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Research Article

RESPONSE OF SILICON ON MEMBRANE STABILITY, PLANT WATER STATUS AND YIELD OF RICE GENOTYPES UNDER DROUGHT

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Abstract: A field experiment was conducted during *kharif* season of 2017 to study the effect of silicon on membrane stability, plant water status and yield of rice genotypes under drought at Department of Rice, Tamil Nadu Agricultural University, Coimbatore. It is observed from the present study, Maximum membrane stability index (MSI) (93.1) was observed in CB06803 and minimum (86.2) in CB08702 under the control, when drought influenced, Sahbhagidhan retained the maximum MSI (79.8) with lower Malondialdehyde (MDA) content (0.68 µmol g^{-1}) and IR64 fetched the lower MSI (67.6) with lower (MDA) (1.75 µmol g^{-1}). Foliar spray of Silicon (Silixol 0.6 %) under drought increased the MSI to maximum (88.4) in Sahbhagidhan wherein minimum (78.7) was observed in CB13805. In the aspect of plant water status, a greater decrease of 18% in RWC under drought, with lower the reduction in drought tolerant check Sahbhagidhan (14.5%). Foliar spray of silicon (Silixol 0.6%) under drought increased the RWC by 12% with greater the increase in genotype CB13805 (16.3%). However, under drought had greater adjustment in osmotic potential was observed in genotype CB12702 (0.674) while, foliar spray of silicon (Silixol 0.6%) under drought had reduced the osmotic adjustment with higher change in genotype CB06803 followed by susceptible check IR64.The grain yield per plant was observed with 30% under drought, a minimal reduction (1.9%) was observed in genotype CB13804. Foliar spray of silicon (Silixol 0.6%) under drought increased per plant yield by 23% with higher the increase (43%) in genotype CB12702. Irrespective of the genotypes, the foliar spray of silicon (Silixol 06 %) under drought enhanced the membrane stability and plant water status in the above genotypes indicating its importance for reducing the effects of drought and improves the drought tolerance mechanism rice.

Keywords: Rice, Drought, Silicon, Membrane stability, Plant water status, Osmotic potential, Grain yield

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Introduction

Rice demands a higher amount of water all over the life cycle as compared to other crops. Rice being a water loving crop got the higher sensitivity to water deficit stress by innate. Drought is a major challenge limiting rice production. It affects rice at physiological level by decline in photosynthetic rate, transpiration rate, stomatal conductance, water use efficiency, relative water content, chlorophyll content, photosystem II efficiency, membrane stability and abscisic acid content and thereby affects its yield [1]. Understanding of the various mechanisms governing the yield of rice under drought condition sets up a streamline in the selection or development of drought tolerant rice varieties.Stage specific water conditions are of prime importance for a good crop performance. Reproductive stage is the most critical phase for drought susceptibility, which can delay flowering in rice, reduce pollen viability, stigma receptivity, alters anthesis resulting in poor fertility, leading in filled and reduced grain production [2]. Silicon (Si) is the second most elements in earth by its abundance next to oxygen. Silicon (Si) has been reported to be effective in alleviating the adverse effects of various edaphic and epiedaphic stresses such as drought, plants generally take up Si in the form of soluble monosilicic acid H4SiO4[3]. Silicon can alleviate the water stress by decreasing transpiration by forming silicon cuticle double layer. Silicon deposition can reduce the transpiration rate by 30 percent in rice. Moreover, a tentative role of silicon-containing compounds in the osmotic adjustment should also be considered. Water leakage is mostly restricted by the formation of hydrophobic barriers in both aboveground and belowground organs. The fortification of cuticle by an additional silica layer remarkably decreases the rates of cuticular transpiration. Transpiration is then mostly restricted to stomata and should be projected in the increase of stomatal conductance, and an increase in total transpiration rates was also observed quite often [4]. The present study was therefore carried out with the hypothesis that exogenous Silicon supply attenuates the damaging effects of water stress in different rice genotypes aiming to understand the membrane stability, plant water status and yield changes under reproductive stage.

Materials and Methods

A field study was carried out in the field No.H8a of department of Rice, Tamil Nadu Agricultural University, Coimbatore to study the effect drought on membrane stability, plant water status and yield of selected rice genotypes and influence of silicon on physiology and yield of rice under drought stress. It was laid out in Factorial Randomized Block Design (FRBD) with three replications. The experiment included seven rice genotypes such as CB06803, CB08702, CB12702, CB13804 and CB13805, SAHABHAGI DHAN and IR 64 were used. The crop was sown on 14th July 2017 in raised seed bed. The 22 days old seedlings of rice genotypes were transplanted in main field on 5th August 2017 with two to three seedlings per hill on well puddled soil. The crop was treated with three treatments (Control, Drought+ No foliar spray and Drought+ Foliar spray (Silixol -0.6 %)). Drought was imposed by withdrawing of irrigation on treatment drought and foliar spray of siliconas SiliXol- Stabilised Orthosilicicacid(0.6%) under drought, plots from 12 days before flowering to 10 days after flowering. Irrigation was checked by bund and the seepage was prevented by placing of plastic sheets.

Table-1 Effect of Silicon on changes in membrane stability index (MSI) and Malondialdehyde (MDA) content (μmol g^{-1}) in rice genotypes under drought

Genotypes	Membrane Stability Index (MSI)			MDA (Malondialdehyde) content (μmol g^{-1})		
	Control	Drought	Drought + Silicon	Control	Drought	Drought + Silicon
CB06803	93.1	78.1	82.4	0.87	1.21	0.97
CB08702	86.2	73.5	81.5	0.71	1.17	0.81
CB12702	88.4	68.4	79.4	0.74	1.45	0.79
CB13804	91.6	76.2	85.3	0.76	1.23	1.14
CB13805	89.5	70.3	78.7	0.83	0.99	0.91
IR 64	90.7	67.6	83.6	0.74	1.75	1.11
SahbhagiDhan	91.2	79.8	88.4	0.68	1.51	1.12
Mean	90.1	73.4	82.8	0.76	1.33	0.98
	SEd		CD (0.05)	SEd		CD (0.05)
G	1.149		2.323	0.010		0.021
T	0.752		1.521	0.007		0.014
G x T	1.990		4.023	0.018		0.037

Table-2 Effect of Silicon on changes in Relative Water Content (RWC), Osmotic potential (MPa)and Osmotic adjustment in rice genotypes under drought

Genotypes	Relative Water Content (RWC)			Osmotic Potential (MPa)			Osmotic Adjustment		
	Control	Drought	Drought + Silicon	Control	Drought	Drought + Silicon	Control	Drought	Drought + Silicon
CB06803	94.22	77.87	90.93	-1.73	-2.18	-2.13	0	0.451	0.396
CB08702	89.15	73.17	81.59	-1.58	-1.80	-1.59	0	0.217	0.011
CB12702	89.87	74.74	87.02	-1.86	-2.54	-1.98	0	0.674	0.116
CB13804	92.33	78.49	85.85	-1.52	-1.68	-1.67	0	0.162	0.154
CB13805	91.64	70.54	84.27	-1.95	-2.00	-1.98	0	0.047	0.028
IR 64	92.78	72.13	83.78	-1.59	-2.00	-1.83	0	0.410	0.237
SahbhagiDhan	89.14	76.18	86.84	-1.63	-1.79	-1.63	0	0.160	0.003
Mean	91.31	74.73	85.75	-1.70	-2.00	-1.83	0	0.303	0.135
	SEd	CD (0.05)		SEd	CD (0.05)		SEd	CD (0.05)	
G	1.168	2.361		0.019	0.039		0.004	0.007	
T	0.765	1.546		0.013	0.025		0.002	0.005	
G x T	2.024	4.090		0.033	0.067		0.006	0.012	

Table-3 Effect of Silicon on changes in yield and yield components of rice genotypes under drought

Genotypes	Productive Tillers Per Plant			Spikelets per Panicle			Spikelet Fertility			Grain Yield (Kg ha^{-1})		
	Control	Drought	Drought + Silicon	Control	Drought	Drought + Silicon	Control	Drought	Drought + Silicon	Control	Drought	Drought + Silicon
CB06803	20.0	17.3	18.7	210	187	200	93.6	73.5	85.7	7043	5712	6528
CB08702	15.0	12.3	13.3	181	177	180	91.7	74.6	84.4	7616	5174	6582
CB12702	18.7	12.7	17.3	199	160	204	90.5	72.1	83.1	6653	4696	6482
CB13804	20.7	16.0	19.7	215	197	206	84.2	68.4	72.1	7309	6270	6983
CB13805	24.0	22.7	23.3	194	169	189	91.1	84.7	90.2	6997	4976	6505
IR 64	18.7	14.3	16.3	139	93	114	83.3	55.6	74.2	6523	5397	5904
SahbhagiDhan	18.7	14.3	15.7	200	169	189	87.2	76.1	82.0	7456	5545	6813
Mean	19.4	15.7	17.8	191	165	183	88.8	72.1	81.7	7085	5396	6543
	SEd		CD (0.05)	SEd		CD (0.05)	SEd		CD (0.05)	SEd		CD (0.05)
G	0.247		0.499	2.208		4.463	1.060		2.143	98.35		198.78
T	0.162		0.327	1.446		2.922	0.694		1.403	64.39		130.13
G x T	0.428		0.865	3.825		7.731	1.837		3.712	170.35		344.30

Buffer channels were made to drain out the water from drought imposed plots. Silicon as SiliXol- Stabilised Orthosilicic acid (0.6%) was given as foliar spray at 50 % flowering in middle of the drought. The following parameters were measured at end of stress period.

Membrane stability index (MSI)

Membrane stability index (MSI) was estimated as per [5],100 mg leaf material weighed and taken in two sets of test tubes containing 10 ml of double distilled water.

$$MSI\ (\%) = [1 - \left(\frac{C1}{C2}\right)]\ x\ 100$$

Relative water content

The relative water content (RWC) was estimated according to [6] and calculated by using following formula and expressed as per cent.

$$RWC = \left[\frac{(Fresh\ weight - Dry\ weight)}{(Turgid\ weight - Dry\ weight)}\right]\ x\ 100$$

Osmotic Potential (OP)

Osmotic potential observed by osmometer (Vapro Model 5520 Wescor Inc., Logan, UT, USA), and values obtained in mmol kg-1, converted to MPa (pressure unit) using the following equation.

$$Osmotic\ potential\ (MPa) = \frac{-R\ x\ T\ x\ Osmometer\ reading}{1000}$$

Where, R is the universal gas constant (0.0832) and
T is the temperature in degrees Kelvin

Osmotic adjustment

Osmotic adjustment was calculated as the difference in Osmotic Potential between the non-stressed control (well watered) and stressed treatment (droughted).

$$Osmotic\ adjustment\ =\ OP\ non-stressed\ -\ OP\ stressed$$

Where OP = Osmotic Potential at full hydration (turgor) status.

Malondialdehyde (MDA)

Malondialdehyde(MDA) content was estimated by following the procedure described by [7] and MDA content expressed in nmol g-1 fresh weight.

For assessing the relationship between yield and its components, the following parameters were recorded at harvest. The number of productive tillers plant-1was measured in each treatment, five plants were selected, labelled and the number of tillersproducing panicles at harvest stage was recorded.The total numbers of filled grains from the five randomly selected primary tillers of the tagged plants in each plot were counted and the mean values were expressed as number of filled grains panicle-1.Spikelet fertility readings are obtained from counts of well-developed spikelets in portion to total number of spikelets on five panicles. Spikelet fertility was calculated by using the formula.

$$Spikelet\ fertility\ \% = \frac{Number\ of\ fertile\ spikelet's}{Total\ number\ of\ spikelet's} x\ 100$$

The grain yield per plant was derived from the mean of five plants from each treatment and expressed in g plant-1. Grains from each plot were sun dried, weighed and adjusted to 14 per cent moisture content and the grain yield was expressed as kg ha-1. The straw obtained from each plot was sun dried and weighed. The straw yield was expressed as kg ha^{-1}.

The data collected were subjected to statistical analysis in Factorial Randomized Block Design (FRBD) [8].

Results and Discussion

Membrane Stability Index (MSI) and MDA (Malondialdehyde) content

Cell membrane remains the primary target of injury when they are exposed to stress. Stress increases the membrane permeability, leading to the greater electrolyte leakage. Present investigation shown that drought had decreased the membrane stability index (MSI) by 18.5%, whereas IR64, drought susceptible check has got the highest percentage of reduction (25%) [Table-1]. Drought induced ROS production, leading to imbalance of the production and scavenging may be decrease the membrane stability index. Foliar spray of silicon (Silixol 0.6%) under drought increased the MSI by 11% as an average in all the genotypes. Similar results were reported in studies [2]. Malondialdehyde(MDA) content in rice plant under drought increased by 40% as a response of membrane lipid peroxidation. Intensive damage of ROS produced by drought may lead to lipid peroxidation, producing more MDA under drought. In our study foliar spray of silicon (Silixol 0.6%) under drought decreased the lipid peroxidation by 15.6% [Table-1]. Silicon may reduce the damage to membrane through MDA formation (lipid peroxidation), by regulating the antioxidant defense in plants, maintaining the membrane integrity and decreasing membrane permeability [9]. Similar results were also reported in several studies of rice[10,11].

Plant water status-related parameters

Plant water status that includes leaf water potential, osmotic potential and relative water content (RWC) represents an easy measure of water deficit and provides best sensor for stress. Water stress reduces the osmotic potential of tissues in the plant which helps in maintenance of turgor potential for normal metabolic activities which has been recognized as basic mechanism of drought tolerance. Present study clearly states a decrease of 18% in RWC under drought, with lower the reduction in drought tolerant check Sahbhagidhan (14.5%). Foliar spray of silicon (Silixol 0.6%) under drought increased the RWC by 12% with greater the increase in genotype CB13805 (16.3%) [Table-2]. Osmotic potential and osmotic adjustment is an important trait in the evaluation of low land rice for drought tolerance. Current investigation shows that rice genotypes under drought shows greater adjustment in osmotic potential was observed in genotype CB12702 (0.674) while, foliar spray of silicon (Silixol 0.6%) under drought had reduced the osmotic adjustment with higher change in genotype CB06803 followed by susceptible check IR64 [Table-2].The higher water retaining ability during dehydration may be due to the osmolyte accumulation in the cells which is associated for maintenance of turgidity and cell membrane stability.Above arguments were supported by previous experiments [12].

Yield components

Number of productive tillers retained under stress is an important yield component that impacts on the grain yield of rice. A significant and positive correlation was found to exist between grain yield and panicle number and productive tillers. Productive tillers per plantaffected significantly under drought in rice. Among the rice genotypes used in the present study, mean reduction of 19% was observed under drought, with the lowest percentage of reduction (1.3%) in genotype CB13805. Foliar spray of silicon (Silixol 0.6%) under middle of drought increased the productive tillers by 11%, wherein a maximum increase (26%) was observed in genotype CB12702 [Table-3].

Spikelet number and spikelet fertility

Number of spikelets is closely related to the spikelet fertility under water stress conditions. The genotypes with increased spikelet sterility recorded less number of spikelets. Spikelets number per panicle decreased under drought by 14%, with lower the reduction (2.2%) in genotype CB08702. Foliar spray of silicon (Silixol 0.6%) under drought increased the spikelets per panicle by 10.5%, with higher the increase in genotype CB12702 (21.6%) [Table-3]. Water deficit around anthesis may reduce spikelet number, fertility of surviving spikelets and from anthesis to maturity, combined with rapid leaf senescence, reduction in duration and rate of grain filling. Foliar spray of silicon (Silixol 0.6%) under drought increased the filled grains per panicle by 20%, with higher the percentage increase (38%) in IR64. Similar results were reported by [13].

Grain yield

Grain yield is the result of the expression and association of several yield components. Present study revealed that the decrease in grain yield per plant was observed with 30% under drought, a minimal reduction (1.9%) was observed in genotype CB13804. Foliar spray of silicon (Silixol 0.6%) under drought increased per plant yield by 23% with higher the increase (43%) in genotype CB12702. Grain yield per hectare also shown a significant decrease under drought by 23%, with higher the reduction percentage (32%) in genotype CB08702. Foliar spray of silicon (Silixol 0.6%) under drought increased grain yield per hectare by 17%, with a higher increase (27.6) in genotype CB12702 [Table-3]. Silicon enhanced yield under drought may be due to the ability of sustain higher plant water status and membrane stability which tend to increase several components of yield including panicle length, weight, spikelet number, spikelet fertility and 1000 grain weight [14].

Conclusion

The overall result revealed that the study showed drought affects the reproductive stage of the rice drastically which is alleviated with the application of silicon resulting in the betterment of membrane stability, plant water status and yield attributes. SahbhagiDhan a drought tolerant check performed better on drought condition and all also in foliar application of silicon under drought.

Application of research: Genotypes CB12702, CB06803 and CB13804 showed better performance in drought even in the absence of silicon application while with these two genotypes CB13805 also shows a better performance with foliar spray of silicon under drought might be due to alteration in the several physiological and metabolic pathways by the involvement of silicon.

Research Category: Crop Physiology

Abbreviations:
FRBD: Factorial Randomized Block Design

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