Original Research Article

INFLUENCE OF NUTRIENT MANAGEMENT ON GROWTH, LODGING AND YIELD OF TRANSPLANTED RICE

ABSTRACT

A field experiment was conducted at AnbilDharmalingam Agricultural College and Research Institute, Tiruchirappalli during *Rabi*, 2021 to evaluate the nutrient management techniques on lodging reduction and to improve the productivity of transplanted rice. The study comprised of eight treatments *viz.*, 100 % NPK, 100 % NP + 125 % K, 75 % N + 100 % PK, 75 % N + 100 % P + 125 % K, 100 % NPK + K_2SiO_4at 50 kg ha^{-1}, 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1}, 100 % NPK + Na_2SiO_3at 50 kg ha^{-1} and absolute control. The results revealed that the application of100 % 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_4at 50 kg ha^{-1}.

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

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, it is grown in an area of about 45.7 million hectare with the production of 124.3 million tonnes and productivity of 2.7 tonnes per hectare (Indiastat, 2021). In Tamil Nadu, rice is grown in an area of 2.03 million hectares with a production of 6.88 million tonnesand productivity of 3.3 tonnes per hectare(Indiastat, 2021). 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 limits to the cultivation of this profitable crop. One among them is crop lodging, Lodging is described as the persistent relocation of stems from their

Comment [A1]: Title in one spacing

Comment [A2]: Abstract in one spacing

Comment [A3]: incorrect

Comment [A4]: incorrect

Comment [A5]: Should be written consistently using the international unit symbol (consistent with the unit symbol in abstract)
Example: tonnes per hectare that is incorrect : tons per hectare = correct with unit symbol t ha^{-1} = **A**

Comment [A6]: incorrect

Comment [A7]: = A

upright posture. In addition, whole grain fields are regularly flattened following storms due to lodging (Crook and Ennos 1995). 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 makes harvesting operations more challenging, shattering of grains during harvesting increases demand for grain drying and ultimately increases production cost. 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. With this background, the present investigation has been carried out to evaluate the influence of nutrient managementon growth, lodging and yield maximization of rice.

Comment [A8]: We recommend using the literature above 2015

Materials and methods

A field experiment was conducted at AnbilDharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu during *Rabi*, 2021. The experimental site was located at 10^{o} 45'Nlatitude, 78^{o} 36'E longitude and at an altitude of 85 m above MSL. 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 *VetricUstropept*with pH of 8.8 and EC of 0.24 dSm^{-1}. The experimental soil was low in available nitrogen (197.0 kg/ha), medium in available phosphorus (15.4 kg/ha), high in available potassium (285.7 kg/ha) and low in available silicon (67 mg/ha). The field experiment was laid out in randomized block design (RBD) with three replications and eight treatments. The treatments comprised of 100 % NPK, 100 % NP + 125 % K, 75 % N + 100 % PK, 75 % N + 100 % P + 125 % K, 100 % NPK + K_2SiO_4at 50 kg ha^{-1}, 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1}, 100 % NPK + Na_2SiO_3at 50 kg ha^{-1} and absolute control. The rice variety IW Ponni was grown during the course of investigation. The recommended fertilizer dose for medium duration variety was 75: 50:50 NPK kg ha^{-1}. NPK wereapplied in the form of urea, DAP and MOP. WhereasSi at 50 kg $ha^{-1}$was applied in soil in the form of potassium silicate, calcium silicate and sodium

Comment [A9]: Consistent : kg ha^{-1}

Comment [A10]: Consistent writing

Comment [A11]: Consistent writing

Comment [A12]: Consistent writing

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 (Islam *et al.*, 2007).

Comment [A13]: We recommend using the literature above 2015

BMN3= Length from the lowest node of N3 to the top of panicle × W_1+W_2.

BMN4= Length from the lowest node of N4 to the top of panicle × W_1+W_2.

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.

$$\text{Lodging score} = \frac{(\text{Lodged area/netplot area})\ \text{X}\ 100\ \text{X Angle of lodging}}{90}$$

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 Gomez and Gomez (1984).

Comment [A14]: We recommend using the literature above 2015

Results and Discussion

Effectofnutrient management ongrowth parameters oftransplantedrice

Plant height

Adoption of different nutrient management practices has significantly influenced the plant height (Table 1). Application of 100 % NPK + K_2SiO_4at 50 kg ha^{-1} registeredthe tallest plant height (87.2, 114.2, 130.4 and 131.7 cm) which was on par with 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1}(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 at all the stages (54.3, 62.1, 77.8 and 78.1 cm). The increase in plant height is due to increase in protoplasm, cell division, cell enlargement and vegetative growth with higher rates of nitrogen and application of silicon aids in upright of leaves which further increases photosynthetic activity causes plants to grow taller. These findings are in conformity with the results obtained by Mallick (1992), Roy *et al.* (2004) and Fallah (2012).

Comment [A15]: We recommend using the literature above 2015

Table1. Effectofnutrient management onplantheight(cm)oftransplantedrice

Treatments	Plant height			
	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

Dry matter production (DMP)

Practicing various nutrient managementtechniques had marked, influence on DMP(Table 2). At active tillering, panicle initiation, flowering and maturity stages, application of 100 % NPK + K_2SiO_4at 50 kg ha^{-1} recorded significantly higher DMP (1296, 4875, 8212 and 11360 kg ha^{-1}) and it was comparable with 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1} (1242, 4749, 7985 and 11032 kg ha^{-1}). The lowest DMP was recorded in absolute control at all the stages (753, 3157, 4708 and 6484 kg ha^{-1}). This might be due to the application of recommended dose of NPK and silicon increased the photosynthetic activity and transfer of photosynthates from source to sink which in turn increases dry matter production. This is in accordance with the findings ofStalin *et al.* (1999), Rao *et al.* (2004) and Prasad *et al.* (2011).

Comment [A16]: We recommend using the literature above 2015

Table2.Effectofnutrient management onDMP (kg ha^{-1}) oftransplantedrice

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

Effect of nutrient management on bending moment and lodging score

Differentnutrient management practices had significantly influenced the bending moment (Table 3). At maturity, application of 100 % NPK + K_2SiO_4at 50 kg ha^{-1} recorded minimum bending moment (1406.8 g.cm) and it on par with 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1} (1425.2 g.cm). The minimum bending moment was recorded in absolute control (1926.9 g.cm). It mightbe due to the thickeningofcellwallofthesclerenchymatissueintheculmand/orthickeningof 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. Bhiah*et al*. (2010) and Zhang *et al.* (2021) were also noticedanincreaseinresistancetolodgingduetoapplicationofsiliconfertilizer to rice.

The lodging score of rice altered by various nutrient management practices (Table 3). Application of 100 % NPK + K_2SiO_4at 50 kg ha^{-1}registered minimum lodging score (2.7) and it was comparable with 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1} (2.9). The maximum lodging score was recorded in absolute control (5.9). The lowest lodging score is due to application of silicon which positively affects the culm thickness that increases the stemstrength, resulted in minimum breaking resistance and consequently, minimum stem strength causes reduction in culm thickness thereby, resulted in poor lodging resistance in rice. Similar findings were also reported by Wei *et al.*(2008), Yang *et al.* (2009), Wang *et al.* (2012) and Zhang *et al.* (2013).

Comment [A17]: We recommend using the literature above 2015

Table 3. Effectofnutrient management on bending momentand lodging score of transplantedrice

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

Effect ofnutrient 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 inapplication of 100 % NPK + K_2SiO_4at 50 kg ha^{-1} and it was on par with 100 % NPK + Ca_2SiO_4at 50 kg ha^{-1} of (4329 and 6915 kg ha^{-1}). The lowest grain and straw yields were obtained from absolute control (1200 and 3029 kg ha^{-1}). Itmightbeduetothesplit application ofnutrients,resultingin morephotosynthesisandapositivesourcetosinkrelationship which increasestheyieldattributingcharacters which ultimately reflected on grain and straw yield.In addition, application of silicon reduced the lodging of rice and ultimately increased the grain yield to the tune of 29.5%.However, the combined application of N and Sihas positive effect in increasing the grain and straw yields due to synergistic effect between nitrogen and silicon.Silicon application further improved P uptake, growth and yield in rice as because silicate anions occupies the phosphate anion's adsorption sites, leads to increasing availability of silicon to plants and thus results in improved growth and yield. This investigation is in agreement with the findings of Sardar *et al.* (1988) and Kim *et al.* (2012).

Comment [A18]: We recommend using the literature above 2015

Table4.Effectofnutrient management ongrain yield, straw yield of transplanted rice

Treatment	**Grain yield (kg ha^{-1})**	**Straw yield (kg ha^{-1})**
T_1 - 100 % NPK	3501	5402
T_2 - 100 % NP + 125 % K	3804	6196
T_3 - 75 % N + 100 % PK	3182	5008
T_4 - 75 % N + 100 % P + 125 % K	3583	5802
T_5 - T_1 + K_2SiO_4at 50 kg ha^{-1}	4535	7259
T_6 - T_1 + Ca_2SiO_4at 50 kg ha^{-1}	4329	6915
T_7 - T_1 + Na_2SiO_3at 50 kg ha^{-1}	4125	6623
T_8 - Absolute control	1200	3029
SEd	123	198
CD(P=0.05)	247	395

Conclusion

From this field experiment, it could be concluded that application of 100 % NPK (75:50:50 kg NPK ha^{-1}) + K_2SiO_4at 50 kg ha^{-1} was recommended for lodging reduction and to improve the productivity of transplanted rice.

References

Bhiah, K. M., Guppy, C., Lockwood, P., and Jessop, R. 2010. Effect of potassium on rice lodging under high nitrogen nutrition. *World congress of soil science, soil solutions for a changing world*, 45(9): 650-658.

Crook, M. J. and Ennos, A.R. 1995. The effect of nitrogen and growth regulators on stem and root characteristics associated with lodging in two cultivars of winter wheat. *Journal of Experimental Botany*, *46*(8): 931-938.

Fallah, A. 2012. Silicon effect on lodging parameters of rice plants underhydroponic culture. *International Journal of Agriculture Science*, 2(7): 630-634.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*. John Wiley and Sons.

Indiastat (2021). www.indiastat.com

Islam, M.S., Peng, SH., Visperas, R.M. and Ereful, N. 2007. Lodging-related morphological traits of hybrid rice in a tropical irrigated ecosystem. *Field Crops Res.*, *104* (2): 240-248.

Kim,Y.H.,Khan,A.L.,Shinwari,Z.K.,Kim,D.H.,Waqas,M.,Kamran,M. and Lee, I.J. 2012. Silicon treatment to rice (*Oryza sativa* L. cv. 'Gopumbyeo') plants during different growth periods and its effects on growth and grain yield. *Pakistan Journal of Botany*,44(3): 891-897.

Mallick,A.1992.IntegratednutrientmanagementinBasmati,Rice-Lentil System under irrigated upland conditions. *Ph.D., Thesis (Agronomy),* Facultyof the Post Graduate School, Indian Agricultural Research Institute, New Delhi, India.

Comment [A19]: One spacing

Comment [A20]: One spacing

Prasad,R.V.,Subbaiah,G.,Chandrasekhar,K.andPrasuna,R.P.2011. Validation of nitrogen recommendations for popular rice (*Oryza sativa* L.) varieties of costal Andhra Pradesh. *The Andhra Agricultural Journal,* 58(1): 1-4.

Rao,V.U.,Reddi,R.Y.,Radha,K.C.andRaghava,R.C.2004.Effectof organic and inorganic sources of nitrogen on growth, yield, nitrogen uptake andeconomicsoflowlandrice.*MadrasAgriculturalJournal,*91(7-12): 389-393.

Roy,B.C.,Leihner,D.E.,Hilger,T.H. andSteinmueller,N.2004.Tilleringpattern of local and modern T. Aman varieties as influenced by nitrogen rate and management practices. *Journal of Subtropical Agricultural Research and Development,* 2(2): 6-14.

Sardar, N.A., Shams, U.A.M. and Khan, N.H. 1988. Yield components ofwetland rice under various sources and levels of nitrogen. *Philippines Journal of Crop Science,* 13: 155-158.

Stalin, P., Thiyagarajan, T.M. and Rangarajan, R. 1999. Nitrogen application strategy and use efficiency in rice. *Oryza,* 36(4): 322-326.

Wang,C.Y.,Dai,X.L.,Shi,Y.H.,Wang,Z.L.,Chen,X.G.andHe,M.R. 2012. Effects of nitrogen application rate and plant density on lodging resistance in winter wheat. *Acta Agronomic Sinica,* 38: 121-128.

Wei, F.Z., Li, J.C., Wang, C.Y., Qu, H.J. and Shen, X.S. 2008. Effects of nitrogenousfertilizerapplicationmodelonculmlodgingresistancein winter wheat. *Acta Agronomic Sinica,* 34: 1080-1085.

Yang. S., Xie, L. and Yuan, J.C. 2009. Effect of nitrogen rate and transplanting density on physical and chemical characteristics and lodging resistance of culms in hybrid rice. *Acta AgronomicaSinica,* 35(1): 93-103.

Zhang,J.,Li,G.H.,Song,Y.P.,Zhang,W.J.,Yang,C.D.,Wang,S.H.and Ding, Y. F. 2013. Lodging resistance of super-hybrid rice intwo ecological regions. *Acta Agronomic Sinica,* 39: 682-692.

Zhang, T., He, X., Chen, B., He, L. and Tang, X. 2021. Effects of different potassium fertilizer rates on yield formation and lodging of rice. *Phyton*. 90(3): 815-818.

Comment [A21]: Each reference source is typed in one space

Comment [A22]: