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Influence of Nutrient Management on Growth, Lodging and Yield of Transplanted Rice

P. Abarajitha [a*φ], S. Rathika [a#], S. Avudaithai [a†], P. Balasubramaniam [b‡] and T. Ramesh [c¥]

[a] Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, TNAU, Tiruchirappalli - 620027, Tamil Nadu, India.
[b] Natural Resource Management, Tamil Nadu Agricultural University, Coimbatore - 641003, Tamil Nadu, India.
[c] Krishi Vigyan Kendra, Vamban, Tamil Nadu, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aim: To study the Influence of nutrient management on growth, lodging and yield of transplanted rice.

Study Design: The study comprised of eight treatments *viz.,*T_1- 100% NPK, T_2- 100% NP + 125% K, T_3- 75% N + 100% PK, T_4- 75% N + 100% P + 125% K, T_5- 100% NPK + K_2SiO_4 at 50 kg ha^{-1}, T_6- 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1}, T_7- 100% NPK + Na_2SiO_3 at 50 kg ha^{-1} and T_8- absolute control in randomized block design.

Place and Duration of Study: This research trail was conducted during the *late samba* (September – February) of 2021-22 at Anbil Dharmalingam Agricultural College and Research Institute. TNAU, Trichy, Tamil Nadu, India.

Methodology: The study consisted of combination of 8 treatments in RBD which was replicated thrice. The rice variety of IW Ponni was used for this study. The observation have been recorded during the different phases of growth at regular intervals.

[φ]PG Scholar;
[#]Assistant Professor;
[†]Professor and Head;
[‡]Director;
[¥]Assistant Professor (Agronomy);
**Corresponding author: E-mail: abarajithapandi.1225@gmail.com;*

Results: The results revealed that the application of 100% NPK + K_2SiO_4 at 50 kg ha^{-1} has recorded significantly taller plant height (131.7 cm), higher dry matter production (11360 kg ha^{-1}), grain (4535 kg ha^{-1}) and straw yield (7259 kg ha^{-1}) over absolute control. Minimum bending moment and lodging score were reported with 100% NPK + K_2SiO_4 at 50 kg ha^{-1} and it was on par with 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1}.

Keywords: Nutrient management; lodging; growth; yield; transplanted rice.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population. Among the rice growing countries, India stands first in area and second in production next to China. In India, at 2021, it is grown in the total area of about 45.7 Mha with the total production of 124.3 Mt and total productivity of 2.7 t ha^{-1} [1]. In Tamil Nadu, rice is grown in the total area of 2.03 Mha with the total production of 6.88 Mt and total productivity of 3.3 t ha^{-1} [1]. Since, from the green revolution, the potential production of rice has increased significantly; there is a critical need to enhance rice production at a growth rate of 2.5% each year since it is predicted that the global population will increase to roughly 8.2 billion in 2030.

Globally, there are significant limitations to the cultivation of this profitable crop. One among them is crop lodging. It is defined as the permanent displacement of crop stems from their vertical position as a result of stem buckling and/or root displacement [2]. A decrease in assimilates for grain filling results from severe lodging because it limits the passage of water, nutrients and assimilates through the xylem and phloem. Therefore, lodging can result in significant reductions in grain output and quality. Additionally, it increases the need for grain drying, complicates harvesting procedures and eventually raises production costs. Therefore, to prevent lodging in rice through agronomical practices, adequate nutrition management technique is needed. Nitrogen (N), Phosphorus (P), Potassium (K) and silicon (Si) fertilizer application that influence lodging in rice.

N is a part of the chlorophyll molecule, which helps plants to use photosynthesis by promoting plant growth and crop yield. N allows the leaves to grow luxuriantly, causing the canopy to become too massive for the culm to maintain, resulting in lodging [2].

The second-most crucial macronutrient for plant nutrition and growth is phosphorus to improve lodging resistance in rice by increasing the root anchorage. Zhao et al. [3] concluded that adding P fertilizer to rice lodging might improve the stem lignin concentration or wall thickness. K has a role of enzyme activation in plants, which has an impact on the synthesis of protein, starch and adenosine triphosphate (ATP). The addition of K to the soil enhanced root development and lowering the possibility of lodging [4]. In rice, Si has a positive effect on plant height, stem length, inter-node length, bending moment (BM), and lodging score (LS). The accumulation of Si in rice shoots increased stem cell wall thickness and vascular bundle size, resulting in a minimum lodging index (LI) [5]. With this background, the present investigation has been carried out to evaluate the influence of nutrient management on growth, lodging and yield maximization of rice.

2. MATERIALS AND METHODS

This field experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu during *Rabi,* 2021. The experimental site was located at 10^o 45'N latitude, 78^o 36'E longitude and at an altitude of 85 m above Mean sea level. Total rainfall recorded during cropping season was 968.6 mm in 40 rainy days. The mean maximum and minimum temperature recorded during the cropping period were 35.1^{o}C and 24.4 ^{o}C, respectively. The mean relative humidity was 75.5% (7.16 hrs) and 40. 7% (14.16 hrs), respectively. The mean bright sunshine hours and mean evaporation per day were 5.7 hrs and 3.7 mm day^{-1}. The mean wind velocity was 9.0 km hr^{-1}.

The soil of the experiment field was sandy clay loam in texture, moderately drained and classified as *Vetric Ustropept* with pH of 8.8 and EC of 0.24 dS m^{-1}. The experimental soil was low in available nitrogen (197.0 kg ha^{-1}) , medium in available phosphorus (15.4 kg ha^{-1}), high in available potassium (285.7 kg ha^{-1}) and low in available silicon (67 mg ha^{-1}) Yoshida, [6]. Experiment was laid out in randomized block design (RBD) with three replications and eight treatments. The treatments comprised of T_1- 100% NPK, T_2- 100% NP + 125% K, T_3- 75% N + 100% PK, T_4- 75% N + 100% P + 125% K, T_5- 100% NPK + K_2SiO_4 at 50 kg ha^{-1}, T_6- 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1}, T_7- 100% NPK + Na_2SiO_3 at 50 kg ha^{-1} and T_8- absolute control. The rice variety IW Ponni was grown during the course of study in net plot size of 5m x 4m and age of the seedling was 21 days old. The recommended fertilizer dose for medium duration variety was 75: 50:50 NPK kg ha^{-1}. NPK were applied in the form of urea, DAP and MOP. Whereas Si at 50 kg ha^{-1} was applied to soil in the form of potassium silicate, calcium silicate and sodium silicate. At the time of transplanting, 25% N, K, Si and 100% P were applied as basal. During active tillering (AT), panicle initiation (PI) and flowering of transplanted rice, the remaining 75% of N, K, Si were top dressed in three equal splits.

Plant height and dry matter production were recorded at active tillering, panicle initiation, flowering and maturity by adopting standard procedure. Lodging characteristics was observed at flowering stage. Fifteen days after flowering, lodging-related stem characteristics were identified. The lengths of the third and fourth internodes from the top, as well as the stem length (the distance between the plant base and panicle neck node) were measured. The following formula was used to compute the bending moment (BM) at the N3 or N4 internode [7].

BMN_3= Length from the lowest node of N_3 to the top of panicle × (W1+W2).

BMN_4= Length from the lowest node of N_4 to the top of panicle × (W1+W2).

Where, W_1 - Fresh weight of third internode and W_2 - Fresh weight of third internode with leaf sheath

The calculation of the lodging score took into account both the percentage and angle of the lodging and described its gravity; the highest lodging score indicates more lodging.

Lodging score = [(Lodged area net plot area^{-1}) X 100 X Angle of lodging] / 90

The grain and straw yields were recorded from the net plot at harvest stage. All the recorded data were analyzed statistically as per the method suggested by Wonu and Ndimele [8].

3. RESULTS AND DISCUSSION

3.1 Effect of Nutrient Management on Growth Parameters of Transplanted Rice

3.1.1 Plant height

Adoption of different nutrient management practices has significantly influenced the plant height (Table 1). Application of 100% NPK + K_2SiO_4 at 50 kg ha^{-1} (T_5) registered the tallest plant height (87.2, 114.2, 130.4 and 131.7 cm) which was on par with 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1} (T_6) (84.1, 107.9, 128.9 and 129.3 cm) at active tillering, panicle initiation, flowering and maturity. The shortest plant height was recorded in absolute control (T_8) at all the stages (54.3, 62.1, 77.8 and 78.1 cm). This could be attributed to the fact that nitrogen induced maximum vegetative growth with higher rates. Application of nitrogen and silica improves plant nutrient content and thus increases the plant height due to increase in protoplasm, cell division and cell enlargement. This findings was affirmed by Chaiwong et al. [9] and Sindhu et al. [10].

3.1.2 Dry Matter Production (DMP)

Practicing various nutrient management techniques had marked, influence on DMP (Table 2). At active tillering, panicle initiation, flowering and maturity stages, application of 100% NPK + K_2SiO_4 at 50 kg ha^{-1} (T_5) recorded significantly higher DMP (1296, 4875, 8212 and 11360 kg ha^{-1}) and it was comparable with 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1} (T_6) (1242, 4749, 7985 and 11032 kg ha^{-1}). The lowest DMP was recorded in absolute control (T_8) at all the stages (753, 3157, 4708 and 6484 kg ha^{-1}). This might be due to the adequate transfer of assimilation to the sink which in turn increases the tiller count resulting in higher yields. Thus Dry matter accumulation considered as a reliable index of crop vigour. This is in accordance with the findings of Huang Li et al. [11] and Jiaying et al. [12].

3.2 Effect of Nutrient Management on Bending Moment and Lodging Score

Different nutrient management practices had significantly influenced the bending moment (Table 3). At maturity, application of 100% NPK + K_2SiO_4 at 50 kg ha^{-1} (T_5) recorded minimum bending moment (1406.8 g.cm)

Table 1. Effect of nutrient management on plant height (cm) of transplanted rice

Treatments	Plant height (cm)			
	Active Tillering	Panicle initiation	Flowering	Maturity
T_1 - 100% NPK	71.7	90.8	108.5	108.9
T_2 - 100% NP + 125% K	74.4	95.4	113.8	114.5
T_3 - 75% N + 100% PK	63.8	79.6	96.3	96.4
T_4 - 75% N + 100% P + 125% K	65.8	81.5	98.4	99.2
T_5 - T_1 + K_2SiO_4 at 50 kg ha^{-1}	87.2	114.2	130.4	131.7
T_6 - T_1 + Ca_2SiO_4 at 50 kg ha^{-1}	84.1	107.9	128.9	129.3
T_7 - T_1 + Na_2SiO_3 at 50 kg ha^{-1}	81.3	98.6	121.5	121.9
T_8 - Absolute control	54.3	62.1	77.8	78.1
SEd	2.7	3.5	3.6	3.8
CD (P=0.05)	5.4	7.0	7.2	7.6

Table 2. Effect of nutrient management on DMP (kg ha^{-1}) of transplanted rice

Treatment	DMP (kg ha^{-1})			
	Active tillering	Panicle initiation	Flowering	Maturity
T_1 - 100% NPK	1025	4149	6680	8854
T_2 - 100% NP + 125% K	1049	4178	6915	9693
T_3 - 75% N + 100% PK	877	3545	5363	7761
T_4 - 75% N + 100% P + 125% K	902	3742	5972	7890
T_5 - T_1 + K_2SiO_4 at 50 kg ha^{-1}	1296	4875	8212	11360
T_6 - T_1 + Ca_2SiO_4 at 50 kg ha^{-1}	1242	4749	7985	11032
T_7 - T_1 + Na_2SiO_3 at 50 kg ha^{-1}	1164	4582	7624	10613
T_8 - Absolute control	753	3157	4708	6484
SEd	53	198	325	421
CD (P=0.05)	106	398	650	843

Table 3. Effect of nutrient management on bending moment and lodging score of transplanted rice

Treatment	Bending moment (g.cm)	Lodging score
T_1 - 100% NPK	1727.9	5.3
T_2 - 100% NP + 125% K	1616.1	4.1
T_3 - 75% N + 100% PK	1772.7	5.6
T_4 - 75% N + 100% P + 125% K	1635.5	4.4
T_5 - T_1 + K_2SiO_4 at 50 kg ha^{-1}	1406.8	2.7
T_6 - T_1 + Ca_2SiO_4 at 50 kg ha^{-1}	1425.2	2.9
T_7 - T_1 + Na_2SiO_3 at 50 kg ha^{-1}	1519.3	3.3
T_8 - Absolute control	1926.9	5.9
SEd	47.3	0.11
CD (P=0.05)	94.2	0.25

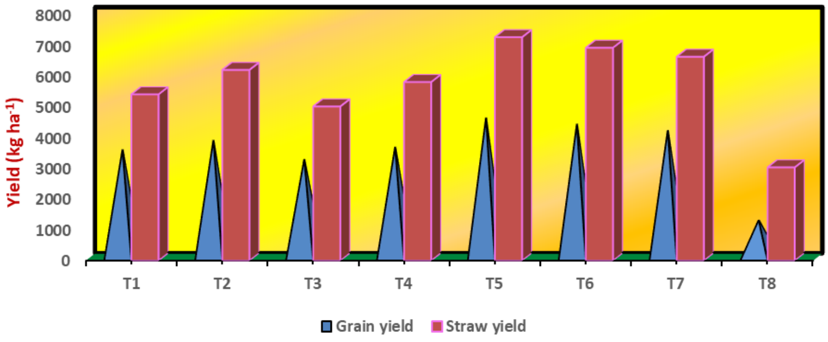

Fig. 1. Effect of nutrient management on grain yield, straw yield of transplanted rice

and it on par with 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1} (T_6) (1425.2 g.cm). The minimum bending moment was recorded in absolute control (T_8) (1926.9 g.cm). It might be due to the thickening of cell wall of the sclerenchyma tissue in the culm and/or thickening of internodes or increase in silicon content of lower internodes provides mechanical strength to enable the plant to resist lodging and also this study showed that bending moment decreased with silicon concentration. Zhang et al. [13] were also noticed an increase in resistance to lodging due to application of silicon fertilizer to rice.

The lodging score of rice altered by various nutrient management practices (Table 3). Application of 100% NPK + K_2SiO_4 at 50 kg ha^{-1} (T_5) registered minimum lodging score (2.7) and it was comparable with 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1} (T_6) (2.9). The maximum lodging score was recorded in absolute control (T_8) (5.9). This might be due to the reason that application of silicon, has a beneficial effect on culm thickness and enhances stem strength while reducing the breaking resistance, resulting to have minimum lodging resistance score in rice and thickness of culm walls and vascular bundles becomes larger to increase the culm strength when silicon is applied. Similar findings were also reported by Ghuman et al. [14] and Zhang et al. [13].

3.3 Effect of Nutrient Management on Grain and Straw Yield

The grain and straw yields of rice were significantly influenced by different nutrient management practices (Table 4). The highest grain and straw yields (4535 and 7259 kg ha^{-1}) were recorded in application of 100% NPK + K_2SiO_4 at 50 kg ha^{-1} (T_5) and it was on par with 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1} (T_6) of (4329 and 6915 kg ha^{-1}). The lowest grain and straw yields were obtained from absolute control (T_8) (1200 and 3029 kg ha^{-1}). It is because of silicon is responsible to control stomatal activity, photosynthesis, water use efficiency which ultimately results in better vegetative growth to achieve higher grain yield and straw yield. It may be attributed to leaf erectness which facilitated better penetration of sunlight leading to higher photosynthetic activity of plant and higher production of carbohydrates. In addition, application of silicon reduced the lodging of rice and ultimately increased the grain yield to the tune of 29.5% due to positive source to sink relationship. This investigation is in agreement with the findings of Artyszak, [15] and Bukhari et al. [16].

4. CONCLUSION

For medium duration variety like IW Ponni, under sodic soil, which is grown during Thaladi or *late samba* season in Cauvery delta zone, application of 100% NPK (75:50:50 kg NPK ha^{-1}) + K_2SiO_4 at 50 kg ha^{-1} (T_5) has positive impact on plant height, dry matter production, bending moment, lodging score and thus increases the grain and straw yields *fb* application of 100% NPK + Ca_2SiO_4 at 50 kg ha^{-1} (T_6). From this field experiment, it could be concluded that application of 100% NPK (75:50:50 kg NPK ha^{-1}) + K_2SiO_4 at 50 kg ha^{-1} was recommended for lodging reduction and to improve the productivity of transplanted rice under sodic soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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