support up to three planting cycles each year. Each planting season involves various activities, including land preparation, seedling production, planting, plant maintenance, and harvesting. Conventional rice cultivation often incurs relatively high costs, lowering profit margins. In contrast, the SS offers greater advantages due to its land and resource utilization efficiency.

The SS can enhance rice production and land productivity annually. This method utilizes the shoots that emerge from the basal stems after cuttings. To maximize the number of tillers, apply the optimal dosage of NPK-base fertilizer. New shoots emerge from the nodes of the remaining stem, followed by the emergence of new roots. Eventually, these shoots grow into independent plants. The formed shoots subsequently develop into new tillers, similar to the rice planting system used in transplanting techniques (Juanda, 2016). The SS can enhance food availability in Indonesia and contribute to food security and resilience. It is more effectively implemented on land that is not always flooded (Jahari and Sinaga, 2019). Rice productivity in tropical regions primarily relies on fertilizers, as soils often lack nitrogen and phosphorus (Hindersah et al., 2022).

Nitrogen (N), phosphorus (P), and potassium (K) are applied in large quantities as fertilizers in rice fields, and a deficiency of any of these nutrients can reduce crop yields (Shrestha et al., 2020). Nitrogen plays a crucial role in the synthesis of chlorophyll and protein. Phosphorus is involved in energy storage and transfer, and it is a key element in nucleic acids, coenzymes, nucleotides, phosphoproteins, phospholipids, and phosphate sugars. Meanwhile, potassium supports starch formation, activates enzymes, and acts as a catalyst in storing photosynthetic products.

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Nitrogen is an essential element that forms plants' amino acids, proteins (enzymes), nucleic acids, and chlorophyll. A nitrogen deficiency in rice cultivation leads to reduced plant height, lower tiller formation, decreased leaf area index, and diminished photosynthesis rates (Bijay-Singh and Singh, 2017). Nitrogen plays a crucial role in promoting growth, enhancing yields, and improving grain quality by improving the number of tillers, expanding leaf area, and facilitating protein synthesis. Plants absorb nitrogen through nitrate ions (NO_3^-) and ammonium ions (NH_4^+) (Kaya, 2013). A lack of nitrogen can limit rice productivity, while excessive nitrogen can result in agronomic and economic losses (Hussain et al., 2023). The yield increases when nitrogen was applied at 202.15 kg ha^{-1}. The fertilization frequency is four times (He et al., 2024). Optimal nitrogen fertilization can effectively compensate for the negative impacts of N fertilizer, enhancing grain quality and nitrogen use efficiency (NUE) while sustaining high yields (Tian-Yang et al., 2022).

Phosphorus (P) is essential in photosynthesis, respiration, energy transfer, storage, cell division, and enlargement. Plants absorb phosphorus in the form of primary orthophosphate ions, $H_2PO_4^-$ (Irwanto, 2014). Additionally, phosphorus is a key component of high-energy compounds such as adenosine triphosphate (ATP) and is involved in the synthesizes phospholipids, nucleotides, and glycoproteins. Phosphorus deficiency can hinder growth and yield in rice, which is evident through reduced tiller numbers and dry matter accumulation, along with symptoms such as stunted growth and upright leaves that exhibit a dark green color (Bijay-Singh and Singh, 2017).

Potassium (K) activates various enzymes in plant metabolic processes and is absorbed as potassium ions (K^+) (Irwanto, 2014). This nutrient is essential for enhancing root growth, promoting plant vigor, and increasing resistance to pests and diseases. Symptoms of potassium deficiency in rice include stunted growth with fewer tillers, dark green upper leaves, and chlorosis in the areas between leaf veins (Bijay-Singh and Singh, 2017). Although chemical fertilizers can improve rice yield, the response highly depends on optimal fertilization management in paddy fields (Yang et al., 2021). Using a combination of 135-210 kg ha^{-1} N and 115-137 kg ha^{-1} K can achieve relatively higher yield and improve quality in rice production (Chen et al., 2024).

The NPK Phonska (15-15-15) fertilizer is complex inorganic NPK with composition of 15% N, 15% P_2O_5, 15% K_2O, and 10% S. This fertilizer is widely utilized by farmers due to its effectiveness in enhancing rice yields and grain quality. According to Shrestha et al. (2020), nitrogen (N), phosphorus (P), and potassium (K) are applied as fertilizers in large quantities to rice fields. Research conducted by Kurniadie (2002), which used a dosage of 300 kg ha^{-1} NPK Phonska along with 333 kg ha^{-1} ZA, resulted in the highest performance for the IR 64 rice variety, including parameters such as the number of panicle clump^{-1}, the number of grain panicle^{-1}, the harvest index, the weight of 1000 grains, as well as dry grain yields (7.50 tons ha^{-1}) and milled rice yields (6.17 tons ha^{-1}).

Optimized fertilization practices represent a promising management approach for achieving sustainable rice production (Zhuang et al., 2022). The application of NPK Phonska fertilizer at a rate of 300 kg ha^{-1}, combined with 200 kg ha^{-1} urea, significantly increased plant height, the number of tillers, and yield up to 7.448 tons ha^{-1}, with relative agronomic effectiveness (RAE) value of 106.46 (Fidiyawati et al., 2022). Combining NPK fertilizer with urea is essential to meet nitrogen nutrient requirements during various rice growth stages. Without urea addition, higher dosages of NPK were needed; specifically, 300 kg ha^{-1} NPK Phonska (15-15-15) required an additional 150

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kg ha^{-1} urea (Hartatik and Widowati, 2015). The greatest yield of 5.81 tons ha^{-1} was achieved with the combined treatment of 250 kg ha^{-1} NPK + 150 kg ha^{-1} urea + 1000 kg ha^{-1} dolomite (Ratmini et al., 2023).

Applying NPK fertilizer can enhance plant height and yield by 3%, although it may reduce the weight of 1000 grains. On the other hand, nitrogen fertilizer significantly contributed to an increase in productive tillers and boosted yield by 6%. The most effective combination for rice fields with high phosphorus levels was 300 kg ha^{-1} NPK and 100 kg ha^{-1} urea (Siska and Ismon, 2019). The NPK application also enhanced the absorption of nutrients N, P, and K, and improved grain yield (Shrestha et al., 2020). Additionally, Srinivas (2017) noted a significant increase in the number of tillers and panicles m^{-2} with the application of 120-60-60 kg ha^{-1} NPK.

The application of NPK fertilizer significantly influenced plant height at 35, 45, and 90 days after planting (DAP), the number of tillers at 35 and 45 DAP, and various production parameters such as the number of panicles clump^{-1} and 1000-filled grains of rice (Waty et al., 2014). However, a dosage of 50 kg ha^{-1} NPK Phonska did not show significant differences in rice production across various agroecological zones (highlands, midlands, and lowlands) using the SS (Fitri et al., 2019). In the SS, fertilization was applied to the parent plants: the first application consisted of 40% of the recommended dosage at 15-20 DAP and the second consisting of 60% at 30-35 DAP (Abdulrachman et al., 2015).

Based on the background and literature review, NPK fertilizer is more commonly used under the transplanting system in rice cultivation. In contrast, its application as base fertilizer in the SS has not been thoroughly investigated. Therefore, the study aimed to determine the optimal timing of NPK-base fertilizer application to enhance rice yield in the SS.

Materials and methods

Study site

The research was conducted from January to June 2024 in Tirtonirmolo Village, Kasihan District, Bantul Regency, Special Region of Yogyakarta, Indonesia. A map of the study site can be seen in *Figure 1*.

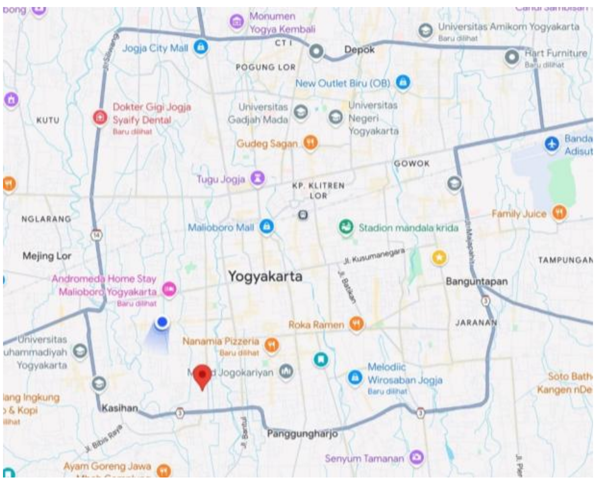

Figure 1. *A map showing the study site in Tirtonirmolo Village, Kasihan District, Bantul Regency, Special Region of Yogyakarta,* Indonesia

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The site was located at an elevation of 70 m above sea level, with an average air temperature of 26.6 °C and humidity of 83%. Kasihan District is 110˚20'40" East Longitude and 7˚48'42" South Latitude.

Experiment design

The experiment was arranged in an RCBD with three replications, where each replication acted as a block. The timing of NPK-base fertilizer application included four treatments: no application (control), at harvest, at stem cuttings, or seven days after harvest (7 DAH), and at seven days after cutting the stems (7 DAC). This study required 12 treatment plots. The size of each treatment plot can be seen in *Figure 2*.

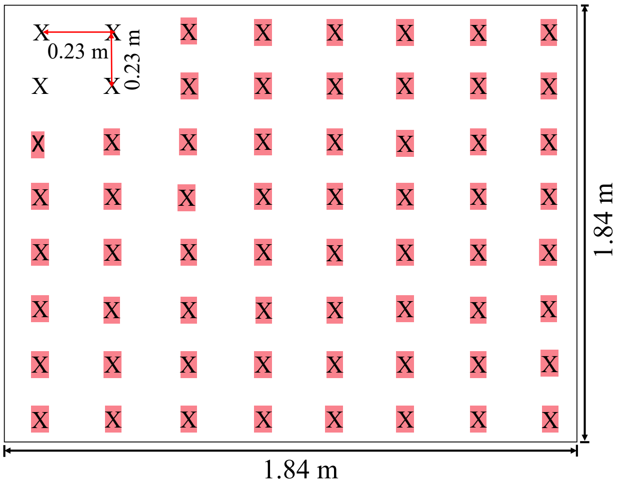

Figure 2. *The size of the treatment plot for experimental*

Each treatment plot size was 1.84 m (length) × 1.84 m (width). Plant spacing within the rows was 0.23 m, with 8 plants per row, making the row length 1.84 m. The spacing between rows was 0.23 m, with a total of 8 rows, resulting in a row width of 1.84 m. The number of rice clumps in each plot was 64. The research flow is shown in *Figure 3*.

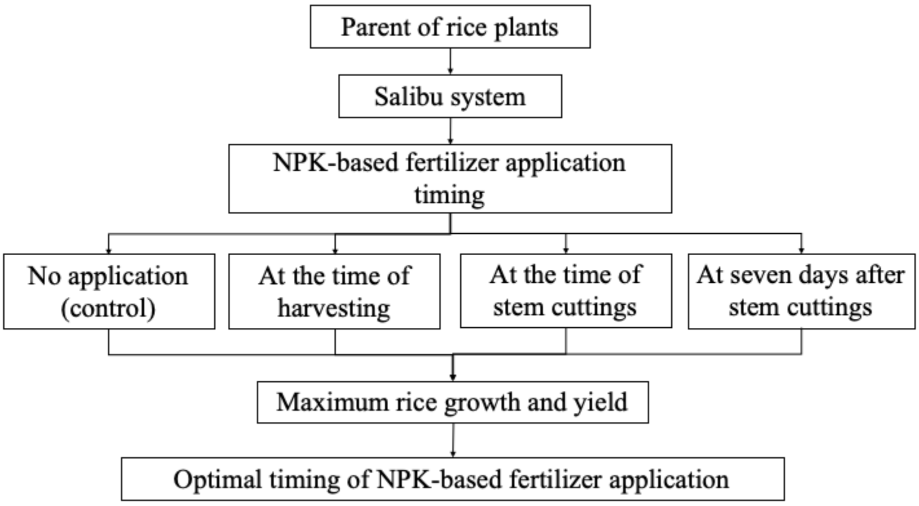

Figure 3. *The flow diagram in research activity*

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Research procedures

Parent plants

In the SS, the parent plants cultivated by farmers were utilized. The rice variety used was Inpari 42, which has a harvesting period of 87 DAP. The spacing was set at 23 × 23 cm. The land used for cultivation was technically irrigated, ensuring a consistent water supply, and consisted of alluvial soil. As the parent plant, harvesting was done manually by cutting the stems (along with the panicle) at a height of 15-20 cm above the soil surface using a sickle.

Salibu system

Then, 7 days after the harvest, the remaining stems above the soil were cut again at a height of 3 cm from the soil surface to stimulate new shoot growth in the SS technology. The new shoots emerged from the remaining cut of parent stems and were carefully maintained. Plant care included irrigation, fertilization, and the management of pests, diseases, and weeds to ensure optimal growth.

Water irrigation was applied to the experimental plots until it reached a height of 3 cm above the soil surface. Once it was evenly distributed across all plots, the water channels were closed. This was done every 7 days until the plants reached 70 DAC.

The application of NPK-base fertilizer occurred according to the treatment schedule, which took place at harvest, at stem cuttings (7 DAH), and 7 DAC. The dosage of NPK-base fertilizer used was 60 g plot^{-1}, equivalent to 150 kg ha^{-1} NPK Phonska, except in the control plots. After applying NPK-base fertilizer, a subsequent fertilizer was recommended with 150 kg ha^{-1} NPK Phonska and 200 kg ha^{-1} urea. It was given in two stages: the first stage (40% of the recommended dosage) was applied at 14 DAC, followed by the second stage (60% of the recommended dosage) at 28 DAC.

Weeding was performed at 12 and 26 DAC to reduce weed competition. Pest and disease management was implemented according to integrated pest management (IPM) principles at 56 and 63 DAC, using Decis 25 EC as the control agent. Rice harvesting occurred at 75 DAC when the rice reached physiological maturity (95% yellowing). With the appropriate maintenance and fertilization practices, the rice yield in the SS is expected to be maximized.

Parameters

The research observations included the growth and yield components from each plot treatment. The plant growth components comprised the percentage of tillering stems (%), plant height (cm), the number of tillers clump^{-1} (stems), and dry weight of shoots (leaves and stems) clump^{-1} (g). In addition, the observed yield components included the grains dry weight clump^{-1} (g), the weight of 1000-filled grains (g), and panicle length (cm).

Statistical analysis

The observation data were analyzed using analysis of variance (ANOVA) at 5% significant level (Gomez and Gomez, 1984) with IBM SPSS Version 23 software. If differences were found between treatment means, further testing was conducted using Duncan's new multiple range test (DMRT) at 5% significant level. The term SD is derived from the abbreviation of standard deviation.

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Results

Component of the rice growth

Tillering stems

Observations of the tillering stems were conducted on 64 clumps plot^{-1} at 14 DAC. The results of the ANOVA (*Appendix 1*) indicated that the timing of NPK-base fertilizer application did not significantly affect the percentage of tillering stems that sprouted. The number of tillering stems is presented in *Table 1*.

Table 1. *The number of tillering stems (%) at 14 DAC*

The timing of NPK-base fertilizer application			
Control	**At harvest**	**At stem cuttings**	**At 7 DAC**
92.7 a	93.8 a	97.9 a	97.4 a

The values in the same row with different letters are significantly different based on DMRT at 5% significant level. $SD_{tillering\ stems}$ = 2.617

Figure 4a shows shoot emergence from the basal stem of the parent at 7 DAC, while *Figure 4b* illustrates the tiller growth at 28 DAC.

a. The shoot emergence from the basal stem of the parents at 7 DAC

b. The tiller growth in the SS at 28 DAC

Figure 4. *Photo of the shoot emergence from the basal stem of the parents at 7 DAC (a) and the tiller growth at 28 DAC (b)*

Plant height

Plant height was observed on 10 clumps plot^{-1} at regular intervals of 14, 28, 42, and 56 DAC. The results of the ANOVA (*Appendix 2*) found that the timing of NPK-base fertilizer application significantly affected the plant height at 28 and 42 DAC, while there was no significance at 14 and 56 DAC. The average plant height is presented in *Table 2*.

Table 2 shows that applying NPK-base fertilizer increased only plant height at the 28 DAC. The application of NPK-base fertilizer at stem cuttings of the parent plants resulted in taller plants compared to applying it at control and 7 DAC, although no different from at harvest. However, at the 42 DAC observation, it appeared that the application of NPK-base fertilizer at 7 DAC led to a decrease in plant height compared to control.

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Table 2. *The plant height at 14, 28, 42, and 56 DAC*

Time of observations (DAC)	The timing of NPK-base fertilizer application			
	Control	**At harvest**	**At stem cuttings**	**At 7 DAC**
14	33.9 a	32.3 a	42.1 a	36.0 a
28	62.4 b	70.3 ab	73.3 a	63.3 b
42	87.0 a	86.9 a	84.3 ab	80.8 b
56	90.1 a	91.3 a	89.5 a	86.8 a

The values in the same row with different letters are significantly different based on DMRT at 5% significant level. $SD_{14\ DAC} = 4.577$, $SD_{28\ DAC} = 4.322$, $SD_{42\ DAC} = 2.211$, and $SD_{28\ DAC} = 3.681$

Tiller numbers

The number of tillers was also observed on 10 clumps plot^{-1} at regular intervals of 14, 28, 42, and 56 DAC. The results of the ANOVA (*Appendix 3*) showed that the timing of NPK-base fertilizer application had no significant effect on the number of tillers clump^{-1} at 14, 28, 42, and 56 DAC. The average number of tillers is shown in *Table 3*.

Table 3. *The number of tiller clump^{-1} at 14, 28, 42, and 56 DAC*

Time of observations (DAC)	The timing of NPK-base fertilizer application			
	Control	**At harvest**	**At stem cuttings**	**At 7 DAC**
14	7.3 a	6.4 a	7.9 a	6.0 a
28	14.6 a	15.9 a	16.9 a	13.6 a
42	17.5 a	18.2 a	19.0 a	15.2 a
56	16.2 a	15.9 a	16.2 a	13.8 a

The values in the same row with different letters are significantly different based on DMRT at 5% significant level. $SD_{14\ DAC} = 2.804$, $SD_{28\ DAC} = 2.567$, $SD_{42\ DAC} = 3.868$, and $SD_{28\ DAC} = 3.636$

Component of the rice yield

The dry weight of shoots clump^{-1} (g), grains clump^{-1} (g), weight of 1000-filled grain (g), and panicle length (cm) were observed on 10 clumps plot^{-1} at 75 DAC. The results of the ANOVA (*Appendix 4*) indicated that the timing of NPK-base fertilizer application significantly affected the dry weight of shoots, grains clump^{-1}, and 1000-filled grains, while panicle length showed no significant effect. The average of dry weight of shoots, grains, 1000-filled grains, and panicle length are presented in *Table 4*.

Table 4. *The means of shoot dry weight, grain dry weight, the weight of 1000-filled grain, and panicle length at 75 DAC*

Parameters observed	The timing of NPK-base fertilizer application			
	Control	**At harvest**	**At stem cuttings**	**At 7 DAC**
Shoots dry weight clump^{-1} (g)	23.1 b	31.3 a	32.2 a	30.1 a
Grains dry weight clump^{-1} (g)	13.2 b	13.9 ab	15.3 a	14.6 ab
1000-filled grains (g)	13.3 b	19.0 a	19.3 a	17.3 a
Panicle length (cm)	18.9 a	18.6 a	20.5 a	19.8 a

The values in the same row with different letters are significantly different based on DMRT at 5% significant level. $SD_{shoot\ dry\ weight} = 2.778$, $SD_{grains\ dry\ weight} = 0.703$, $SD_{1000\text{-}filled\ grains} = 1.803$, and $SD_{panicle\ length} = 1.682$

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Table 4 shows that the application of NPK-base fertilizer significantly increase the shoot dry weight clump^{-1} (g), grain dry weight clump^{-1} (g), and 1000-filled grains (g). However, the application of NPK-base fertilizer at stem cuttings led to a significantly increase in grain dry weight clump^{-1} and were not significantly different from those at harvest and 7 DAC. No significant differences were observed among the treatments at harvest, 7 DAC, and the control.

Discussion

Components of rice growth

The application of NPK-base fertilizer in the SS did not influence the percentage of new shoots emerging from cut stems and tillers number. This might have been because the new shoots primarily relied on the food reserve stored in the parent stems. After cutting, the emerging shoots utilized the resources available in the remaining stem for growth. Therefore, although NPK provided essential nutrients, internal factors such as the energy stored in the parent stem might have been more dominant in determining the success of new shoot emergence.

While NPK contained essential nutrients, the growth of tillers was influenced by various factors, including the genetic traits of the rice variety, soil conditions, and management techniques. In the SS, which emphasizes effective resource use, the number of tillers might have been more influenced by care practices and other cultivation techniques rather than by fertilizer alone. Thus, applying NPK as a fertilizer was insufficient to increase the number of tillers significantly.

In contrast, the application of NPK-base fertilizer significantly impacted plant height at 28 DAC in the SS, although this was not always the case for all plant height observations, particularly at 42 DAC. The delayed application of NPK base fertilizer at 7 DAC actually disrupted plant height growth during the maximum vegetative phase, with inhibition observed at 45 DAC. At 56 DAC, there was a tendency for plant height to be lower than control, although the difference was not significant.

The NPK provided nitrogen, phosphorus, and potassium, which were crucial for vegetative growth. Nitrogen played a role in protein synthesis and leaf growth, directly affecting plant height. Additionally, phosphorus supported better root development, allowing the plant to absorb more nutrients from the soil. With optimal nutrient availability, the plant could grow taller, demonstrating that while NPK did not affect new shoots and tillers numbers, it was key in supporting plant height growth. According to Samira et al. (2012), the application of NPK could increase the plant height of rice.

Components of rice yield

In the early stages of growth, new shoots utilized the food reserves from the remains of the parent stems while forming new roots that replaced the function of the parent plant's roots. New shoots were ready to utilize nutrients available in their environment 10 days after the stem cuttings. The application of NPK-base fertilizer at stem cuttings the parent enhanced the availability of essential nutrients, including nitrogen (N), phosphorus (P), and potassium (K), which were crucial for rice growth in the SS. The new shoot's roots quickly absorbed available nutrients to support their development. This base fertilizer helped provide the essential nutrients needed by the new shoots that

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emerged from the stem cuttings. New shoots will appeared the day after cutting, although small and without leaves.

The application of NPK-base fertilizer significantly increased shoot dry weight compared to the control. This fertilizer contained essential nutrients such as nitrogen, phosphorus, and potassium, which were crucial for plant growth. Nitrogen played a vital role in chlorophyll formation and leaf development. With the application of NPK, plants can developed denser leaves and wider shoots, enhancing their photosynthetic capacity. As a result, the shoots' dry weight was higher than those that did not receive the fertilizer. Yang et al. (2004) emphasized that the rice root system was vital in absorbing water and nutrients from the soil. According to Wang et al. (2006), root system formation was closely coordinated with shoot growth, where the shoot regulated the root development through the circulation of materials between the two. Root distribution determined the structure of the root system within the soil, affecting the acquisition of soil resources such as nutrients and water.

In addition to increasing shoots dry weight, it also increased grain dry weight clump^{-1} higher than the control. The nutrients provided by NPK supported the grain-filling process, enabling the plants to produce more and heavier grains. Applying nitrogen and phosphorus was crucial for optimal grain development during the grain-filling phase. Plants receiving NPK-base fertilizer showed a significant increase in the dry weight of grains clump^{-1}, indicating that a good nutrient supply contributed to better harvest yields. The product of photosynthesis in the leaves could be translocated in the seed-filling process if the plants were supplied with this nutrient.

According to Rawat et al. (2022), phosphorus is the most abundant element after nitrogen and is involved in many physiological processes such as photosynthesis and translocation. Sarkar et al. (2021) stated that the capacity for source-sink dynamics and assimilate translocation can play an important role during grain formation. As explained by Wei et al. (2018), rice grain yield depends on the supply assimilates (source) and the grain capacity to utilize them (sink).

The application of NPK resulted in the resulting grains being heavier and of higher quality than the control. Adequate nutrients aided in grain-filling, allowing the grains to fill out properly and achieve greater dry weight. The application of NPK-base fertilizer not only increased the quantity of the harvest but also improved the quality of the rice grains, which was essential for determining the market value of the produce. According to Metwally et al. (2020), the grain quality characteristics can be enhanced by the NPK fertilizer application.

As explain by Pasaribu et al. (2018), the parent plant's ability to generate new shoots depends highly on the carbohydrate content and phytohormones retained in the intercalary meristem tissues of the stubble after harvest. Additionally, increasing the rice yield with the SS can be achieved by improving fertilization, especially nitrogen.

Therefore, applying NPK-base fertilizer at stem cuttings was more effective in increasing grain dry weight clump^{-1} than using it at harvest or 7 DAC. The application of NPK-base fertilizer at stem cutting provided essential nutrients for the new shoots that emerged from the remaining parts of the parent plants. The fertilizer applied at this time could be directly utilized by the shoots after ten days, as nitrogen, phosphorus, and potassium are crucial for accelerating the formation of new tissues and photosynthesis. In contrast, applying NPK-base fertilizer at harvest or 7 DAC was less effective because the growth of new shoots had not yet started during that period. The availability of nutrients was not optimally utilized, leading to lower dry weight and harvest yields.

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Therefore, the timing of NPK-base fertilizer application significantly influenced nutrient absorption efficiency and the final yield of the plants. Moreover, the application of NPK-base fertilizer at stem cuttings optimally enhanced the rice yield in the SS.

Conclusions

The results indicated that the application of NPK-base fertilizer could significantly increase the shoot dry weight clump^{-1} and 1000-filled grains. The application of NPK-base fertilizer could enhance the plant height (cm) at 28 DAC, with no significant difference compared to the time of harvesting. Furthermore, this treatment resulted in a higher grains dry weight clump^{-1} (15.3 g) compared to the control (13.2 g), and was not significantly different from the treatments at harvest (13.9 g) or 7 DAC (14.6 g). No significant differences were observed among the treatments at harvest, 7 DAC, and the control. The conclusion indicate that applying NPK-base fertilizer at stem cuttings of the parent plants optimally enhances rice yield in the SS. Future research should recommend determining the optimal dosage of NPK-base fertilizer to maximize rice yields.

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APPENDIX

Appendix 1. *ANOVA of tillering stem*

Source of variance	Degree of freedom	Sum of squares	Mean square	F calc.	F *table* 5%
Block	2	37.028	18.514	2.703 ns	5.14
Treatment	3	60.832	20.277	2.960 ns	4.76
Error	6	41.097	6.850		
Total	11	138.957			

ns = not significant at 5%

Appendix 2. *ANOVA of plant height*

Source of variance	Degree of freedom	Mean square				F table 5%
		14 DAC	28 DAC	42 DAC	56 DAC	
Block	2	9.027 ns	6.754 ns	5.127 ns	4.868 ns	5.14
Treatment	3	55.394 ns	84.675 *	25.636 *	10.640 ns	4.76
Error	6	20.947	18.678	4.934	13.549	
Total	11					

ns = not significant at 5% and * = significance different at 5%

Appendix 3. *ANOVA of tiller number*

Source of variance	Degree of freedom	Mean square				F table 5%
		14 DAC	28 DAC	42 DAC	56 DAC	
Block	2	9.896 ns	17.453 ns	20.818 ns	12.766 ns	5.14
Treatment	3	2.200 ns	6.444 ns	8.132 ns	4.125 ns	4.76
Error	6	7.861	4.960	10.220	14.141	
Total	11					

ns = not significant at 5%

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Appendix 4. *ANOVA of shoot dry weight, grain dry weight, 1000-filled grains, and panicle length*

Source of variance	Degree of freedom	Mean square				F table 5%
		Shoot dry weight	Grain dry weight	1000-filled grains	Panicle length	
Block	2	13.898 ns	0.259 ns	0.250 ns	0.002 ns	5.14
Treatment	3	51.490 *	2.570 *	22.750 *	2.207 ns	4.76
Error	6	7.719	0.494	3.250	2.829	
Total	11					

ns = not significant at 5% and * = significance different at 5%

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