

Effects of nitrogen and silicon on rice yield formation and Lodging resistance for Rice (*Oryza sativa* L.) stem under SRI production systems

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(Received 29 July, 2025; Accepted 23 September, 2025)

ABSTRACT

Rice, a key staple crop worldwide, is highly vulnerable to lodging, particularly when cultivated for high yields. Although both Nitrogen (N) and Silicon (Si) are known to influence plant growth and structural integrity, their combined effects on enhancing grain yield and reducing lodging have rarely been examined in field-based studies. This study analyzed the effect of nitrogen and silicon fertilizers on rice yield and lodging resistance for rice stem ensuing from farmer holding rice field during kharif 2025. The treatments consists of viz., T₁ - No RDF (Control), T₂ - Farmers practices, T₃ - 100% RDN, T₄ - 75% RDN, T₅ - 50 % RDN, T₆ - 50% RDN + 150 kg of Silicon ha⁻¹, T₇ - 75% RDN + 150 kg of Silicon ha⁻¹, T₈ - 100% RDN + 150 kg of Silicon ha⁻¹. The test crop was rice var. ADT 59. The results showed that the significantly increasing rice yield and resistance to lodging in the application of 75% RDN + 150 kg of Silicon ha⁻¹ in over control.

Key word: Lodging, rice, yield, Zn and N

Introduction

Rice (*Oryza sativa* L.) is a pivotal cereal crop globally (Gamage and Thompson, 2018). To meet the demands of a growing population, rice production will need to increase by 20% in 2030 compared to 2017. India was estimated to be the leading global producer of rice and to harvest about 47 million hectares of rice. Moreover, Rice is the world's third most producer cereal crop following maize and wheat. Over 530 million metric tons of milled rice was produced in the last harvesting year worldwide. Maintaining high rice yield on limited arable land is an effective approach to address the increasing food demand (Hung and Zou, 2018). Lodging, a widespread issue in rice production worldwide, poses

challenges in harvesting and results in reduced rice yield and quality. It inhibits rice photosynthesis, hampers dry matter accumulation and impedes the transport of organic matter to grains (Zhao and Bai, 2021). Previous research indicates that plant lodging can cause a decrease in rice yield ranging from 10 to 40 % (Liu *et al.*, 2024).

Rice lodging is a complex physiological phenomenon that occurs due to the interaction between the plant itself and external factors. It can be broadly categorized into two types: root lodging and stem lodging (Peng and Zeng, 2009). Root lodging occurs when the plant has shallow roots or poorly developed lower roots, resulting in tilting of the entire plant. On the other hand, stem lodging is characterized by bending, breaking and fracturing of the

basal internodes, primarily caused by a slender stem and underdeveloped mechanical tissue at the base (Zhang *et al.*, 2016). Stem lodging is the more common type of lodging and is mainly influenced by the weight of the upper part of the plant (stem, leaf and ear) and the mechanical strength of the stem base (Darshana *et al.*, 2022).

As one of the most important nutrients for normal growth and development of plants, the content of potassium (K) in rice plant tissue is generally 2.0% to 5.0 % (Dai *et al.*, 2008) and also the essential nutrient elements for normal growth and development of plants, K is very important to improve the metabolic function and stress resistance of rice. One of the fundamental biotic burdens which compromise rice creation at different stages from seed to seed is saltiness. Si supplementation considerably reduced a variety of symptoms associated with biotic and abiotic stress. To increase plant performance and productivity, silicate- containing fertilizers must be used in agricultural crop production systems. Rice lodging refers to the irrecoverable dislocation phenomenon that the rice plant inclines or even adheres to the ground or breaks the stem caused by its own factors or environmental factors (bad weather, diseases and pests, etc.) in the process of growth and development. Many studies have revealed the harm of lodging to crop production. Zhao *et al.* (2018) demonstrated that lodging would reduce the mechanical harvesting efficiency and thereby causes economic loss. The study of Xie *et al.* (2019) also revealed that lodging would induce the change in contribution proportion of stem, leaf and panicle in the canopy of rice in paddy field.

Studies have shown that lodging is most likely to occur in the fourth segment from the top of rice 40 days after the full heading stage (Liang *et al.*, 2015). Nitrogen is essential for plant growth and development and is often a limiting factor for high productivities. However, when applied in excess it may limit yield because of lodging, especially for cultivars of the traditional and intermediate groups, and promote shading and disease problems. These effects could be minimized by the use of Potassium silicate. Therefore, increasing the planting density and applying appropriate amounts of urea and potassium silicate fertilizers at a reduced N fertilizer application rate can ensure rice yield and improve lodging resistance. In this part of the delta region not much work has been done to study the effects a urea and potassium silicate fertilizers application in

improving the rice yield especially under system of rice intensification (SRI) production systems.

Materials and Methods

The field experiment was conducted to Padugai series (Vertic Ustropept) at the farmer's holding during the kuruvai season of year 2025. The experimental soil was clay loam in texture with pH 7.78, EC 0.84 dS m⁻¹, organic carbon 3.9 g kg⁻¹ (low), low in KMnO₄-N 275 kg ha⁻¹, low in Olsen-P 10.4 kg ha⁻¹, high in NH₄OAc-K 294 kg ha⁻¹ and low in available DTPA-Zn 0.68 mg kg⁻¹. The experiment was laid out in randomized block design. The treatments consists of eight treatments viz., T₁ - No RDF (Control), T₂ - Farmers practices, T₃ - 100% RDN, T₄ - 75% RDN, T₅ - 50 % RDN, T₆ - 50% RDN +150 kg of Silicon ha⁻¹, T₇ - 75% RDN + 150 kg of Silicon ha⁻¹, T₈ - 100% RDN +150 kg of Silicon ha⁻¹. The recommended dose of 50:50 N, P₂O₅, K₂O ha⁻¹ through superphosphate and muriate of potash was added uniformly to all the plots. Nitrogen was applied in three split doses i.e., 50% as basal, 25% each at active tillering and 25% panicle initiation stages as per the treatments. The entire dose of P₂O₅ and K₂O were applied basally as per the treatment schedule. The test crop rice ADT 59. The silicon was applied through potassium silicate formulations.

Internode length (cm)

Number of internode lengths were counted at four stages viz. mid-tillering, panicle initiation, anthesis and maturity from five randomly tagged hills of eachplot and expressed as cm28.

Culm thickness (mm)

Culm thickness was recorded at 15 days interval after transplanting till harvest using vernier clipper.

Lodging parameters

Breaking resistance (g.cm)

The rice plant was tied to the hook of a weighing balance with the help of rope. The rope was then pulled and the weight (in grams) at which the rice plant got lodged was recorded and the length of that whole plant was measured expressed in cm.

Bending moment (g.cm)

Bending moment (g.cm) using the formula, BMN₃ = Length from the lowest node of N₃ to the

top of panicle $\times (W_1+W_2)$, Where w_1 is the fresh weight of whole plant and w_2 is the fresh weight of third internode with leaf sheath.

Lodging index (%)

Lodging index (%) = Bending moment/Breaking resistance $\times 100$

Results and Discussion

Rice Yield

A significant improvement in both grain and straw yield of rice was observed with nitrogen and silicon application compared to the control (Table 1). Grain yield ranged from 3021 to 6564 kg ha⁻¹, while straw yield ranged from 3747 to 7263 kg ha⁻¹. The maximum grain (6564 kg ha⁻¹) and straw yield (7263 kg ha⁻¹) were recorded with 75% RDN+ 150 kg of Silicon ha⁻¹ (T₇), which was statistically on par with 100% RDN+ 150 kg of Silicon ha⁻¹(T₆). These treatments were significantly followed by T₈, T₄, and T₅. The highest percentage increase in grain (46%) and straw yield (43%) was obtained with T₇ over the control (T₁). Conversely, the lowest yields were recorded in the treatment receiving absolute control. The increase in grain yield with nitrogen and silicon application can be attributed to the enhancement of yield components. It might be due to the optimum availability of nitrogen, resulting in more synthesis of photosynthesis and a positive source to sink relationship (Zaheen *et al.*, 2006 and Islam *et al.*, 2008). This finding was further supported by strong linear relationships between grain yield and yield attributes: number of panicles m⁻² ($Y = 3628 - 0.703x + 0.010x^2$, $R^2 = 0.99^{**}$), number of grains panicle⁻¹ ($Y =$

$4688 - 83.49x - 9.322x^2$, $R^2 = 0.99^{**}$), and panicle length ($Y = -353.6 + 393.6x - 4.473x^2$, $R^2 = 0.99^{**}$), indicating that 99% of the variation in grain yield was explained by these attributes. Application both silicon and nitrogen changes in the number of tillers during critical growth stages, affecting the morphological characteristics of stems, lignin, and cellulose composition, and lodging resistance, ultimately altering rice yield (Chen *et al.*, 2022). The combined application of silicon fertilizer is beneficial for normal physiological metabolism in rice and significantly promotes the growth of rice (Han *et al.*, 2012). Silicon application can increase the number of productive panicles, grains per panicle, seed setting rate, and thousand grain weight of rice while reducing the number of unfertilized grains, thereby increasing rice yield (Lou *et al.*, 2023). Studies have shown that the nutrient content, effective panicle number, and yield of rice plants under the combined application of nitrogen and silicon fertilizer are higher than those under the application of nitrogen fertilizer or silicon fertilizer alone (Guo *et al.*, 2004).

Lodging parameters

Breaking resistance and Pending movement (g.cm)

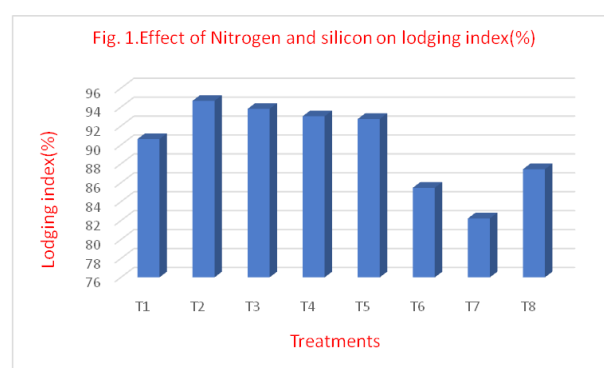
Data presented in Table 2 indicated that breaking resistance and pending movement were significantly highest with 75% RDN+ 150 kg of Silicon ha⁻¹(T₇)(1649 and 1568 g.cm) it is on par with application 100% RDN+ 150 kg of Silicon ha⁻¹(T₆) (1597g.cm and 1558 g.cm) and lowest were recorded with absolute control (896 and 812g.cm). It may be due to lower plant height and internode length. Guo *et al.* (2003) were reported the similar results. In the present study among silicon with RDN application

Table 1. Effect of nitrogen and silicon application on grain and straw yield of rice (kg ha⁻¹)

Treatments	Grain Yield (kg ha ⁻¹)	Straw Yield (kg ha ⁻¹)
T ₁ – Absolute control	3021	3747
T ₂ – Farmers practises	4383	5365
T ₃ – 100% RDN	5058	5718
T ₄ – 75% RDN	5522	6572
T ₅ – 50% RDN	4945	5561
T ₆ – 100% RDN+ 150 kg of Silicon ha ⁻¹	6383	6877
T ₇ – 75% RDN+ 150 kg of Silicon ha ⁻¹	6564	7263
T ₈ – 50 % RDN+ 150 kg of Silicon ha ⁻¹	5338	6480
SEd	121.41	116.57
CD (P = 0.05)	271.56	213.21

Table 2. Effect of nitrogen and silicon application on lodging parameters transplanted rice .

Treatments	Breaking resistance (g.cm)	Bending moment (g.cm)
T ₁ – Absolute control	896	812
T ₂ – Farmers practises	1012	958
T ₃ – 100% RDN	1197	1123
T ₄ – 75% RDN	1221	1136
T ₅ – 50% RDN	1186	1100
T ₆ – 100% RDN+ 150 kg of Silicon ha ⁻¹	1597	1558
T ₇ – 75% RDN+ 150 kg of Silicon ha ⁻¹	1649	1568
T ₈ – 50 % RDN+ 150 kg of Silicon ha ⁻¹	1325	1226
SEd	27	25
CD (P = 0.05)	89	78



75% RDN+ 150 kg of Silicon ha⁻¹ significantly highest breaking resistance and pending movement. It may be due to the thickening of cell wall of the sclerenchyma tissue in the culm and/or shortening.

Lodging index (%)

Out of the three 75% RDN+ 150 kg of Silicon ha⁻¹ (T₇), proved significantly efficient in controlling lodging (82.23) it is on par with 100% RDN+ 150 kg of Silicon ha⁻¹ (T₆) (85.47). Significantly highest lodging index was recorded with T₂ – Farmers practices (90.62%) in (Fig. 1). This is in accordance to the study of Hui *et al.* (2013) where optimum nitrogen input increased basal internode length, breaking resistance and lodging index. 75% RDN+ 150 kg of Silicon ha⁻¹ recorded significantly lowest lodging index. It could be ascribed to the fact that increased silicon content plant has been reported to increase mechanical strength of plant tissue, which resulted in reduced lodging index (Takahashi *et al.*, 1990 and Liang, 1994). Shimoyama (1958) has mentioned that thickness of culm walls and vascular bundles becomes larger when silicon is applied. Silica deposited in these plant sections also contributes to an increase in the mechanical strength of culms. There-

fore, sufficient supply of silicon has an effect on the stability of culms and serves to decrease the risk of lodging.

Conclusion

Considering the influence of optimal nitrogen and silicon applications, it can be suggested that adopting a nutrient management strategy of 75% Recommended Dose of Nitrogen (RDN) combined with 150 kg of silicon per hectare is effective in achieving economically higher grain yields in rice while also reducing lodging. This approach resulted in the highest net returns.

Conflict of Interest- None

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