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Response of Nitrogen and Silica on Growth and Yield of Paddy (*Oryza sativa* L.) Variety Improved White Ponni

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ABSTRACT: Rice is one of the leading food crops in the world and the main staple food in India that plays important role in agricultural and economic level. Silicon (Si) is the most abundant element in the earth's crust and improves the erectness of leaves and allows higher light transmittance in and above plant canopies and thus improves photosynthesis. The present study is conducted with interaction of N × Si to increase the productivity potentials in rice genotype. A pot experiment was conducted at glasshouse, TNAU, Coimbatore to assess the response of nitrogen and silica on growth and yield traits of paddy. The treatments comprised of the two factors, Nitrogen and Silica with three replications. The growth parameter likes plant height, number of tillers per plant and total dry matter production were recorded at various stages and yield traits were recorded at harvest stage. Plant height, number of tillers and total dry matter production were higher in N_2S_2. The highest grain and straw yield were recorded in treatment with (N_2S_2)150 kg ha^{-1} of urea + 200 kg ha^{-1} of Calcium silicate (52.3 and 45.7g pot^{-1}) in the pot experiment.

Keywords: Nitrogen, urea, silica, calcium silicate, grain yield and straw yield.

INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food crop for half of the world's population and one of the world's most significant crops. World population is expected to reach 9 billion by 2050 in the increasing climatic change conditions which adds additional demand on increasing productivity. Farmers must produce increased grain productivity with enhanced quality to meet consumer demand in the coming years to ensure food security (Magdoff *et al.*, 2009). Ever increasing population is a major threat for attaining food security and to achieve that, nutrient management can be an interesting option as it improves rice production and productivity. Most of the farmers use only major nutrients like nitrogen, phosphorus and potassium fertilizers but at present condition, paddy cultivation needs to be increased to feed world population. Hence, application of beneficial nutrients could be considered as a strategy to increase productivity (Siregar *et al.*, 2021). Rice requires a considerable amount of silicon for growth (Tamai and Ma, 2008; Artyszak *et al.*, 2018). Nitrogen (N) is a nutrient that is frequently used as a limiting nutrient in crop production (Dhillon *et al.*, 2018). Cereals, such as rice, accounted for over half of all nitrogen fertilizer used worldwide (Vanotti *et al.*, 2019). Determining grain yield through application of N fertilizer is the one of the favorable outcome in enhancing number of tillers per plant (Qiao *et al.*, 2011; Ullah *et al.*, 2018).

Silicon has been linked to a number of positive benefits in rice plant physiology. Appropriate silicon (Si) intake has been shown to boost the tolerance of agronomic crops, particularly in rice, to both abiotic and biotic stress. Silicon is a beneficial micronutrient for rice, as it strengthens plant health (Meena *et al.*, 2014; Wang *et al.*, 2019; Garg *et al.*, 2020). Rice growth and productivity are significantly reduced when Si is absent, owing to lower fertility as it is well known for its silicon accumulating capacity (Ma and Takahashi, 2002; Mbaraka *et al.*, 2021). Plants uptake silica in the form of Mono-silicic acid ($Si(OH)_4$) and increases the concentration of Phytoliths, which in turn bind with many other biological compounds and enhances the toughness and strength of the cell wall (Al-Shahmani and Al-Juthery, 2021; Sharma *et al.*, 2016). Application of nitrogenous fertilizers with silica significantly increases rice production (Ma *et al.,* 1989 and Mauad *et al.,* 2003). Due to a synergistic effect, the application of Si has the potential to raise the optimum N rate, resulting in enhancing productivity of lowland rice field (Ho *et al.,* 1980; Saleh *et al.,* 2020). Silicon has several potential benefits and its sufficient supply in soil is required for healthy growth and high productivity in rice crop (Singh *et al.,* 2006; Klotzbücher *et al.,* 2018). Si fertilizers are applied to crops in several countries for increased productivity and sustainable production and high silica uptake has been shown increase plant growth rate and yield. However, many positive effects of Si are most apparent in cases of biotic and abiotic stresses (Datnoff *et al.,* 2005; Devanur, 2015; Sipahutar *et al.,* 2021; Sun *et al.,* 2021). Phytoliths formed in Si treated plants provide mechanical strength and rigidness to plant parts and act as defence system against insects, pests, fungal infestations and as well as improve water status, photosynthetic rate, plant growth and yield (Zargar *et al.,* 2019; Wijayanti *et al.,* 2021; Anggria *et al.,* 2021). With this background, the present study was taken up to study the interactive effect of N and Si on rice growth and productivity and sustainable agriculture.

MATERIALS AND METHODS

The pot culture experiment was conducted at glasshouse, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in factorial completely randomized block design and replicated thrice. The experimental treatments were N_0 –without urea, N_1–100 kg ha^{-1} urea, N_2–150 kg ha^{-1} urea, N_3–175 kg ha^{-1} urea, S_0–0 kg ha^{-1} of Calcium silicate, S_1–150 kg ha^{-1} of Calcium silicate, S_2–200 kg ha^{-1} of Calcium silicate and S_3–250 kg ha^{-1} of Calcium silicate. The experimental soil belongs to Noyyal soil series taxonomically grouped as Clay loamy, mixed iso-hyperthermic, *Typic haplustalf*. The composite soil samples were collected initially from the experimental field and had been subjected to analysis of initial physio-chemical characteristics. The soil was clay loam in texture with a pH range of 7.4, EC 0.60 dSm^{-1}, bulk density 1.26 Mg m^{-3}, particle density 2.53 Mg m^{-3} and total porosity (50%). The initial soil fertility status revealed that the experimental soil has low available N (265 kg ha^{-1}), medium available P (20 kg ha^{-1}) and high available K (575 kg ha^{-1}) status.

Data collection. The growth parameters like plant height, number of tillers per plant and total dry matter production were measured at 30, 60, 90 days after transplanting (DAT) and harvest stage and yield attributes (grain yield, straw yield and harvest index) at harvest stage.

The plant height was measured from the base of the leaf to tip of the longest leaf stretched and the mean value was expressed in centimeter at 30, 60, 90 days after transplanting (DAT) and harvest stage.

Tiller population was counted from the labeled plants and is denoted as number of tillers m^{-2} at 30, 60, 90 days after transplanting (DAT) and harvest stage.

Samples were shade dried and then oven dried at 60°C for 72 hrs. The dry weight of the samples were used for the estimation of dry matter production and it is expressed in g pot^{-1} at 30, 60, 90 days after transplanting (DAT) and harvest stage.

The harvested grains from the pot was threshed, cleaned, sun dried, weighed and are symbolized in terms of g pot^{-1}.

The paddy straw collected from the pot was sun dried, weighed and is represented as g pot^{-1}.

Harvest index is the ratio of harvested grain yield to total shoot dry matter and this can be used as a measure of reproductive efficiency.

Harvest index (%) = Economic yield /Biological yield × 100

The results of growth and yield parameters were statistically analyzed as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The interactive effect of nitrogen and silica on plant height was furnished in the Table 1. The application of fertilizers significantly improved the plant height. Highest plant height were recorded in the treatment T_{11}-N_2S_2 (33.8cm, 59.4cm, 109.4cm and 112.7cm respectively) followed by the treatment T_8- N_1S_3 (31.4cm, 54.2cm, 101.8 cm and 104.4cm respectively) on 30, 60, 90 days after transplanting (DAT) and harvest stage. The lowest plant height were recorded in the treatment T_{16}-N_3S_3 (15.1cm, 31.7cm, 67.4cm and 69.1cm respectively) and the treatment T_1-N_0S_0 (15.5cm, 33.7cm, 68.2 cm and 70.6 cm respectively). Application of nitrogen and silica improves plant nutrient content and increases plant height. The present findings were supported by Singh *et al.,* (2006) that increased plant height was due to increased level of nitrogen and different silicon. Application of 120 kg Si ha^{-1} significantly influenced growth of rice when compared with 60 kg Si/ha. Shuhei *et al.,* (2009) showed silicate fertilizers increased vegetative growth in paddy. Yogendra *et al.,* (2014) observed that difference in paddy height was more favorable in treatments of calcium silicate. Gerami *et al.,* (2012); Cuong *et al.,* (2017) revealed that N had more considerable effect than Si on grain yield because of its increased growth attributes. Malav *et al.,* (2015) reported that increased level of silicon improved plant height in rice. This present study suggested by Pati *et al.,* (2016); Anggria *et al.,* (2021) that the Si fertilizer application could increase vegetative stage growth.

Table 1: Response of Nitrogen and Silica on plant height at 30, 60, 90 DAT and Harvest of IWP (cm).

	30 DAT					60 DAT					90 DAT					Harvest				
Treatment	S_0	S_1	S_2	S_3	**Mean**	S_0	S_1	S_2	S_3	**Mean**	S_0	S_1	S_2	S_3	**Mean**	S_0	S_1	S_2	S_3	**Mean**
N_0	15.5	19.7	20.1	20.8	19.0	33.7	38.6	39.5	40.7	38.1	68.2	75.1	76.2	77.8	74.3	70.6	78.8	79.6	80.4	77.3
N_1	21.7	22.9	27.7	31.4	25.9	41.3	42.1	48.2	54.2	46.4	78.6	79.9	86.9	101.8	86.8	81.7	82.9	88.7	104.4	89.4
N_2	25.6	26.8	33.8	29.3	28.8	46.2	47.8	59.4	51.8	51.3	84.9	85.2	109.4	94.4	93.4	86.7	87.5	112.7	96.3	95.8
N_3	24	23.9	24.5	15.1	21.8	43.5	44.7	45.8	31.7	41.4	81.6	82.4	83.8	67.4	78.8	83.7	84.2	85.5	69.1	80.6
Mean	21.7	23.3	26.5	24.1		41.1	43.3	48.2	44.6		78.3	80.6	89.0	85.3		80.6	83.3	91.6	87.5	
Factors	**S**	**N**	**S*N**			**S**	**N**	**S*N**			**S**	**N**	**S*N**			**S**	**N**	**S*N**		
SEd	0.6	0.8	1.2			1.1	1.6	2.2			2.1	3.0	4.3			2.1	3.0	4.3		
CD	1.3	1.8	2.6			2.4	3.4	4.8			4.6	6.6	9.2			4.6	6.5	9.2		

N_0 –without urea	N_2–150 kg ha^{-1} urea	S_0–0 kg ha^{-1} of Calcium silicate	S_2–200 kg ha^{-1} of Calcium silicate
N_1– 100 kg ha^{-1} urea	N_3 – 175 kg ha^{-1} urea	S_1– 150 kg ha^{-1} of Calcium silicate	S_3–250 kg ha^{-1} of Calcium silicate

The effect of Nitrogen and Si fertilizer on plant growth parameter as number of tillers per plant is presented in Table 2. Similarly, highest number of tillers per plant were recorded in the treatment T_{11}- N_2S_2 (15.1, 22.5, 27.8 and 30.4 respectively) followed by the treatment T_8-N_1S_3 (12.8, 18.8, 22.4 and 26.4 respectively) on 30, 60, 90 days after transplanting (DAT) and harvest stage. The least number of tillers per plant were recorded in the treatment T_{16}- N_3S_3 (5.1, 7.1, 8.8 and 9.8 respectively) and the treatment T_1- N_0S_0 (5.7, 7.7, 9.8 and 10.8) respectively on 30, 60, 90 days after transplanting (DAT) and harvest stage. Similar findings were reported by Singh *et al.,* (2006); Mahendran *et al.,* (2021); Anggria *et al.,* (2021) that the application of increased level of nitrogen and different silicon levels significantly increased tiller numbers in rice. Malav *et al.,* (2015) revealed that the maximum number of tillers was recorded in 300 mg kg^{-1} soil silicon over the control. Prakash and Chandrashekhar, (2011); Cuong *et al.,* (2017) also observed that after transplanting, Si fertilization increased the numbers of tillers in paddy.

Table 2: Response of Nitrogen and Silica on Number of tillers $plant^{-1}$ at 30, 60, 90 DAT and Harvest of IWP.

	30DAT					60DAT					90DAT						Harvest			
Treatment	S_0	S_1	S_2	S_3	**Mean**	S_0	S_1	S_2	S_3	**Mean**	S_0	S_1	S_2	S_3	**Mean**	S_0	S_1	S_2	S_3	**Mean**
N_0	5.7	6.1	6.5	7.1	6.3	7.7	8.2	8.7	9.1	8.4	9.8	10.4	11.8	12.4	11.1	10.8	11.9	12.4	13.7	12.2
N_1	7.5	7.6	10.1	12.8	9.5	9.8	10.1	15.1	18.8	13.4	13.8	14.8	20.5	22.4	17.8	15.5	16.8	24.5	26.4	20.8
N_2	9.1	9.8	15.1	10.7	11.1	13.7	14.8	22.5	17.4	17.1	18.1	19.5	27.8	21.8	21.8	21.7	22.4	30.4	25.9	25.1
N_3	7.8	8.1	8.8	5.1	7.4	10.5	11.8	12.7	7.1	10.5	15.2	16.9	17.8	8.8	14.6	18.9	19.4	20.7	9.8	17.2
Mean	7.5	7.9	10.1	8.9		10.4	11.2	14.7	13.1		14.2	15.4	19.4	16.3		16.7	17.6	22	18.9	
Factors	**S**	**N**	**S*N**			**S**	**N**	**S*N**			**S**	**N**	**S*N**			**S**	**N**	**S*N**		
SEd	0.2	0.3	0.4			0.3	0.4	0.6			0.4	0.5	0.8			0.4	0.6	0.9		
CD	0.5	0.7	0.9			0.6	0.9	1.3			0.8	1.2	1.7			1.0	1.4	2.1		

N_0 –without urea	N_2–150 kg ha^{-1} urea	S_0–0 kg ha^{-1} of Calcium silicate	S_2–200 kg ha^{-1} of Calcium silicate
N_1– 100 kg ha^{-1} urea	N_3 – 175 kg ha^{-1} urea	S_1– 150 kg ha^{-1} of Calcium silicate	S_3–250 kg ha^{-1} of Calcium silicate

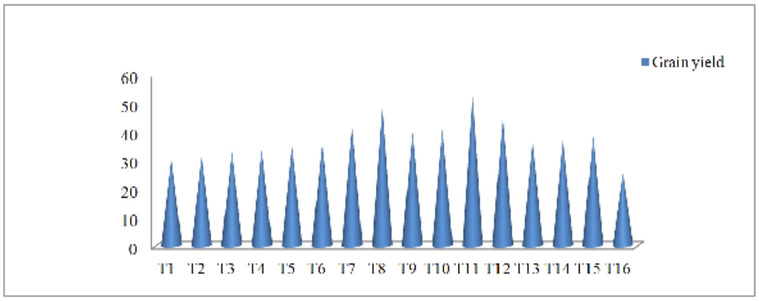
Dry matter production was directly correlated with yield was given in the Table 3. The highest dry matter production were recorded in the treatment T_{11}-N_2S_2 (24.4, 32.5, 42.9 and 51.4 g $plant^{-1}$ respectively) followed by the treatment T_8-N_1S_3 (21.5, 29.4, 39.5 and 46.4 g $plant^{-1}$ respectively) on 30, 60, 90 days after transplanting (DAT) and harvest stage. The lowest dry matter production were observed in the treatment T_{16} - N_3S_3 (7.4, 10.4, 18.4 and 25.4 g $plant^{-1}$ respectively) and T_1-N_0S_0 (7.8, 11.7, 15.1 and 28.8 g $plant^{-1}$ respectively) at 30, 60, 90 DAT and harvest stage. Singh *et al.,* (2006) reported that the increase in dry matter production was due to increased level of nitrogen and different silicon than control. Shuhei *et al.,* (2009); Mahendran *et al.,* (2021) reported that the silicate fertilizers increased dry matter accumulation in paddy. Yogendra *et al.,* (2014) observed that the increased dry matter yield through application of calcium silicate.

The results revealed that the grain yield and straw yield were recorded highest in the treatment T_{11}-N_2S_2 (52.3 and 45.7g pot^{-1} respectively) followed by the treatment T_8 -N_1S_3 (48.5 and 40.4g pot^{-1} respectively). The lowest grain yield and straw yield were recorded in T_{16} - N_3S_3 (25.4 and 18.4 g pot^{-1} respectively) and the treatment T_1 - N_0S_0 (30.2 and 21.8 g pot^{-1} respectively) (Fig. 1, 2). However, there was no significant difference in the harvest index of paddy by fertilization of nitrogen and silica (Fig. 3). Singh *et al.,* (2006) reported that the application of different levels of nitrogen and silicon significantly improved grain yield. Hyun-Hwoi *et al.,* (2020) reported that the different silicon levels also influenced the yield of grain and straw along with the application of highest level of nitrogen, which might be attributed due to synergistic effect. Similar reports were reported by Shuhei *et al.,* (2009) that silicate fertilizers significantly increased grain yield in paddy. Similar results were also observed by Korndorfer *et al.,* (2005) that increased Si fertilization under flooded condition increased the grain and straw yield in rice. Li *et al.,* (2011) showed that application of calcium silicate increased grain yield and straw yield in paddy with supply of available Si. Similar findings were also reported by Datnoff *et al.,* (2005); Gerami *et al.,* (2012); Gautam *et al.,* (2016); Wang *et al.,* (2019); Sharma *et al.,* (2021); Anggria *et al.,* (2021).

Table 3: Response of Nitrogen and Silica on Total Dry matter production at 30, 60, 90 DAT and Harvest of IWP(g pot^{-1}).

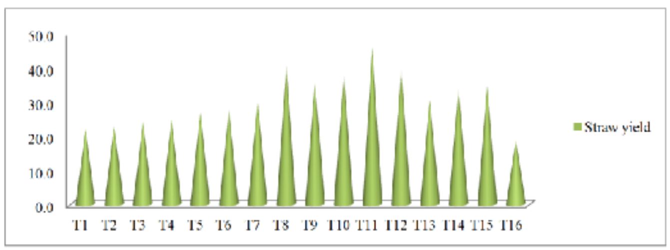
	30DAT					60DAT					90DAT					Harvest				
Treatment	**S_0**	**S_1**	**S_2**	**S_3**	**Mean**	**S_0**	**S_1**	**S_2**	**S_3**	**Mean**	**S_0**	**S_1**	**S_2**	**S_3**	**Mean**	**S_0**	**S_1**	**S_2**	**S_3**	**Mean**
N_0	7.8	8	8.7	9.1	8.4	11.7	14.5	16.9	17.5	15.1	19.8	21.7	23.9	25.5	22.7	28.8	32.1	34.8	35.8	32.8
N_1	9.8	10.8	18.1	21.5	15.0	18.4	19.1	26.5	29.4	23.3	28.7	29.9	36.6	39.5	33.6	36.9	38.4	43.2	46.4	41.2
N_2	14.1	15.8	24.4	19.8	18.5	24.7	25.4	32.5	27.8	27.6	34.4	35.7	42.9	37.4	37.6	41.9	42.4	51.4	44.7	45.1
N_3	11.8	12.2	13.7	7.4	11.2	20.5	21.7	22.5	10.4	18.7	30.7	31.5	33.8	18.4	28.6	39.7	40.1	40.9	25.4	36.5
Mean	10.8	11.7	16.2	14.4		18.8	20.1	24.6	21.2		28.4	29.7	34.3	30.2		36.8	38.2	42.5	38.0	
Factors	**S**	**N**	**S*N**			**S**	**N**	**S*N**			**S**	**N**	**S*N**			**S**	**N**	**S*N**		
SEd	0.3	0.5	0.7			0.5	0.8	1.0			0.7	1.1	1.5			0.9	1.2	1.7		
CD	0.7	1.0	1.3			1.1	1.6	2.3			1.6	2.3	3.2			1.9	2.6	3.7		

N_0 –without urea	N_2–150 kg ha^{-1} urea	S_0–0 kg ha^{-1} of Calcium silicate	S_2–200 kg ha^{-1} of Calcium silicate
N_1– 100 kg ha^{-1} urea	N_3 – 175 kg ha^{-1} urea	S_1– 150 kg ha^{-1} of Calcium silicate	S_3–250 kg ha^{-1} of Calcium silicate



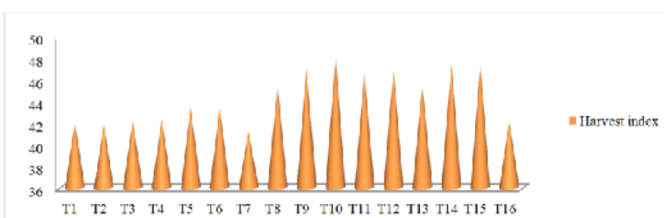
T_1 – N_0S_0	T_5– N_1S_0	T_9– N_2S_0	T_{13}– N_3S_0
T_2– N_0S_1	T_6– N_1S_1	T_{10}– N_2S_1	T_{14}– N_3S_1
T_3– N_0S_2	T_7– N_1S_2	T_{11}– N_2S_2	T_{15}– N_3S_2
T_4– N_0S_3	T_8– N_1S_3	T_{12}– N_2S_3	T_{16}– N_3S_3

Fig. 1. Response of Nitrogen and Silica on grain yield in IWP.



T_1 – N_0S_0	T_5– N_1S_0	T_9– N_2S_0	T_{13}– N_3S_0
T_2– N_0S_1	T_6– N_1S_1	T_{10}– N_2S_1	T_{14}– N_3S_1
T_3– N_0S_2	T_7– N_1S_2	T_{11}– N_2S_2	T_{15}– N_3S_2
T_4– N_0S_3	T_8– N_1S_3	T_{12}– N_2S_3	T_{16}– N_3S_3

Fig. 2. Response of Nitrogen and Silica on straw yield in IWP.



T_1 – N_0S_0	T_5– N_1S_0	T_9– N_2S_0	T_{13}– N_3S_0
T_2– N_0S_1	T_6– N_1S_1	T_{10}– N_2S_1	T_{14}– N_3S_1
T_3– N_0S_2	T_7– N_1S_2	T_{11}– N_2S_2	T_{15}– N_3S_2
T_4– N_0S_3	T_8– N_1S_3	T_{12}– N_2S_3	T_{16}– N_3S_3

Fig. 3. Response of Nitrogen and Silica on Harvest index in IWP.

CONCLUSION

The findings suggested that 150 kg ha^{-1} of Urea and 200 kg ha^{-1} of calcium silicate boosted rice yield and yield attributes in this study. Urea and calcium silicate showed substantial increment in grain and straw yield over the control. Grain and straw yield were positively correlated with plant height, number of tillers per plant and total dry matter production in paddy. From this study, it can be concluded that the combined fertilization of different levels of urea and silicon significantly improved the rice productivity through improved growth attributes.

FUTURE SCOPE

Studies on plant nutrition helps the researchers to understand more about the crop growth status and how it responds when there is a deficiency of some nutrients and the adaptive mechanism plants rely on to cope up in the current scenario to improve productivity. Furthermore, advancements in the plant nutrition research have greater impact on food security. Insights into the interactive effects of N and Si proves that, in future, such interactive studies between major nutrients and beneficial/ micronutrients will be of in greater need to increase the rice productivity.

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Conflict of Interest. None.

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