

Effect of Nitrogen and Silica on Growth and Yield of Paddy (*Oryza sativa* L.) Variety CO 51

Comment [s1]: Overall, this paper needs too much improvement

ABSTRACT

World agriculture is facing increasing demand due to multiple challenges. It has to produce more food to feed a growing population in the increasing climatic conditions. Rice (*Oryza sativa* L.) is considered to be a Si accumulator plant and tends to actively accumulate Si into tissue up to concentrations of 5% or even higher. The present study aimed to use different forms of N and Si sources at different levels to improve the growth traits contributing to the yield increment in rice. A pot experiment was conducted in glasshouse, TNAU, Coimbatore to assess the response of nitrogen and silica on paddy during October 2020 – January, 2021. The treatments comprised of the two factors, nitrogen and silica with three replications. The growth parameters like plant height, number of tillers per plant and total dry matter production were recorded at all stages and yield traits at harvest stage. The treatment, T₁₁ - N₂S₂ (53.4 and 110.2 g pot⁻¹ respectively) significantly enhanced the grain yield and straw yield than control in the pot experiment. Highest growth and yield parameters were recorded with application of combined fertilization of nitrogen and silica (T₁₁-N₂S₂) which comprises 150 kg ha⁻¹ of urea and 200 kg ha⁻¹ of calcium silicate compared to control.

Comment [s2]: Write methodology in comprehensive way

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Comment [s4]: Use scientific language

Comment [s5]: How much?

Key words: Urea, calcium silicate, growth parameters and yield attributes.

INTRODUCTION

Rice is the major staple food for human population of southeastern Asia and occupies a predominant position among the cereal crops. Rice grain production in India is about 118.87 and 121.46 million tons during the year 2019-2020 and 2020-2021 respectively [1]. Increased population in turn increased the global rice demand and the only way to meet the growing demand is through increased the production of cereals. Nitrogen (N) and silicon (Si) are two important nutritional elements required for plant growth and development in rice. Nitrogen (N) is the important and primary element. It is one of the key inputs to paddy fields along with phosphorus to improve initial vigor of rice plants. Healthy plants contain 3 to 4 percent nitrogen in the aerial biomass. It is a major component of photosynthesis; enhance the chlorophyll content, amino acids and serves as building blocks of protein. Silicon (Si) is a beneficial element for paddy growth and development [2, 3]. Rice is a typical silicon accumulator that benefited through exogenous silicon nutrition. Silicon supply is essential for healthy growth of plant which results in improved economic yield of rice crop [4]. Hence, the application of silicon to soil or crop is practically applicable and also it increases the crop yield and alleviates the Fe toxicity [5]. Si concentration is much higher than other nutrients such as nitrogen (N), phosphorus (P), and potassium (K) in rice plants when plants are supplied with exogenous silica [6]. Since, Si is a beneficial element, rice crop deficient in silica considerably reduces the growth and fertility which in turn declines yield [3]. Application of N and Si fertilizers significantly increases the plant height and number of panicles than control [7]. With this background, the present study was formulated to study the interactive effect of nitrogen and silica on growth parameters and yield traits in paddy variety CO 51.

Comment [s6]: Modify in paragraphs

Comment [s7]: This introduction is not enough

Comment [s8]: Add more about variety, silicon role and nitrogen and silicon interactive uptake

MATERIALS AND METHODS

A pot experiment was conducted in glasshouse, TNAU, coimbatore with treatment were N₀ –without urea, N₁– 100 kg ha⁻¹ urea, N₂–150 kg ha⁻¹ urea, N₃ – 175 kg ha⁻¹ urea, S₀–0 kg of Calcium silicate, S₁– 150 kg of Calcium silicate, S₂–200 kg of Calcium silicate, S₃–250 kg of Calcium silicate. The experiment was conducted in factorial completely randomized block design and replicated thrice. The experimental soil belongs to Noyyal soil

Comment [s9]: Give treatments in a table

Comment [s10]: Methodology should be very clear

series taxonomically grouped as Clay loamy, mixed iso-hyperthermic, *Typic haplustalf* [8]. The composite soil samples were collected initially from the experimental field and had been subjected to analysis initial characteristics. The soil was clay loam in texture, pH - 7.4, non-saline (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. Fertilizers were applied basal, 20th and 45th DAT. Rice variety CO51 was released by Tamil Nadu Agricultural University in the year 2013. The parentage of this variety is ADT43 / RR272-1745. It is a high yielding semi dwarf rice variety with 105-110 days duration. Variety CO51 is moderately resistant to blast, brown plant hopper. It is white medium slender rice with high milling (69%) and head rice recovery (63%) percentage. The analytical methods of soil analysis were furnished below the Table 1.

Table 1. Analytical methods of soil analysis

Sl. No	Parameters	Methods	References
1.	pH	pH meter (soil water ratio 1:2.5)	Jackson (1973)
2.	Electrical conductivity	Conductivity meter (soil water ratio 1:2.5)	Jackson (1973)
3.	Bulk density	Measuring Cylinder Method	Sree ramulu (2003)
4.	Particle density	Measuring Cylinder Method	Sree ramulu (2003)
5.	Porosity	Measuring Cylinder Method	Sree ramulu (2003)
6.	Available nitrogen	Alkaline potassium permanganate method	Subbiah and Asija (1956)
7.	Available phosphorous	Bray No 1 extraction and photoelectric colorimetry	Jackson (1973)
8.	Available potassium	Neutral normal ammonium acetate extraction and flame photometry	Stanford and English (1949)

DATA COLLECTION

The growth parameters were (plant height, number of tillers per plant and total dry matter production) measured at 30, 60 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.

Tiller population was counted from plant and is denoted as number of tillers m⁻² at 30, 60 and harvest stage.

Samples were collected from pot and shade dried and then oven dried at 60^o C for 72 hrs. The dry weight of the samples was used for the estimation of dry matter production and it is expressed in g pot⁻¹ at 30, 60 and harvest stage.

The harvested grains from the pot was threshed, cleaned, sun dried and 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.

$$\text{Harvest index (\%)} = \text{Economic yield} / \text{Biological yield} \times 100$$

The results of growth and yield parameters were statistically analyzed as suggested by [9]

RESULTS AND DISCUSSION

Comment [s11]: Can you give uptake quantity in grain yield and biomass

Plant height is an important morphological trait which determines the overall plant frame work. The treatment T₁₁ - N₂S₂ significantly recorded higher plant height (35.4, 79.8, and 84.9 cm respectively), followed by the treatment T₈ - N₁S₃ (31.8, 75.6 and 80.1 cm respectively) and the treatments T₁ - N₀S₀ and T₁₆ - N₃S₃ were recorded significantly lower plant height (11.6, 42 and 46.8 cm) and (10.3, 41.5 and 45.2 cm) respectively (Table 2) at 30, 60 and harvest stage. Application of nutrients helps in cell elongation and increased plant height. Similar findings were reported by Mazid *et al.*, [10] and Arf [11] that the application of nitrogen at increasing level boosts the plant metabolism and significantly increased plant height. Present study were supported by Chu *et al.*, [12] and Yoshida *et al.*, [13] that the silica fertilization improves the plant rigidity and leaf erectness in high density population.

Table 2. Effect of Nitrogen and silica on plant height in paddy at 30, 60 DAT and harvest stage of CO 51 (cm)

Treatment	30 DAT					60 DAT					Harvest				
	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	11.6	15.4	16.9	17.3	15.3	42.1	47.4	48.5	49.7	46.9	46.8	52.8	53.1	54.6	51.8
N ₁	18.2	19.8	25.8	31.8	23.9	50.3	51.2	65.9	75.6	60.7	55.2	56.9	67.9	80.1	65.0
N ₂	23.4	24.5	35.4	26.1	27.3	55.4	59.8	79.8	71.4	66.6	60.1	62.5	84.9	74.8	70.5
N ₃	20.1	21.9	22.4	10.3	18.6	52.1	53.7	54.8	41.5	50.5	57.2	58.4	59.8	45.2	55.1
Mean	18.3	20.4	25.1	21.3		49.9	53.0	62.2	59.5		54.8	57.6	66.4	63.6	
Factor	S	N	S*N			S	N	S*N			S	N	S*N		
SEd	0.6	0.8	1.1			1.5	2.1	2.9			1.6	2.2	3.2		
CD	1.2	1.7	2.4			3.1	4.4	6.3			3.3	4.8	6.9		

N₀ –without urea N₂–150 kg ha⁻¹ urea S₀–0 kg of Calcium silicate S₂–200 kg of Calcium silicate
N₁– 100 kg ha⁻¹ urea N₃ – 175 kg ha⁻¹ urea S₁– 150 kg of Calcium silicate S₃–250 kg of Calcium silicate

The application of nitrogen and silicon fertilizer greatly enhanced the number of tillers per hill. Increased number of tillers per plant were recorded in the treatment, T₁₁ - N₂S₂ (12.4, 22.1 and 28.9 respectively) followed by the treatment, T₈ - N₁S₃ (11.8, 20.8 and 25.4 respectively). Least number of tillers per plant were recorded in the treatments, T₁ - N₀S₀ (6.2, 7.1 and 8.8 respectively) and the treatment T₁₆ -N₃S₃ (6.1, 7.0 and 8.1 respectively) at 30, 60 and harvest stage (Table 3). Fertilization of rice crop with silicon and nitrogen positively increases plant vigor and increases tiller number per hill. Similar findings were reported by Mazid *et al.*, [10]; Pati *et al.*, [14]; Dorairaj *et al.*, [15]; and Cuong *et al.*, [16] that the number of tillers per hill were increased due Si silica fertilization at top dressing and reproductive stage.

Table 3. Effect of Nitrogen and silica on number of tillers in paddy at 30, 60 DAT and harvest stage of CO 51

Treatment	30 DAT					60 DAT					Harvest				
	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	6.2	6.9	7.5	7.9	7.1	7.1	7.8	8.2	8.7	7.9	8.8	9.4	10.5	11.3	10
N ₁	8.1	8.4	10.6	11.8	9.7	9.5	10.8	16.5	20.8	14.4	12.4	13.9	19.8	25.4	17.8
N ₂	9.8	10.1	12.4	11.2	10.8	14.3	15.8	22.1	18.2	17.6	17.9	18.5	28.9	22.1	21.8
N ₃	9	9.3	9.6	6.1	8.5	11.2	12.7	13.8	7.0	11.1	14.2	15.7	16.5	8.1	13.6

Mean	8.2	8.6	10.0	9.2	10.5	11.7	15.1	13.6	13.3	14.3	18.9	16.7
Factor	S	N	S*N		S	N	S*N		S	N	S*N	
SEd	0.2	0.3	0.5		0.3	0.5	0.7		0.4	0.6	0.8	
CD	0.5	0.7	1.1		0.7	1.0	1.4		0.9	1.2	1.7	

N₀ –without urea N₂–150 kg ha⁻¹ urea S₀–0 kg of Calcium silicate S₂–200 kg of Calcium silicate
N₁– 100 kg ha⁻¹ urea N₃– 175 kg ha⁻¹ urea S₁– 150 kg of Calcium silicate S₃–250 kg of Calcium silicate

Plant height, number of tillers was positively correlated with total dry matter production and the data was furnished in the Table 4. The treatment T₁₁ - N₂S₂ (35.4, 43.6 and 55.8 g pot⁻¹ respectively) was recorded highest total dry matter production followed by the treatment T₈- N₁S₃ (31.2, 39.4 and 51.2 g pot⁻¹ respectively). Lowest total dry matter production were recorded in the treatment, T₁ - N₀S₀ (10.3, 18.1 and 27.9 g pot⁻¹ respectively) and the treatment, T₁₆ - N₃S₃ (9.8, 17.4 and 24.6 g pot⁻¹ respectively) at 30, 60 DAT and harvest. The present findings were supported by Yogendra *et al.*, [17] that increase in number of tillers increases the total dry matter production with the application of calcium silicate at 2 t ha⁻¹ and Mazid *et al.* [10] observed that increased plant height and number of tillers per plant substantially increased the total dry matter production. The study suggested by Agarie *et al.*, [18] found that the application of Si significantly enhanced the dry matter production which is mainly could be maintenance of photosynthetic activity in the leaves.

Table 4. Effect of Nitrogen and silica on total dry matter production in paddy at 30, 60 DAT and harvest stage of CO51 (g pot⁻¹)

Treatment	30 DAT					60 DAT					Harvest				
	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	10.3	13.6	15.1	16.2	13.8	18.1	21.2	23.8	24.9	22	27.9	31.8	33.6	34.1	31.8
N ₁	17.8	18.7	24.6	31.2	23.0	25.1	26.3	32.9	39.4	30.9	35.9	36.4	42.1	51.2	41.4
N ₂	18.7	24.6	34.5	22.1	24.1	30.7	31.8	43.6	35.1	35.3	40.6	41.1	55.8	46.7	46.0
N ₃	19.5	20.9	21.6	9.8	17.9	27.4	28.2	29.8	17.4	25.7	37.2	38.4	39.6	24.6	34.9
Mean	16.5	19.4	23.9	19.8		25.3	26.8	32.5	29.2		35.4	36.9	42.7	39.1	
Factor	S	N	S*N			S	N	S*N			S	N	S*N		
SEd	0.5	0.7	1.1			0.7	1.0	1.5			0.9	1.4	2.0		
CD	1.0	1.6	2.2			1.6	2.2	3.1			2.1	3.0	4.3		

N₀ –without urea N₂–150 kg ha⁻¹ urea S₀–0 kg of Calcium silicate S₂–200 kg of Calcium silicate
N₁– 100 kg ha⁻¹ urea N₃– 175 kg ha⁻¹ urea S₁– 150 kg of Calcium silicate S₃–250 kg of Calcium silicate

Number of productive tillers and total dry matter production positively enhanced the rice grain yield and straw yield. The results revealed that the grain yield and straw yield were recorded higher in the nutrient treatments. The treatment T₁₁ - N₂S₂ (53.4 and 110.2 g pot⁻¹ respectively) recorded maximum grain and straw yield followed by the treatment, T₈ - N₁S₃ (48.9 and 101.4 g pot⁻¹ respectively). The treatment, T₁ - N₀S₀ (19.5 and 46.8 g pot⁻¹ respectively) and the treatment T₁₆ - N₃S₃ (18.2 and 44.2 g pot⁻¹ respectively) recorded the lowest grain yield and straw yield (Fig. 1 & 2). [The present findings was in accordance with Chen *et al.*, [19] that the silica transferred preferentially into the flag leaves and grains during the reproductive stage which increased the grain yield. The research findings found by Sudhakara *et al.*, [20]; Savant *et al.*, [2]; Ghanbari-Malidareh [21]; Balastra *et al.*, [22]; and Deren *et al.*, [23] reported that the high rates of silicon fertilization was substantially enhanced grain mass,

straw yield leaf culm strengths. The nutrient treatments positively influenced the harvest index but however, it was not significant in the interaction of nitrogen and silica treatments in the experiment (Fig. 3).

Comment [s12]: Please give the reason why accumulated

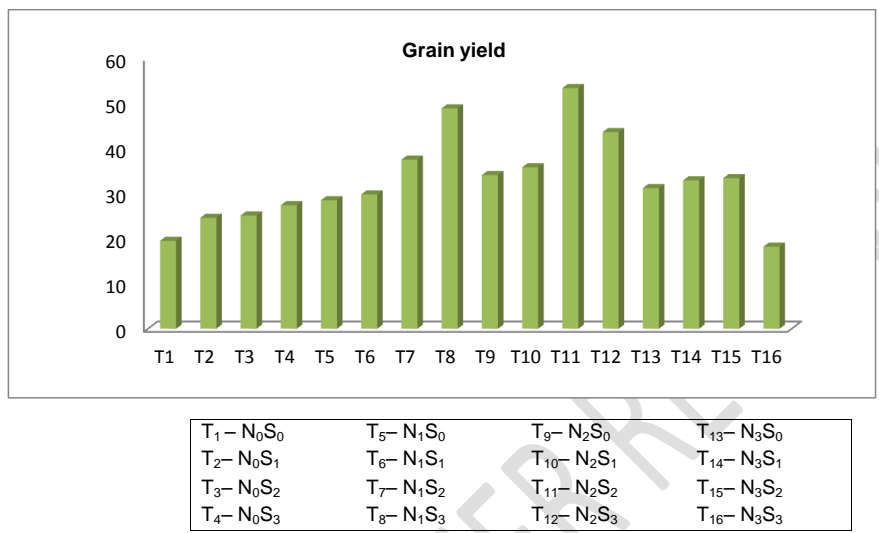


Fig.1. Effect of Nitrogen and silica on grain yield in paddy of CO51 (g pot⁻¹)

Comment [s13]: Tables and graphs should have letters

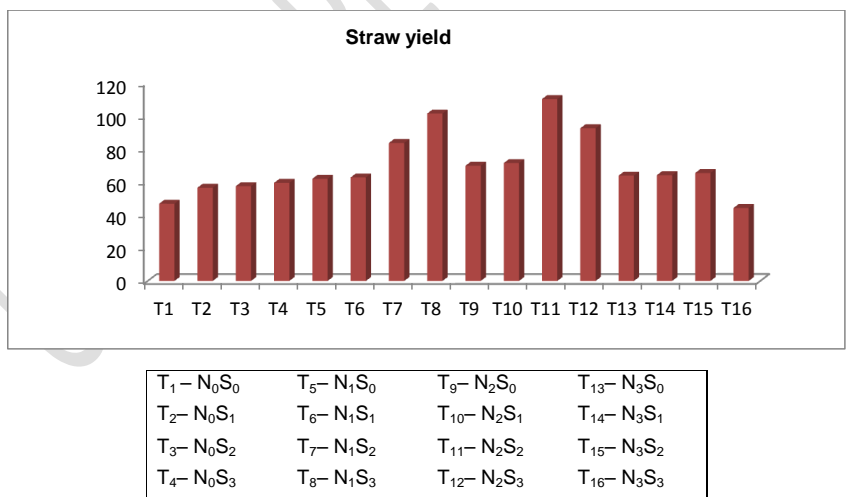


Fig.2. Effect of Nitrogen and silica on straw yield in paddy of CO51 (g pot⁻¹)

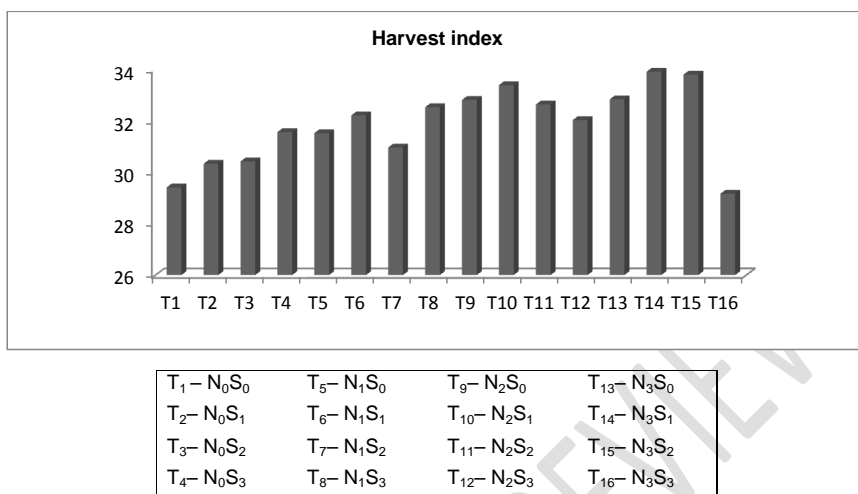


Fig.3. Effect of Nitrogen and silica on harvest index in paddy of CO51 (g pot⁻¹)

The correlation coefficient were established between grain yield and growth parameters. The effect of plant height($r = 0.98^{**}$), number of tillers per plant ($r = 0.98^{**}$), total drymatter production ($r = 0.99$) were significant and positive in influencing the grain yield of paddy in pot experiment. (Table 5. and Fig.4.)

Table 5. Correlation between yield and growth parameters

	Grain yield per pot	Plant height	No of tillers per plant	DMP per plant
Grain yield	1			
Plant height	0.991087	1		
No of tillers per plant	0.989314	0.979455	1	
DMP per plant	0.99525	0.981821	0.982373	1

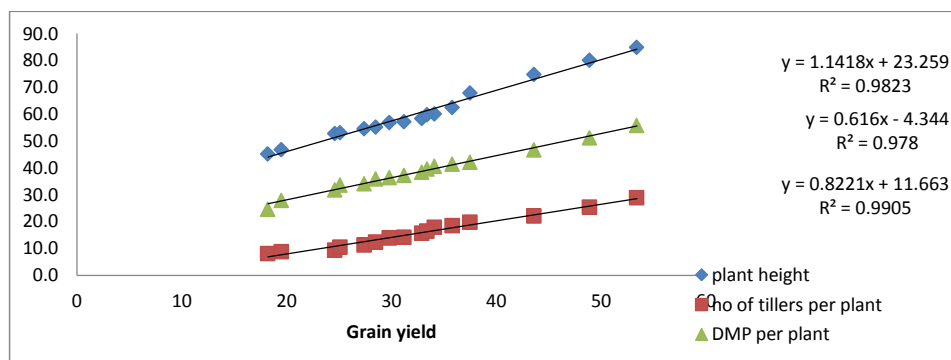


Fig.4. Regression between yield and growth parameters

CONCLUSION

Higher plant height, number of tillers per plant and total dry matter production were recorded in the treatment N_2S_2 which also boosted yield and yield attributes in this study. Silica fertilization positively correlated with plant height, number of tillers and total dry matter production which in turn significantly increased the yield. The production of paddy with application of combined fertilizer is proven to be beneficial to the paddy farmers.

Comment [s14]: This is not conclusion.. this can be improved

REFERENCES

- [1]. Ministry of Agriculture and Farmers Welfare releases Third Advance Estimates of Principal Crops for 2020-21. <https://pib.gov.in/PressReleasframePage.aspx?PRID=1721692>.
- [2]. Savant NK, Snyder GH, Datnoff LE. Silicon management and sustainable rice production. *Advances in Agronomy*, 1996;58:151-199.
- [3]. Ma JF, Yamaji N. Functions and Transport of Silicon in Plants. *Cellular and Molecular Life Science*. 2008;65:3049-3057.
- [4]. Singh V, Singh V, Singh S, Khanna R. Effect of zinc and silicon on growth and yield of aromatic rice (*Oryza sativa*) in North-Western plains of India. *J. Rice Res. Dev.* 2020; 3(1) :82-86.
- [5]. Das A, Samant, PK, Sahu G, Santra GH. Evaluation of silicon nutrition on yield, growth attributes and available nutrient status of paddy in coastal zone of Odisha. *Int. J. Pl. & Soil Sci.*, 2021; 33(23): 277-288.
- [6]. Ma JF, Takahashi E. Soil, Fertilizer and Plant Silicon Research in Japan. Elsevier. Amsterdam.2002.
- [7]. Malav JK, Patel KC, Sajid M, Ramani VP. Effect of silicon levels on growth, yield attributes and yield of rice in typic ustochrepts soils. *Eco. Env. & Cons.*,2005; pp. 205-208.
- [8]. Searle JR. A taxonomy of illocutionary acts.1975.
- [9]. Gomez KA, Gomez AA. *Statistical Procedures for Agricultural Research*. John Wiley & Sons.1984.
- [10]. Mazid A. Impact of modern agricultural technologies on durum wheat production in Syria. *Aleppo, Syria: International Center for Agricultural Research in the Dry Areas (ICARDA)*.2003.
- [11]. Arf O, Rodrigues RAF, Sá MED, Crusciol CA. CResposta de cultivares de arroz de sequeiro ao preparo do solo e à irrigação por aspersão. *Pesquisa Agropecuária Brasileira*. 2001; 3: 871-879.

- [12]. Chu M, Liu M, Ding Y, Wang S, Liu Z, Tang S, Li G. Effect of nitrogen and silicon on rice submerged at tillering stage. *Agronomy Journal*, 2018;110(1):183-192.
- [13]. Yoshida S, Naveser SA, Ramirez EA. Effects of silica and nitrogen supply on some leaf characters of rice plant. *Plant and Soil*.1969;31:48-56.
- [14]. Pati S, Pal B, Badole S, Hazra GC, Mandal B. Effect of Silicon Fertilization on Growth, Yield and Nutrient Uptake of Rice. *Communications in Soil Science and Plant Analysis*. 2001;47:284-290.
- [15]. Dorairaj D, Ismail MR, Sinniah UR, Tan KB. Silicon mediated improvement in agronomic traits, physiological parameters and fiber content in *Oryza sativa*. *Acta Physiologiae Plantarum*.2020;42(3): 1-11.
- [16]. Cuong TX, Ullah H, Datta A, Hanh. Effects of silicon-based fertilizer on growth, yield and nutrient uptake of rice in tropical zone of Vietnam. *Rice Science*.2001;24(5):283-290.
- [17]. Yogendra ND, Kumara BH, Chandrashekar N, Prakash NB, Anantha MS, Jeyadeva HM. Effect of silicon on real time nitrogen management in a rice ecosystem. *African Journal of Agricultural Research*.2014 ;9(9):831-840.
- [18]. Agarie S, Agata W, Kubota F, Kaufman, PB. Physiological roles of silicon in photosynthesis and dry matter production in rice plants: I. Effects of silicon and shading treatments. *Japanese Journal of Crop Science*, 1991;61(2):200-206.
- [19]. Chen JX, Tu NM, Yi, ZX, Zhu HL. Effect of silicon fertilizer on nitrogen utilization efficiency of super early rice. *Crop Research*, 01.(2011).
- [20]. Sudhakara N, Anjaiah T, Qureshi AA, Sagar, GCV,Chary DS. Effect of different sources and levels of Silicon application on growth, yield attributes and yield of rice (*Oryza sativa* L.). *The J. Res. Pjtsau*. 2020;48(55):1-99.
- [21]. Ghanbari-Malidareh A. Silicon application and nitrogen on yield and yield components in rice (*Oryza sativa* L.) in two irrigation systems. *International Journal of Agricultural and Biosystems Engineering*. 2020;5(2): 40-47.
- [22]. Barbosa Filho MP. Nutrição e adubação do arroz. Piracicaba: Associação Brasileira para Pesquisa da Potassa e do Fosfato, 127.
- [23]. Deren CW, Datnoff, LE, Snyder, GH, Martin, FG. Silicon concentration, disease response, and yield components of rice genotypes grown on flooded organic Histosols. *Crop Science*.1994;34:73.