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

ABSTRACT

World agriculture is facing increasing demand due to multiple challenges. The biggest challenge is to attain food security in the ever increasing growing population. Rice (*Oryza sativa* L.) is a staple food crop for half of the world's population and one of the world's most significant food crops. Farmers must produce more rice with enhanced quality in order to ensure food security in rice-consuming countries across the world. 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 increase yield of 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, T_{11} - N_2S_2 (53.4 and 110.2 g pot^{-1} respectively) significantly enhanced the grain yield (34%) and straw yield (40%) than control in the pot experiment. Highest growth and yield parameters were recorded with application of combined fertilization of nitrogen and silica (T_{11}-N_2S_2) which comprises150 kg $ha^{-1}$of urea and 200 kg ha^{-1} of calcium silicate compared to control.

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

1. 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]. Lavinsky *et al.,* [6] reported that silicon application at reproductive growth stage (panicle initiation to heading) rather than the vegetative and ripening stages had a positive effect on photosynthesis with increased stomatal conductance. Along with improvement in photosynthetic traits, exogeneous application of Si provides biotic and abiotic tolerance and has improved plant metabolism [7].

Experimental variety is Rice variety CO51. It 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. It has been recommended for cultivation as transplanted rice throughout Tamil Nadu except Nilgiris district. Average yield of the variety is 6641 kg ha^{-1}. 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 [8]. 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 [9]. When nitrogen and silica is used in combination, the ideal level of both nitrogen and silica has been determined to be raised from its current level which is responsible for improved crop growth and high productivity [10]. 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.

2. MATERIALS AND METHODS

A pot experiment was conducted in glasshouse, TNAU, Coimbatore with treatment 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 of Calcium silicate, S_1– 150 kg of Calcium silicate, S_2–200 kg of Calcium silicate, S_3–250 kg of Calcium silicate. The experiment was conducted in factorial completely randomized block design and replicated thrice. The experimental soil belongs to Noyyal soil 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 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)

2.1. 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 60^0 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.

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

The results of growth and yield parameters were statistically analyzed as suggested by [11].

3. RESULTS AND DISCUSSION

Plant height is an important morphological trait which determines the overall plant frame work. The treatment T_{11} - N_2S_2 significantly recorded higher plant height (35.4, 79.8, and 84.9 cm respectively), followed by the treatment T_8 -N_1S_3 (31.8, 75.6 and 80.1 cm respectively) and the treatments T_1 - N_0S_0 and T_{16} - N_3S_3 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.,* [11] and Arf [13] 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.,* [13] and Yoshida *et al.,* [14] that the silica fertilization improves the plant rigidness 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)

	30 DAT					60 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
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		

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 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, T_{11} - N_2S_2 (12.4, 22.1 and 28.9 respectively) followed by the treatment, T_8 - N_1S_3 (11.8, 20.8 and 25.4 respectively). Least number of tillers per plant were recorded in the treatments, T_1 - N_0S_0 (6.2, 7.1 and 8.8 respectively) and the treatment T_{16} -N_3S_3 (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.,*[12]; Pati *et al.,* [16]; Dorairaj *et al,*[17]; and Cuong *et al.,*[18] 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

	30 DAT					60 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
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		

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

Plant height, number of tillers was positively correlated with total dry matter production and tha data was furnished in the Table 4. The treatment T_{11} - N_2S_2 (35.4, 43.6 and 55.8 g pot^{-1} respectively) was recorded highest total dry matter production followed by the treatment T_8- N_1S_3 (31.2, 39.4 and 51.2 g pot^{-1} respectively). Lowest total dry matter production were recorded in the treatment, T_1 - N_0S_0 (10.3, 18.1 and 27.9 g pot^{-1} respectively) and the treatment, T_{16} - N_3S_3 (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.,* [19] 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.* [12] 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.,* [20] found that the application of Si significantly enhanced the dry matter production which is mainly could be maintenance of photosynthetic activity in the leaves.

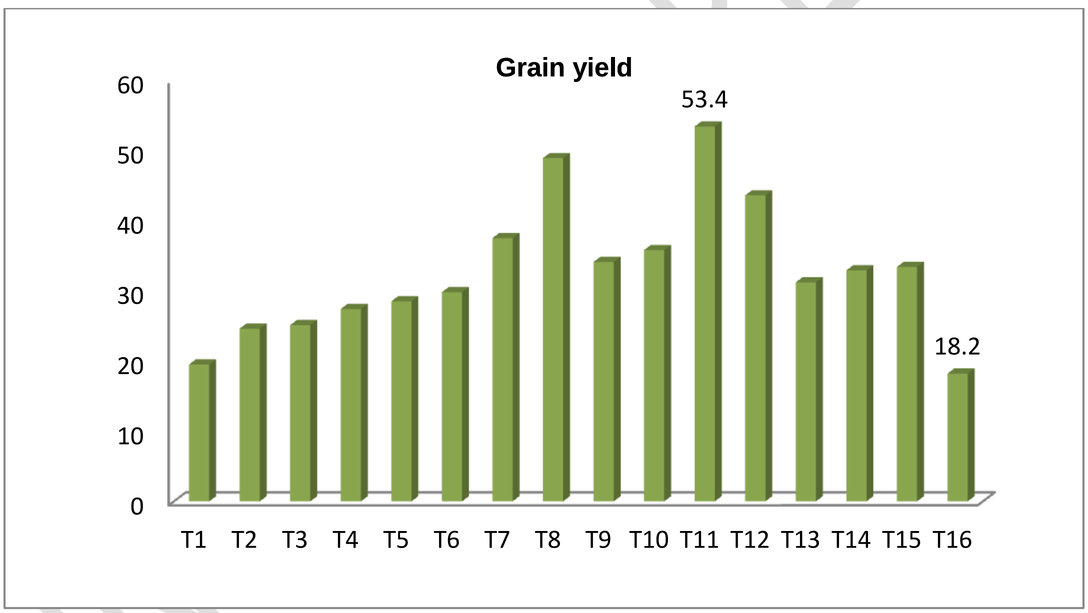
Table 4. Effect of Nitrogen and silica on total dry matter production in paddy at 30, 60 DAT and harvest stage of CO51 (g pot^{-1})

	30 DAT					60 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
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		

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

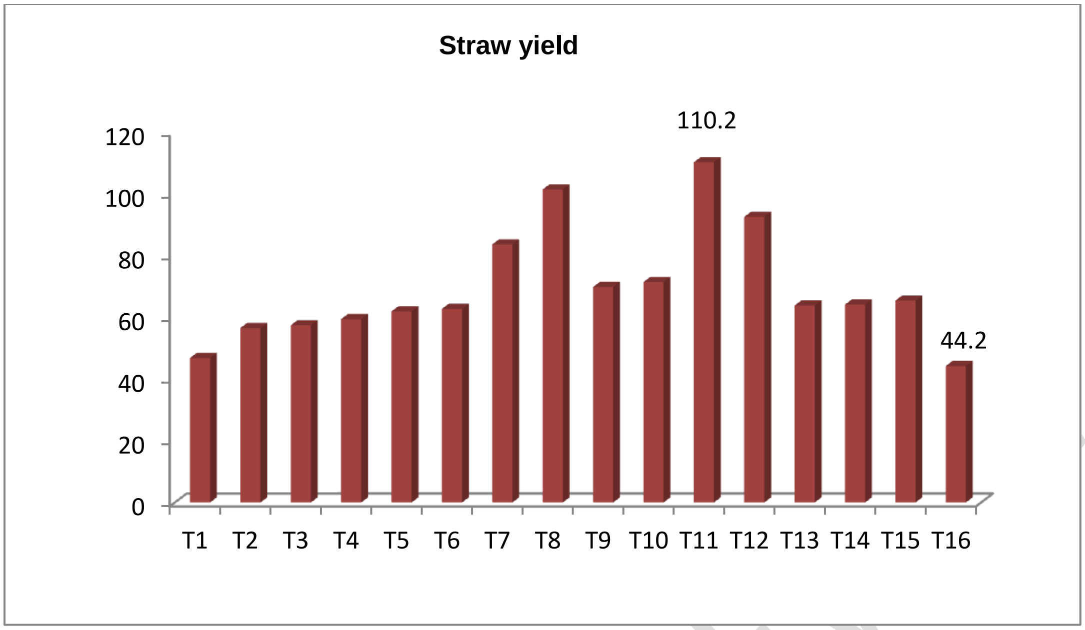
N_1– 100 kg ha^{-1} urea | N_3 – 175 kg ha^{-1} urea | S_1– 150 ha^{-1} kg of Calcium silicate | S_3–250 ha^{-1} kg of Calcium silicate

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 T_{11} - N_2S_2 (53.4 and 110.2 g pot^{-1} respectively) recorded maximum grain and straw yield followed by the treatment, T_8 - N_1S_3 (48.9 and 101.4 g pot^{-1} respectively). The treatment, T_1 - N_0S_0 (19.5 and 46.8 g pot^{-1} respectively) and the treatment T_{16} - N_3S_3 (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.,* [21] 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.,*[22]; Savant *et al.,* [2]; Ghanbari-Malidareh [23]; Balastra *et al.,* [24]; and Deren *et al.,* [25] reported that the high rates of silicon fertilization was substantially enhanced grain mass, straw yield leaf culm strengthens because, majority of the silica absorbed by the plant is precipitated and deposited inside or between plant cells and forming 'phytoliths', which offer mechanical strength and help protect the plant from physical, chemical, and biological stressors. Phytoliths are found in a wide range of monocot and dicot plants. 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).



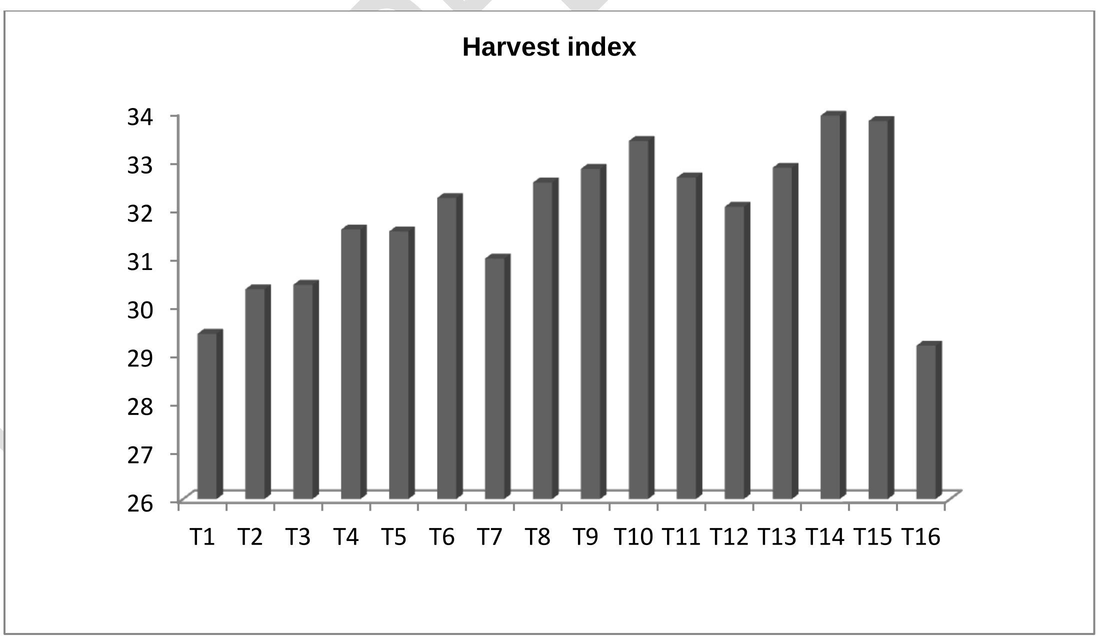
T_1– N_0S_0	T_5– N_1S_0	T_9– N_2S_0	T_{13}– N_3S_0
T_2– N_0S_1	T_6– N_1S_1	T_{10}– N_2S_1	T_{14}– N_3S_1
T_3– N_0S_2	T_7– N_1S_2	T_{11}– N_2S_2	T_{15}– N_3S_2
T_4– N_0S_3	T_8– N_1S_3	T_{12}– N_2S_3	T_{16}– N_3S_3

Fig.1. Effect of Nitrogen and silica on grain yield in paddy of CO51 (g pot^{-1})



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. Effect of Nitrogen and silica on straw yield in paddy of CO51 (g pot^{-1})



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. Effect of Nitrogen and silica on harvest index in paddy of CO51 (g pot^{-1})

The correlation coeffienct 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

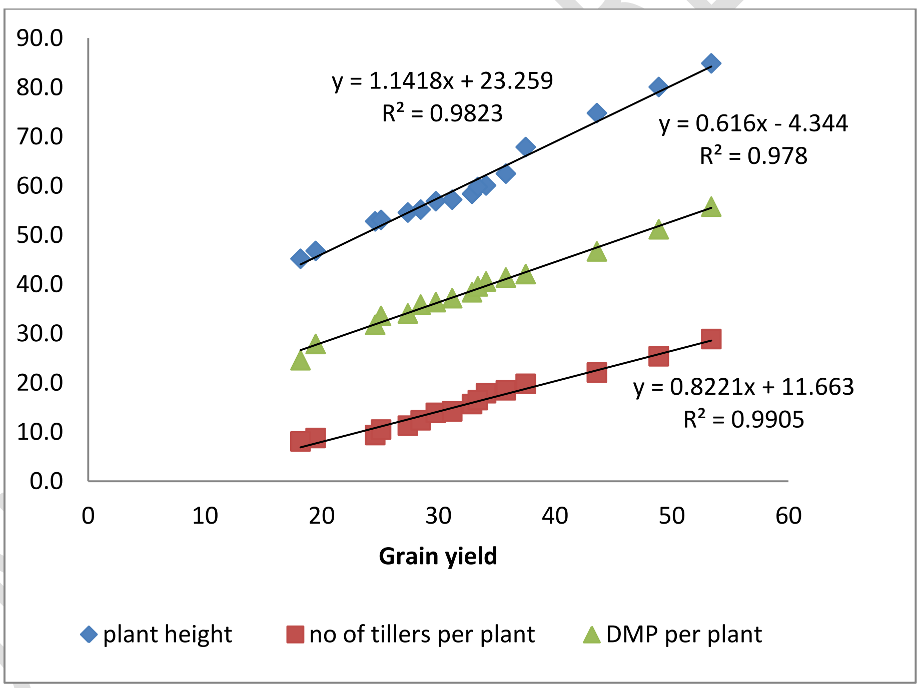


Fig.4. Regression between yield and growth parameters

4. CONCLUSION

The results revealed that the application of fertilizer like Nitrogen and Silica in combinations significantly improved the growth parameters and yield traits. Increased silicon levels resulted in a considerable increase in straw yield. This could be owing to silicon's function in improving photosynthetic activity, water use efficiency, and nutrient use efficiency. As a result, there is better vegetative growth. The increased plant height and number of tillers per hill were primarily responsible for the enhanced straw yield. Higher plant height, number of tillers per plant and total dry matter production were recorded in the treatment N_2S_2 (150 kg $ha^{-1}$of urea and 200 kg ha^{-1} of calcium silicate). 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.

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