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# Influence of silicon and nitrogen fertility rates on rice (*Oryza sativa* L.) yield and uptake

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**Abstract**
Negative impacts of excessive nitrogenous fertilizers could be minimized by the use of silicon. In order to study the effects of silicon and nitrogen on rice yield and uptake, a field experiment was conducted in two phases. Initially Si concentration in rice index leaves and available silicon status accessed and found low status of available silicon (73.62 to 96.41 kg ha$^{-1}$) content. As well as, the mean Si concentration in rice index leaves also low, ranged from 1.54 to 3.15 per cent with an overall mean of 2.48 per cent. The grain yields ranged from 2653 to 6860 kg ha$^{-1}$ with a mean of 5624 kg ha$^{-1}$ and both were exerted a significant positive correlation (r = 0.55**). Based on these results, second phase of field experiment was conducted with sixteen combinations of Si and N with high Si (JGL-3855) and low Si (RNR-2354) content genotypes in strip plot design. Conjunctive application of N and Si to both genotypes, JGL-3855 recorded significantly higher grain and straw yields, nutrient content and total uptake compared to RNR-2354. Among the different combinations of Si and N, application of 160 kg N + 600 kg Si ha$^{-1}$ recorded significantly higher grain and straw yields, nutrient concentration and total uptake over control $N_0 + Si_0$ and was on par with $N_{160} + Si_{400}$, $N_{160} + Si_{200}$, $N_{120} + Si_{600}$, $N_{120} + Si_{400}$ and $N_{120} + Si_{200}$.

**Keywords:** Silicon, nitrogen, rice genotypes, nutrient concentration, total uptake

## Introduction
Significant achievement of production and productivity in rice crop due to the introduction of high yielding varieties and chemical fertilizers in sixties, and their wide spread of adoption we accomplished self-sufficiency in nineties. This gigantic achievement compelled with intensive farming over a period of time and crops has set a decline trend in yields as well as deterioration in soil productivity even with optimum use of fertilizers in post-green revolutionary period. This situation necessitates adoption of advanced soil fertility techniques for narrowing the yield gap and to broken the seal on yield by acquiring new eco-friendly technologies which can boost the present rice yield by 15-20% with present level of input use for growing population demand.

Response of rice grown soils of different regions to N application is more wherever soils are low in available nitrogen. This excessive nitrogen application may limit the crop yield because of lodging, shading and susceptibility to pests and diseases. These effects could be minimized by the use of Silicon (Munir *et al*. 2003) [9], where the nature has provided bountiful of resources and it would be a possible source to meet the requirement for sustainable farming. Silicon is the only element, which does not damage plants upon its excess accumulation and reduce the concentration of toxic elements like Fe, Mn and other heavy metals. It also improves P metabolism and increase the yield attributing parameters. High accumulation of Si in rice has been demonstrated to be necessary for healthy growth and stable production. For this reason, Si has been recognized as an “agronomically essential element” (Ma *et al.* 2001) [7] and rice genotypes are known to differ with respect to acquisition, translocation and accumulation of silicon (Winslow *et al.* 1997) [15].

However, intensification of production system calls for the best nutrient management practices, which could restore soil fertility and enhance productivity. In order to achieve an intensive production of grain with good quality, this experiment envisages the use of different levels of silicon along with nitrogen in judicious combinations to sustain soil productivity and crop production.

**Materials and Methods**

Experiment was carried out in two stages, initially survey work carried out to assess the concentration of silica in the index leaves of rice plant from varietal display plots at Agricultural Research stations throughout Telangana region. The collected leaves were analyzed for plant Si concentration according to Saito *et al*. (2005) [11] and representative soil samples also estimated according to standard procedure outlined by Korndorfer *et al*. (2001) [6]. Finally, grain yield of various display plots were recorded at harvest and were correlated with silica content in rice index leaves.

The field experiment was conducted at RARS, Jagtial, Karimnagar, Telangana and the soils are sandy clay loam in texture, neutral in reaction, non-saline, non- calcareous, low in organic carbon, low in available nitrogen, medium in phosphorus and potassium contents. Evaluation of all genotypes analyzed and two promising varieties one with high (JGL-3855) and another with low (RNR-2354) Si content were selected for field experiment with four levels of Nitrogen (0, 80, 120 and 160 kg ha$^{-1}$) and four levels of Silicon (0, 200, 400 and 600 kg ha$^{-1}$) consisting of sixteen treatments, replicated thrice in strip-plot design. Recommended doses of phosphorus and potassium (60 and 40 kg ha$^{-1}$) were applied uniformly to all treatments in the form of single super phosphate (SSP) and muriate of potash (MOP) as basal. Nitrogen was applied in the form of urea in 3 equal splits (1/3 basal, 1/3 at active tillering stage and 1/3 at panicle initiation stage). Silica was applied as basal in the form of silica gel and composition of gel was 99.71, 0.02, 0.03, 0.1, 0.09, 0.01 and 0.02 % of $SiO_2$, $Na_2O$, $Fe_2O_3$, $Al_2O_3$, $TiO_2$, CaO and $ZrO_2$. Soil samples were analyzed for nitrogen, phosphorus and potassium by following standard methods (AOAC, 1980) [1], whereas grain and straw samples were analyzed for N, P, K as described by Piper (1966) [10]. The analysis of variance for grain and straw yield, grain and straw concentration of N, P, K and Si, and total uptake was worked out by feeding the replicated data into the INDOSTAT software.

**Results and Discussion**

Among the various locations of the present study (Table 1), the Si content in the index leaf of the promising varieties at tillering ranged from 1.50 to 3.20 (mean value of 2.50) per cent at RARS, Jagtial, 1.60 to 3.15 (mean value of 2.47) per cent at RARS, Warangal, 1.49 to 3.20 (mean value of 2.51) per cent at ARI, Rajendranagar and 1.55 to 3.06 (mean value of 2.43) per cent at RS & RRS, Rudrur. The Si content of index leaves were slightly more (2.51%) at ARI, Rajendranagar followed by RARS, Jagtial as (2.50 %), RARS, Warangal was (2.47 %) and RS & RRS, Rudrur has (2.43 %). The variation in Si concentration in plant species was due to the difference in efficiency of plant roots for Si acquisition (Takahashi and Hino, 1978) [13].

The yields of promising rice varieties of Telangana region were recorded and presented in Table (1). The overall yield ranged from 2653 kg ha$^{-1}$ to 7198 kg ha$^{-1}$ with a mean of 5624 kg ha$^{-1}$ and this variation in yields were might be due to genotypic variation and also due to variations in climatic conditions of different locations Telangana region. The variety *Chitti muthyalu* from ARI, Rajendranagar yielded the lowest (2653 kg ha$^{-1}$) and JGL-18065 from RARS, Jagtial produced the highest grain yield of 7198 kg ha$^{-1}$. The variation in yields among the varieties could be due to the reason that certain genotypes are more efficient than others in the accumulation of Si as revealed by Winslow, (1992) [14]. The correlation coefficients between different genotypes for silica concentration and their yields (kg ha$^{-1}$) were presented in Table (2) and it showed positive and significant correlation (r=0.55**).

Among the soils studied from three different agro climatic zones of Telangana region research station soils were sandy clay loam to clayey texture, slightly alkaline and non-saline. Soils of rice display plots of different locations at different stages were low in available nitrogen (196.7 to 237.25 kg ha$^{-1}$); high in available phosphorus (26.48 to 37.82 kg ha$^{-1}$) and medium in available potassium (165.22 to 265.92 kg ha$^{-1}$). The available Si content of the rice grown display plots of Telangana region under study ranged from 79.06 to 94.19, 80.73 to 96.41 and 73.62 to 87.53 kg SiO2 ha$^{-1}$ at initial, tillering and harvest stage respectively. Among all the soils of the rice grown plots studied, it was observed that the soils at ARI, Rajendranagar recorded highest available Si with corresponding values of 94.19, 96.41, 87.53 kg ha$^{-1}$ at the respective stages. While, the soil at RS & RRS, Rudrur recorded the lowest Si content with the values being 79.06, 80.73, 73.62 kg ha$^{-1}$ at initial, tillering and at harvest respectively (Table 3). The available Si content was observed to be low to medium in three different agro climatic zones of Telangana region. This could be attributed to the depletion of available Si due to continuous rice cultivation, low solubility and slow dissolution kinetics of soil Si (Drees *et al.* 1989) [5].

From the Fig (1), it was observed that both the varieties as well as the nutrient levels showed a significant influence on rice grain and straw yields. Among the varieties, JGL-3855 showed significantly higher grain yield (6779 kg ha$^{-1}$) as well as straw yield (8949 kg ha$^{-1}$) compared to RNR-2354 which recorded grain yield of 6460 kg ha$^{-1}$ and straw yield of 8530 kg ha$^{-1}$. According to Agarie *et al.* (1992) [2], the maintenance of photosynthetic activity due to Si fertilization could be one of the reasons for increased dry matter production.

Among different silicon and nitrogen levels, $N_{160}$ + $Si_{600}$ recorded highest grain yield of 7180 kg ha$^{-1}$ and was at par with other treatments which received N @ 120 and 160 kg ha$^{-1}$ along with silicon levels. This may be influenced by the conjunctive application of Si and N, which decreased per cent spikelet sterility with increased Si levels. Such effect can be explained by improvement of plant architecture (Deren *et al*. 1994) [4]. N applied @ 80, 120 and 160 kg ha$^{-1}$along with different levels of Si resulted an increase of 9.7, 10.8 and 10.8 % in grain yields compared to N applied alone without any Si. The treatments received no nitrogen, but received only Si @ 200, 400 and 600 kg ha$^{-1}$ were considered, it was observed that the rice grain yields increased by 5.60, 9.69 and 13.1% over the control. Application of silicon increased rice yield mainly due to the supply of plant available Si and not due to supply of other nutrients as per Synder *et al.* (1986) [12].

Among the varieties (Fig. II), JGL-3855 recorded significantly higher N, P, K and Si concentration in straw at harvest (1.02, 0.09, 1.14 and 4.32%) as well as in grain (1.24, 0.13, 0.49 and 1.26%) compared to RNR-2354 (Table 4 and 5) which recorded corresponding lower N, P, K and Si contents in straw (0.99, 0.08, 1.12 and 4.29 %) and in grain (1.19, 0.10, 0.48 and 1.23). Among different N and Si treatments, $N_{160}$ + $Si_{600}$ recorded significantly highest concentration of N, P, K and Si in straw 1.13, 0.13, 1.28 and 4.43 % and 1.35, 0.15, 0.58 and 1.35% in grain which was at par with other treatments *viz.*, $N_{120}$ + $Si_{200}$, $N_{120}$ + $Si_{400}$, $N_{120}$ + $Si_{600}$, $N_{160}$ + $Si_{400}$ and $N_{160}$ + $Si_{400}$. Usually, excessive levels of certain nutrients in soil hinder uptake of other nutrients by plants, leading to deficiencies. This stresses the importance of

Si and N ratios as a key factor in the multi-nutrient factor balance concept, which states that all the nutrients must be well-balanced for the most economic production of rice. The critical levels for N and Si at different growth stages has mainly influenced by acquisition and translocation capacity of rice plants (Malidareh *et al.* 2009) [8].

From the Fig (III), it was observed that the total uptake of nutrients *viz.*, N, P, K, and Si was significantly influenced by the varieties, different N and Si levels, as well as their interaction effects. Among the varieties, it was observed that JGL-3855 recorded significantly higher total uptake of N (205.96 kg ha$^{-1}$), P (21.16 kg ha$^{-1}$), K (148.53 kg ha$^{-1}$) and Si to the extent of 321.5 kg ha$^{-1}$, compared to RNR-2354 which recorded N, P, K, and Si to the extent of 189.91, 18.17, 138.89 and 300.6 kg ha$^{-1}$. Among the different levels of N and Si treatments, $N_{160}$ + $Si_{600}$ recorded significantly higher total N (241.55 kg ha$^{-1}$), total P (28.79 kg ha$^{-1}$), total K (181.07 kg ha$^{-1}$) and total Si to the extent of 364.83 kg ha$^{-1}$ and was at par with many other treatments *viz.*, $N_{120}$ + $Si_{200}$, $N_{120}$ + $Si_{400}$, $N_{120}$ + $Si_{600}$, $N_{160}$ + $Si_{200}$ and $N_{160}$ + $Si_{400}$. It was observed that with increase in N and Si levels the total nutrient uptake also increased. The treatments which received nitrogen without Si showed a very lower response in nutrient uptake compared to the treatments receiving both N and Si together. It was reported that silicon is not much mobile element in plants; therefore a continued supply of this element would be required particularly for healthy and productive development of plant during all growth stages (Aziz *et al.* 2002) [3].

**Table 1:** Mean values of Si content in index leaves and Yield at different locations of the Telangana State

| S. No | Location | No of Varieties screened | Yield (kg ha$^{-1}$) | | Silicon (%) | |
|---|---|---|---|---|---|---|
| | | | Range | Mean | Range | Mean |
| 1 | RARS, Jagtial | 41 | 2886-7198 | 5845 | 1.50-3.20 | 2.50 |
| 2 | RARS, Warangal | 32 | 2693-6831 | 5871 | 1.60-3.15 | 2.47 |
| 3 | ARI, Rajendra nagar | 48 | 2653-6860 | 5646 | 1.49-3.20 | 2.51 |
| 4 | RS&RRS, Rudrur | 12 | 4399-5950 | 5069 | 1.55-3.06 | 2.43 |
| Mean | | 133 | 3157-6709 | 4933 | 1.54-3.15 | 2.48 |

**Table 2:** Correlation coefficients of various genotypes silica concentration in index leaves and their grain yields

| Parameters | Yield (kg/ha) | Si (%) |
|---|---|---|
| Yield ( kg ha$^{-1}$ ) | 1.00 | 0.55** |
| Si (%) | | 1.00 |

**Table 3:** Salient characteristics of rice grown varietal display soils at Telangana during different crop growth stages

| | Particulars | ARI (Rajendranagar) | | | RARS (Jagtial) | | | RARS (Warangal) | | | RS & RRS (Rudrur) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Initial | Tillering | Harvest | Initial | Tillering | Harvest | Initial | Tillering | Harvest | Initial | Tillering | Harvest |
| 1) | Physical properties | | | | | | | | | | | | |
| a) | Mechanical composition (%) | | | | | | | | | | | | |
| | i) Sand | 39.4 | | | 52.1 | | | 50.6 | | | 55.3 | | |
| | ii) Silt | 18.1 | | | 16.5 | | | 18.3 | | | 19.5 | | |
| | iii) Clay | 42.3 | | | 30.2 | | | 30.8 | | | 20.4 | | |
| | iv) Textural class | Clay | | | Sandy clay loam | | | Sandy clay loam | | | Sandy loam | | |
| 2) | Physico-chemical properties | | | | | | | | | | | | |
| a) | Soil reaction (pH) | 8.06 | 8.08 | 8.05 | 7.73 | 7.77 | 7.75 | 7.85 | 7.88 | 7.83 | 8.02 | 8.03 | 8.00 |
| b) | Electrical conductivity (d Sm$^{-1}$) | 0.31 | 0.33 | 0.32 | 0.27 | 0.27 | 0.26 | 0.16 | 0.17 | 0.17 | 0.14 | 0.15 | 0.15 |
| c) | Organic carbon (%) | 0.68 | 0.70 | 0.69 | 0.52 | 0.55 | 0.51 | 0.46 | 0.49 | 0.48 | 0.40 | 0.43 | 0.40 |
| 3) | Chemical properties | | | | | | | | | | | | |
| | Available Macro nutrients | | | | | | | | | | | | |
| a) | Nitrogen (kg N ha$^{-1}$) | 215.63 | 237.25 | 223.74 | 203.18 | 214.07 | 201.35 | 219.47 | 224.31 | 215.49 | 196.79 | 207.36 | 201.58 |
| b) | Phosphorus (kg $P_2O_5$ ha$^{-1}$) | 30.67 | 34.03 | 31.52 | 31.57 | 32.16 | 29.72 | 27.53 | 30.17 | 26.48 | 31.64 | 37.82 | 33.51 |
| c) | Potassium (kg $K_2O$ ha$^{-1}$) | 250.34 | 265.92 | 253.26 | 187.64 | 201.39 | 197.49 | 221.36 | 234.75 | 219.11 | 165.22 | 178.23 | 169.46 |
| 4) | Silicon (kg $SiO_2$ ha$^{-1}$) | 94.19 | 96.41 | 87.53 | 86.80 | 87.53 | 80.16 | 81.72 | 83.18 | 77.51 | 79.06 | 80.73 | 73.62 |

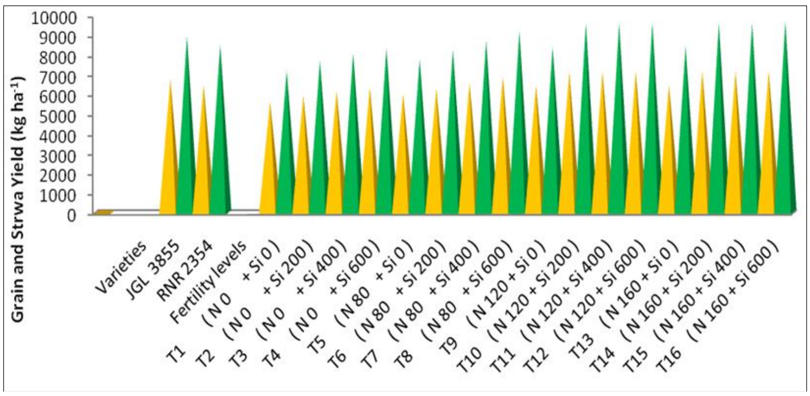


**Fig 1:** Influence of Si and N levels on grain and straw yields of rice genotypes

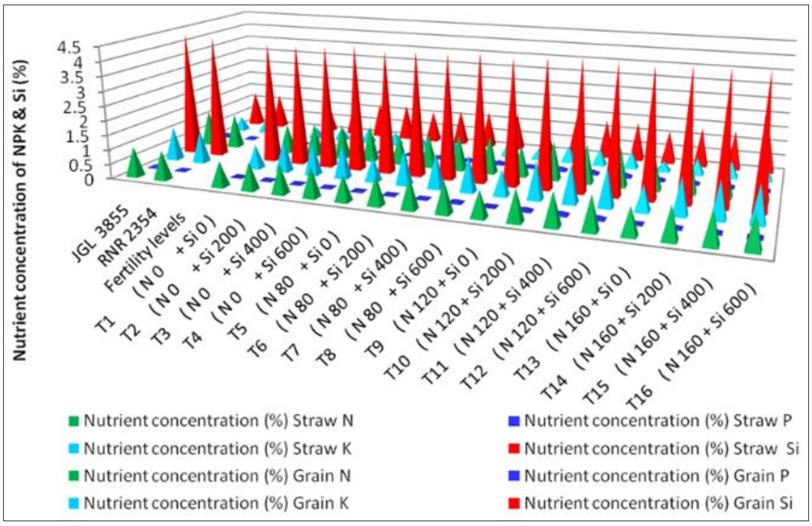


**Fig 2:** Nutrient concentration of NPK & Si (%) at harvest influenced by Si and N

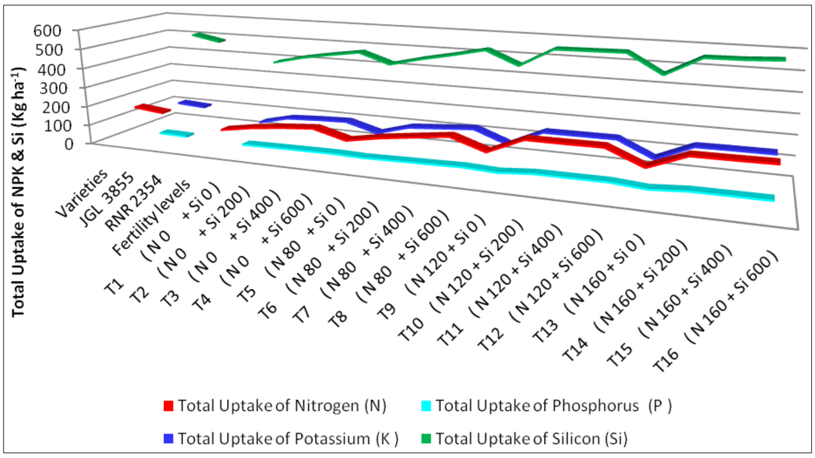


**Fig 3:** Si and N nutrition on total uptake of NPK & Si (kg ha$^{-1}$) at harvest

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