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Effect of Silicon Application on Growth, Development and Grain Yield of Rice Genotypes under Water Stress

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ABSTRACT: Rice (*Oryza sativa* L.) is a main cereal crop and a staple food across the world. Drought is one of the most critical limiting factors for rice production, which adversely affects food security globally. Silica reduces oxidative damage in plants under stress by enhancing antioxidant activity. The integration of silica in breeding programs is also recommended to improve the quality of yield and to provide drought-tolerant rice cultivars under drought-stress conditions. The present investigation evaluated the impact of silicon application in alleviating water stress of rice genotypes. The results revealed that water stress significantly reduced leaf area index, chlorophyll content, total dry matter, spikelets, number of filled grains and grain yield. In comparison with control, silicon application (T_2) has increased LAI by 39.63%, SCMR value by 2.85%, total dry matter by 23.63%, panicle weight by 24.66%, number of filled grains by 24.21%, number of spikelets panicle^{-1} by 16.34% and grain yield by 10.60%; water stress alone (T_3) reduced LAI by 2.51%, SCMR value by 2.19%, total dry matter by 21.93%, panicle weight by 41.43%, number of filled grains by 43.20%, number of spikelets panicle^{-1} by 33.74% and grain yield by 40.88%; while silicon + water stress (T_4) enhanced LAI by 30.26%, SCMR value by 1.64%, total dry matter by 1.06% and reduced panicle weight by 23.53%, number of filled grains by 18.39%, number of spikelets panicle^{-1} by 18.48%, grain yield by 19.24%. In conclusion, silicon application has reduced the adverse impacts of water stress on rice and improved the growth and development under both well-watered and water stress conditions compared to water stress alone. Hence, silicon application can be adopted as a cost-effective strategy to mitigate the negative impacts of drought in rice and to improve the yield potential of rice genotypes.

Keywords: Silicon, water stress, leaf area index, grain yield and rice.

INTRODUCTION

Rice (*Oryza sativa* L) is one of the most important food crops grown and is consumed by one-third of the world's population. It is the staple food for more than 65% of Indian population contributing approximately 40% to the total food grain production, thereby, occupying a pivotal role in the food and livelihood security of people. In India, rice is grown over an area of 43.9 ha^{-1} with total production of 110 mt and productivity of 2505 kg ha^{-1} (Jinger *et al*., 2018). To ensure food and nutritional security of rice, the country ought to add 3 mt grain production every year by raising rice yield levels substantially (Dass *et al*., 2017). Currently, various physical, abiotic (crop lodging, water-deficit, low and high temperature, etc.) and chemical stresses (salinity, heavy metal injury, etc.) are the major constraints in rice production. Moreover, declining water table, climate change, imbalanced use of fertilizers and lack of tolerant rice cultivars to biotic and abiotic stresses, impose serious limitations to rice production (Vijayakumar *et al*., 2019).

One of the most catastrophic climate disasters that endangers global agricultural productivity is drought. Water deprivation prevents cell development, weakened root systems, and shortened tilling capabilities (Hannan *et al*., 2020). It also reduces dry and fresh biomass (Sikuku *et al*., 2012). According to studies done on rice plants, drought stress results in variable root lengths, changed root morphology, and impaired root development (Kim *et al*., 2020). In addition, drought stress circumstances have a negative impact on a variety of metabolic activities, including photosynthesis, respiration, ion absorption, hormone development, and nutrient intake (Farooq *et al*., 2008; Usman *et al*., 2013; Lee *et al*., 2015).

Silicon is a beneficial element for rice crop and its application is imperative for rice production to minimize the yield gap (Ma and Yamaji 2006). Rice has a tremendous capacity to absorb silicon for growth and production. Inadequate uptake of Si reduces rice yield and quality as well. Accumulation of Si in the roots minimizes the uptake and translocation of harmful heavy metals and salts, imparts toughness and integrity to plant cell walls and reduces transpiration thereby making the plant resistant to lodging, temperature, and water stresses. Its antioxidant defense abilities minimize negative impacts of water and salt stresses (Gong *et al*., 2005). Besides, Si application in soil influences the absorption, translocation and uptake of almost all micro and macro nutrients. Si application reduces nutrient losses like leaching of phosphate, nitrate and potash (Epstein, 1999). Silicon acts as an anti-transparent which reduces water stress by suppressing the transpiration process. Silicon imparts drought resistance in crop plants by retaining water, improving CO_2 fixation efficiency, maintains uprightness of canopy and anatomy of water transporting tissues (Hattori *et al*., 2005). The supply of silica resulting in physical environment leading to better aeration, root activity, nutrient absorption and the consequent complementary effect would have resulted in higher grain and straw yield of rice. Plants become more resistant to fungal disease and raised the percentage of the filled spikelets and seed yield by increase of cell wall thickness below the cuticle, imparting mechanical resistance to the penetration of fungi, and improvement of the leaf angle, making leaves more erect and enhanced carbohydrate translocation from vegetative parts to grains (Sarma *et al*., 2017).

Beneficial nutrients such as silicon are equally important as macronutrients like nitrogen and phosphorus (Ahmad *et al*., 2013) and balancing these nutrients in rice cultivation can enhance the quality and yield of the crop (Ma, 2004). Hence, present investigation was conducted to study the effect of silicon application on growth and development of rice genotypes under both irrigated and water stress conditions.

MATERIALS AND METHODS

Experiment was conducted at ICAR- Indian Institute of Rice Research farm, Rajendranagar, Hyderabad, during kharif-2021 as a part of AICRIP conducted at multi locations. The farm is geographically situated between 170 19' N latitude and 780 29' E longitude at an altitude of 542.7 m above mean sea level and comes under the southern Telangana Agro-Climatic region. During the crop growth period, the mean maximum temperature ranged from 27.5ºC to 37.0ºC with an average of 31.9ºC and the mean minimum temperature for the corresponding period varied between 18.5ºC to 24.5ºC with an average of 22.7ºC. Mean RH during the crop growth period ranged from 92 to 95% with an average of 87.4%. The total rainfall received during the cropping period was 823.8 mm.

Soil analysis indicated that the soil was clay in texture, non-saline and alkaline in reaction (pH-8.1). It was medium in organic carbon (0.62%) and low in available nitrogen (205 kg ha^{-1}), medium in available phosphorus (65 kg ha^{-1}) and available potassium (450 kg ha^{-1}). The experiment was laid out in split plot design comprising of eight rice genotypes replicated three times with a spacing of 20 x 10 cm. All the package of practices was followed as per standard package for crop production and crop protection.

Main plot treatments:

T_1: Control

T_2: Spray of 0.6% silicon as foliar spray at tillering, panicle initiation, 50%flowering and milky grain stages

T_3: water stress only

T_4: Silicon + water stress (water stress imposed by with holding irrigation from 12 days before flowering to 10 days after anthesis (a total of 22 days water stress will be imposed)

Sub plot treatments: 8 rice genotypes.

Number of days required for yellowing of the leaves and stem (symptoms of maturity) was recorded and reported as days to physiological maturity. Chlorophyll content of the leaves on a relative basis was measured by SPAD chlorophyll meter (SCMR) readings at panicle initiation stage. Leaf area index was measured at panicle initiation stage. LAI is the total leaf area present for unit land area and was calculated by using the formula of Watson (1958).

LAI = Total leaf area / Land area

Total dry matter at flowering was estimated by cutting the plants at ground level and panicle weight at maturity was estimated by separating panicles from the plants, followed by over drying at 80ºC until the constant weight is obtained and weight was recorded using electronic balance. Panicles were threshed, cleaned and weight of grains was recorded using electronic balance and expressed in t ha^{-1}. The filled and unfilled grains were separated and counted using seed counter and expressed as number of filled grains $panicle^{-1}$ and spikelets $panicle^{-1}$. Harvest index is defined as ratio of economic yield to total biological yield (Donald and Hamblin 1976) and is expressed in percentage. Harvest index of rice was calculated by using the formula

$$\text{Harvest index } (\%) = \frac{\text{Economic yield}}{\text{Total biological yield}} \times 100$$

The experimental data was analyzed statistically by following standard procedure outlined by Panse and Sukhatme (1985). Significance was tested by comparing "F" value at 1 and 5 percent level of probability. The percentage values were transformed using arc sign and square root values wherever necessary (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Days to physiological maturity. Effect of silicon application and water stress treatments on days to physiological maturity of rice genotypes found to be insignificant (Table 1) and all the treatments had recorded duration of 122 days to reach physiological maturity. Significant differences were noticed among the tested genotypes for days to physiological maturity. Maximum mean number of days to physiological maturity recorded in HRI-174 (129 days) whereas IIRRH-143 (116 days) recorded minimum mean days. Interaction between treatments and genotypes for days to physiological maturity found to be non-significant. Attainment of maturity as per the duration of cultivars was reported by Sinha *et al*. (1999) who observed considerable variation in days to maturity in rice.

Similar results were reported by Waseem *et al*. (2016) that silicon application had no significant effect on days from heading to maturity.

Leaf area index (LAI). Increasing leaf area index (LAI) is one of the ways of increasing the capture of solar radiation within the canopy and production of dry matter (Dalirie *et al*., 2010). LAI significantly varied with different treatments (Table 1). Highest mean leaf area index (4.34) recorded with silicon application (T_2) while lowest mean leaf area index (3.03) was observed in water stress alone (T_3). In comparison with control (T_1), silicon application (T_2) increased LAI by 39.63%, silicon application + water stress (T_4) increased LAI by 30.26% and water stress alone (T_3) reduced LAI by 2.51%. The tested genotypes differed significantly for LAI. 27P63 recorded significantly highest mean LAI (4.63) whereas US-314 recorded lowest mean LAI (3.05). No significant interaction was observed between treatments and genotypes for LAI. US-314 with water stress alone (T_3) exhibited least LAI (1.78) while highest LAI (5.35) was observed in 27P63 with silicon application + water stress (T_4). The increase in LAI could be attributed to increase in leaf expansion (length and breadth), high rate of cell division and cell enlargement, rapid growth and there by improved quality of vegetative growth due to applied silicon which corroborates with the results of Jaliya *et al*. (2008); Jat *et al*. (2010); Bisht *et al*. (2012).

Chlorophyll content. SPAD Chlorophyll Meter Reading (SCMR) value represents the relative content of chlorophyll, which was convenient and effective for sensing chlorophyll level without damaging rice plants leaves. A strong correlation between chlorophyll content and SCMR value has been identified, the higher the SCMR value, the higher chlorophyll content was found in rice leaves (Xie *et al*., 2012). Effect of silicon application and water stress treatments on the SCMR values of rice genotypes found to be non-significant (Table 2). Silicon application (T_2) has recorded higher mean SCMR value (42.2) while lowest mean SCMR value (40.1) was recorded in water stress alone (T_3). In comparison with control (T_1), silicon application (T_2) increased SCMR value by 2.85%, silicon application + water stress (T_4) increased SCMR value by 1.64% and water stress alone (T_3) reduced SCMR value by 2.19%. Significant variation was observed among the tested genotypes for SCMR values. Higher mean SCMR value (44.7) was noticed in US-314 whereas 27P63 recorded lowest value (37.1). No significant interaction was observed between treatments and genotypes for SCMR values. Highest chlorophyll content (45.5) observed in IIRRH-143 with silicon application (T_2) while least chlorophyll content (36.0) was recorded in 27P63 with water stress alone (T_3). Ranganathan *et al*. (2006) reported that silicon sources application increased the SPAD chlorophyll content.

Total dry matter. Plant with greater dry matter accumulation could be expected to have more seed yield per plant as dry matter is one of the factors determining the grain yield (Venkateshwarlu and Prasad 1982). Data revealed significant differences between treatments for total dry matter at flowering (Table 2). Significantly highest mean total dry matter (33.0 g $hill^{-1}$) recorded with application of silicon (T_2) while lowest total dry matter (20.8 g $hill^{-1}$) recorded with water stress alone (T_3). In comparison with control(T_1), silicon application (T_2) increased total dry matter by 23.63%, silicon application + water stress (T_4) increased total dry matter by 1.06% and water stress alone (T_3) reduced total dry matter by 21.93%. No significant variation observed among the genotypes for total dry matter. Lowest mean total dry matter (24.4 g $hill^{-1}$) was noticed in 27P63 whereas IIRRH-148 has exhibited highest mean total dry matter (28.8 g $hill^{-1}$). Interaction between treatments and genotypes for total dry matter found to be non-significant. SB. Dhan with water stress alone (T_3) recorded lowest total dry matter (17.8 g $hill^{-1}$) whereas HRI-174 with silicon application (T_2) recorded highest total dry matter (39.7 g $hill^{-1}$). The increase in dry matter might be attributed due to increased availability of phosphorus and other beneficial effect of silicon on growth of rice. The maintenance of photosynthetic activity due to silicon fertilization could be one of the reasons for increased dry matter production in rice crop (Agurie *et al*., 1992). Similar results for significant increase in dry matter with silicon application was reported in rice by Gholami and Falah (2013); Pati *et al*. (2016); Ullah *et al*. (2017).

Panicle weight (g m^{-2}). Silicon application and water stress treatments significantly influenced panicle weight of rice genotypes (Table 3). Maximum mean panicle weight (763.7 g m^{-2}) was recorded with application of silicon (T_2) whereas water stress alone (T_3) exhibited minimum mean value (358.8 g m^{-2}). In comparison with control (T_1), silicon application (T_2) improved panicle weight by 24.66% while water stress alone (T_3) reduced panicle weight by 41.43% and silicon + water stress (T_4) reduced panicle weight by 23.53%. Variation among the tested genotypes for panicle weight found to be significant. HRI-174 exhibited highest mean panicle weight (825.1 g m^{-2}) while lowest mean value (336.0 g m^{-2}) was noticed in SB. Dhan. Interaction between treatments and genotypes for panicle weight found to be significant. HRI-174 recorded maximum panicle weight (1114.2 g m^{-2}) with silicon application (T_2) whereas SB. Dhan recorded minimum panicle weight (170.4 g m^{-2}) with water stress alone (T_3). Dorairaj *et al*. (2020) reported similar results of significant increase in panicle weight of rice when silicon was applied as topdressing at the reproductive stage.

Number of filled grains m^{-2}. Significant difference was observed among the treatments for number of filled grains m^{-2} (Table 3). Application of silicon (T_2) has recorded significantly higher mean number of filled grains m^{-2} (39177) whereas water stress alone (T_3) has recorded the lowest mean number (17917). In comparison with control(T_1), silicon application (T_2) increased the of number of filled grains by 24.21%, while water stress alone (T_3) reduced number of filled grains by 43.20% and silicon + water stress (T_4) reduced number of filled grains by 18.39%. The tested genotypes have differed significantly for number of filled grains m^{-2}. HRI-174 recorded higher mean number of filled grains m^{-2}(35271) while lowest mean number (20208) observed in SB. Dhan. No significant interaction was observed between treatments and genotypes for number of filled grains m^{-2}. Least number of filled grains m^{-2} (7667) recorded in US-314 with water stress (T_3) while highest number of filled grains m^{-2} (49417) observed in IIRRH-148 with silicon application (T_2). The application of silicon might have led to higher grain filling through increased photosynthetic rate. The contribution of carbohydrates from photosynthetic activity for longer period might have resulted in efficient translocation of photosynthates into the sink (grain) thereby increased the number of filled grains. These results are in conformity with the findings of Meena *et al*. (2014).

Spikelets panicle^{-1}. Spikelet number panicle^{-1} is one of the most important yield components used to estimate rice yields. Data on number of spikelets panicle^{-1} pertaining to rice genotypes under different treatments is presented in Table 4. Results revealed significant variation between treatments for number of spikelets panicle^{-1}. Maximum mean number of spikelets panicle^{-1} (181) were counted with silicon application (T_2) while minimum mean number (103) were counted in water stress alone (T_3). In comparison with control (T_1), silicon application (T_2) improved number of spikelets panicle^{-1} by 16.34% while water stress alone (T_3) reduced number of spikelets panicle^{-1} by 33.74% and silicon + water stress (T_4) reduced number of spikelets panicle^{-1} by 18.48%. Significant differences were observed among the genotypes for number of spikelets panicle^{-1}. HRI-174 recorded highest mean number of spikelets panicle^{-1} (171) whereas US-314 recorded lowest mean number (104). No significant interaction was observed between treatments and genotypes for number of spikelets panicle^{-1}. IIRRH-148 recorded significantly higher number of spikelets panicle^{-1} (230) with silicon treatment (T_2) and US-314 recorded lowest number of spikelets panicle^{-1} (58) with water stress alone (T_3). The silicon fertilizer application has increased the number of spikelets panicle^{-1} (Deren and Datnoff 1994; Takahashi, 1995; Swe *et al*., 2021).

Grain yield (t ha^{-1}). The grain yield of a genotype depends on the total dry matter and its distribution after anthesis, as the major portion of the dry matter produced during post anthesis period is translocated to the panicle. Data on grain yield of rice genotypes revealed significant differences between treatments (Fig.1). Significantly highest mean grain yield (4.29 t ha^{-1}) was recorded with application of silicon (T_2) which is on par with control (3.88 t ha^{-1}) while lowest grain yield (2.29 t ha^{-1}) recorded with water stress alone (T_3). In comparison with control (T_1), silicon application (T_2) improved grain yield by 10.60% while water stress alone (T_3) reduced grain yield by 40.88% and silicon + water stress (T_4) reduced grain yield by 19.24%. The tested genotypes differed significantly for grain yield. 27P63 recorded highest mean grain yield (4.23 t ha^{-1}) which is on par with US312 (4.04 t ha^{-1}) and HRI-174 (4.04 t ha^{-1}) whereas SB. Dhan has exhibited lowest mean grain yield (1.81 t ha^{-1}). No significant interaction was noticed between treatments and genotypes for grain yield. SB. Dhan with water stress alone (T_3) recorded lowest grain yield (1.11 t ha^{-1}) whereas 27P63 with application of silicon (T_2) recorded highest grain yield (5.84 t ha^{-1}). Improvement in grain yield might be due to an enhanced growth, yield components and nutrient uptake of rice with the addition of Silicon. The yield increase through Si application was largely attributed to advantage gained in grain filling and grain weight because of better translocation of photosynthates (Rani and Narayanan 1994; Rani *et al*., 1997); Pati *et al*. (2016) also reported a significant increase in grain yield of rice with increasing silicon level.

Harvest index. Application of silicon and water stress treatments has non-significant effect on harvest index of rice (Table 4). No significant variation was observed among the tested genotypes for harvest index and interaction between treatments and genotypes found to be non-significant. Harvest index is in the order of water stress alone (T_3) > silicon application (T_2) > control (T_3) > silicon + water stress (T_4). Among the genotypes, SB. Dhan has recorded maximum harvest index (42.0%) while lowest harvest index (30.7%)noticed in DRR Dhan. IIRRH-148 with water stress alone (T_3) exhibited highest harvest index (52.8%) whereas IIRRH-148 with silicon + water stress (T_4) exhibited least harvest index (22.2%). Similar results of insignificant effects of silicon application on harvest index of rice was reported by Ahmad *et al*. (2013) ; Swe *et al*. (2021).

Table 1: Effect of silicon and water stress on days to physiological maturity and leaf area index of rice genotypes.

	Days to physiological maturity					Leaf area index at panicle initiation				
Genotypes	**T1**	**T2**	**T3**	**T4**	**Mean**	**T1**	**T2**	**T3**	**T4**	**Mean**
27P63	127	124	125	121	124	4.69	5.01	3.46	5.35	4.63
DRR Dhan-48	128	128	128	128	128	2.96	3.73	2.90	3.69	3.32
HRI-174	129	129	129	129	129	3.32	4.37	4.02	4.00	3.93
IIRRH-143	117	116	116	116	116	3.65	4.63	3.00	3.31	3.65
IIRRH-148	121	121	120	120	121	2.51	4.29	2.72	3.67	3.30
SB. DHAN	117	119	117	116	117	2.35	3.78	2.80	3.67	3.15
US-312	120	123	123	124	123	3.62	4.80	3.03	4.78	4.06
US-314	118	119	119	119	119	1.78	4.13	2.33	3.95	3.05
Mean	122	122	122	122	122	3.11	4.34	3.03	4.05	3.63
Treatment (T)	NS					0.72**				
Genotype (G)	2.85**					0.70**				
T × G	NS					NS				
CV (%)	1.87					18.61				

Table 2: Effect of silicon and water stress on SCMR values and total dry matter (g $hill^{-1}$) of rice genotypes.

	SCMR values at panicle initiation					Total dry matter at flowering (g $hill^{-1}$)				
Genotypes	**T1**	**T2**	**T3**	**T4**	**Mean**	**T1**	**T2**	**T3**	**T4**	**Mean**
27P63	38.4	36.2	36.0	37.9	37.1	25.1	26.5	21.6	24.5	24.4
DRR Dhan-48	37.4	37.3	37.5	39.8	38.0	27.0	30.6	20.6	25.4	25.9
HRI-174	40.2	42.8	40.8	39.9	40.9	24.4	39.7	21.0	28.3	28.4
IIRRH-143	42.1	45.5	41.0	43.7	43.1	28.4	32.1	23.0	28.3	28.0
IIRRH-148	41.1	44.1	41.3	40.7	41.8	26.6	37.3	22.4	28.8	28.8
SB. DHAN	41.7	44.0	41.7	44.8	43.0	28.0	34.1	17.8	24.0	26.0
US-312	42.0	42.5	38.9	42.7	41.5	25.8	32.6	20.7	28.9	27.0
US-314	45.4	45.3	44.0	44.1	44.7	28.0	30.9	19.4	27.5	26.5
Mean	41.0	42.2	40.1	41.7	41.3	26.7	33.0	20.8	27.0	26.9
Treatment (T)	NS					3.70**				
Genotype (G)	3.10**					NS				
T × G	NS					NS				
CV (%)	7.43					12.85				

Table 3: Effect of silicon and water stress on panicle(g m^{-2}) weight and number of filled grains $m^{-2}$of rice genotypes.

	Panicle weight (g m^{-2})					Number of filled grains m^{-2}				
Genotypes	**T1**	**T2**	**T3**	**T4**	**Mean**	**T1**	**T2**	**T3**	**T4**	**Mean**
27P63	607.9	770.4	378.8	430.8	547.0	36917	42083	17917	31917	32208
DRR Dhan-48	693.3	767.9	266.3	295.4	505.7	30167	42333	21167	25250	29729
HRI-174	974.6	1114.2	495.4	716.3	825.1	39167	45917	25000	31000	35271
IIRRH-143	577.1	764.2	317.1	343.3	500.4	34833	40583	10667	25917	28000
IIRRH-148	674.6	918.3	587.1	681.7	715.4	35833	49417	20000	25833	32771
SB.DHAN	324.6	516.3	170.4	332.9	336.0	22917	29000	15833	19417	21792
US-312	623.3	692.1	268.3	570.4	538.5	27750	37417	25083	24833	28771
US-314	425.4	566.3	387.1	376.7	438.9	24750	26667	7667	21750	20208
Mean	612.6	763.7	358.8	468.4	550.9	31542	39177	17917	25740	28594
Treatment (T)	197.8*					7696**				
Genotype (G)	124.7**					7100**				
T × G	187.4*					NS				
CV (%)	20.81					25.2				

Table 4: Effect of silicon and water stress on spikelets $panicle^{-1}$ and harvest index (%) of rice genotypes.

	Spikelets $panicle^{-1}$					Harvest index (%)				
Silicon	**T1**	**T2**	**T3**	**T4**	**Mean**	**T1**	**T2**	**T3**	**T4**	**Mean**
27P63	168	180	100	162	153	35.1	43.8	28.4	27.5	33.7
DRR Dhan-48	156	194	126	115	148	31.3	31.7	30.5	29.3	30.7
HRI-174	177	209	149	149	171	36.2	38.1	48.8	32.0	38.8
IIRRH-143	164	191	69	128	138	27.7	31.4	48.1	28.9	34.0
IIRRH-148	170	230	97	130	157	25.3	32.7	52.8	22.2	33.2
SB. DHAN	145	128	96	92	115	44.6	45.3	47.8	30.4	42.0
US-312	148	191	130	126	149	41.0	39.2	23.8	32.6	34.2
US-314	118	128	58	113	104	34.4	35.2	29.5	35.8	33.7
Mean	156	181	103	127	142	34.5	37.2	38.7	29.8	35.0
Treatment (T)	47.6**					NS				
Genotype (G)	33.3**					NS				
T × G	NS					NS				
CV (%)	21.5					20.6				

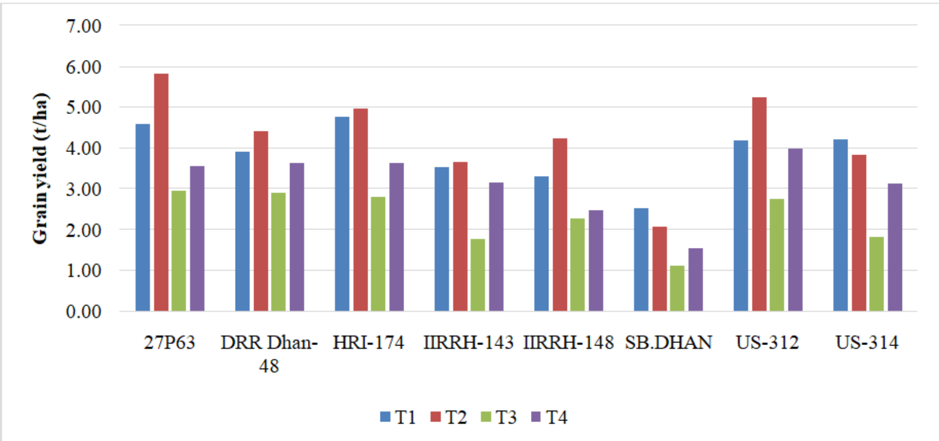

Fig. 1. Effect of silicon and water stress on grain yield of rice genotypes.

CONCLUSIONS

Silicon application has enhanced the growth and grain yield of rice under both well-watered and water stress conditions. Hence, silicon application can be adopted as a cost-effective strategy to enhance growth, development, grain yield and its attributes such as leaf area index, chlorophyll content, biomass, culm strength, grain number and panicle weight.

FUTURE SCOPE

It is still necessary to conduct further in-depth studies for better understanding of role of silicon in regulating plant metabolism under water stress conditions. Therefore, research work in future may be undertaken on plant metabolic processes that are affected by silicon particularly under drought.

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Conflict of Interest. None.

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