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Efficacy of calcium silicate on morphological and yield of rice in salt affected soil

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Abstract
A pot experiment was conducted in the pot culture yard of the Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, during July-October, 2016. The experiment revealed that grain and straw yield was significantly enhanced on addition of silicon, organics and their combinations over control. The highest grain and straw yield was obtained with combined application of RDF + 100% (Si + RSC). The application of RDF + 100% (Si + RSC) registered the highest tiller count, leaf area index, root dry weight and root length. Based on the study, it is concluded that the application of RDF + 100% (Si @ 200 kg ha^{-1} + RSC @ 14.5 t ha^{-1}) is needed to achieve the improve the yield of rice in the soil.

Keywords: silicon, organics, rice yield and growth

1. Introduction

Salinity is a major actual abiotic stress. One of the most severe environmental problems affecting crop growth [1] and along with drought, it seems to be one of the world's most serious agricultural problems. Excess of soluble salts in the root zone negatively affects plant growth and yield through osmotic effects, nutritional imbalances and specific ion toxicities [2] due to the excessive build up of $Na^+$and Cl^- [3]. It is reported that Na^+ disturbs K^+ nutrition, which in turn inhibits enzyme activity [4]. While sodium (Na^+) is the dominant cation in saline soils which create physiological disturbance of crop [5]. The tissues of plants growing in saline media generally exhibit an accumulation of Na^+ and Cl^- and /or the reduced uptake of mineral nutrients, especially Ca^{++}, K^+, N, P and micronutrients [6]. Rice (*Oryza sativa L)*, a Halophytic plant, is adversely affected by salinity stress and yield losses of up to 45% have been reported [7]. Silicon can alleviate the adverse effects of salt stress on plants by increasing cell membrane integrity and stability through its ability to stimulate the plants antioxidant system [8]. Furthermore Si application can moderate the salinity and sodicity stress in plants and plays a multitude of roles in plant existence and crop performance and silicon is deposited in leaves leading towards decreased transpiration and hence dilutes salts accumulated in saline environment [9].

Another important practice is the application of organic matter conditioners, which can both ameliorate and increase the fertility of saline soils [10]. Both organic and inorganic amendments are found to be effective in the amelioration of saline soils. The best means of maintaining soil fertility, productivity and salt tolerance could be through addition of organic manures. Various organic amendments such as farmyard manure, compost, poultry manure and mulch can be used for the amelioration of saline soils. Salt affected soils generally exhibit poor structural stability due to low organic matter content. Many researchers have suggested that the structural stability of soil can be improved by the addition of organic materials [11]. There are evidences that soil amendments with organic manures reduce the toxic effects of salinity in various plant species [12]. Rice straw compost, poultry manure and FYM are the farm products which can be used for reclamation of saline soils as it offers an opportunity to improve the physico-chemical conditions of the soil and also to some extent improves soil fertility.

2. Materials and Methods

The pot experiment was conducted in the pot culture yard of the Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, during July-October, 2016. The experimental soil was collected from coastal area Parangipettai, Bhuvanagiri Taluk of Cuddalore District. The soil was clay loam with pH 8.34, EC 4.58 dS $m^{-1,}$ organic carbon 3.8 g/kg and available Nitrogen 190 kg ha^{-1}, Phosphorus10.4 kg ha^{-1}, potassium 134.2 kg ha^{-1} and Silicon 29.231 mg kg $^{-1}$. The soil samples were dried in shade, powdered with wooden mallet and sieved to pass through 2 mm sieve, thoroughly homogenized and used for the pot experiments. Twenty kilogram of air dried homogenized soil was filled in one foot cement pots and the following treatments were applied in completely randomized design with three replications. T_1 - Control (RDF), T_2 -RDF + Silicon (Si) @ 200 kg ha^{-1}, T_3 - RDF + Poultry manure (P.M) @ 6.5 t ha^{-1}, T_4 - RDF+ Rice straw compost (RSC) @ 14.5 t ha^{-1}, T_5 - RDF + FYM @ 12.5 t $ha^{-1,}$ T_6 - RDF + 100% (Si + P.M), T_7 - RDF + 100% (Si + RSC) andT_8 - RDF + 100% (Si + FYM). Calculated quantities of organic manures namely poultry manure (P.M) @ 6.5 t ha^{-1}, Rice straw compost (RSC) @ 14.5 t ha^{-1} and FYM @ 12.5 t ha^{-1} were incorporated into the soil as per the treatment schedule. The amount fertilizer dose using a schedule of 150: 50: 50 kg ha^{-1} of N: P_2O_5: K_2O were applied to pots. Nitrogen was applied in three split doses i.e., 50% as basal, 25% each at active tillering and panicle initiation stages. The entire dose of P_2O_5 and K_2O were applied basally as per the treatment schedule and Si was applied as per the treatment schedule in the respective pots with calcium silicate used 20-30 days before transplanting. Twenty five days old rice seedling var. ADT 43 were planted in the experiments pots at 10 hills pot^{-1} with 3 seedlings $hill^{-1}$. The soil samples were collected at each stage. At harvest stages, grain and straw yield were recorded and expressed as g pot^{-1}. While the plant sample was collected and observed morphological characters.

3. Results

3.1 Rice yield

On close examination of data on grain and straw yield furnished in table 1 showed that grain and straw yield was significantly enhanced on addition of silicon, organics and their combinations over control. Grain and straw yield ranged from (58.33 to 82.10 and 81.42 to 108.80 g pot^{-1}). The highest grain and straw yield was obtained with combined application of RDF + 100% (Si + RSC) T_7 (82.10 and 108.80 g pot^{-1}). It was significantly followed by T_8 (79.02 and 105.30 g pot^{-1}) and T_6 (75.92 and 101.74 g pot^{-1}). The percentage increase in grain yield (40.75 and 24.86: 33.63 and 20.63) was noticed with combined application of RDF + 100% (Si + RSC) and silicon alone compared to over control (T_1). With respect to organics alone application of RDF + RSC (T_4) recorded maximum grain and straw yield but superior to rest of organics treatments. The lowest grain and straw yield was observed in the absence of Si and organics (T_1).

3.2 Tiller count

Tiller production $hill^{-1}$ was significantly influenced on application of silicon, organics and their combinations over control at both stages table 2. The number of tillers $hill^{-1}$ at both stages and number of productive tillers $hill^{-1}$ was the highest with combined application of RDF + 100% (Si + RSC) (T_7). It was significantly followed by T_8 and T_6. With respect to organics alone application of (T_4) RDF + RSC recorded maximum tillers $hill^{-1}$ at both stages and number of productive tillers $hill^{-1}$ but superior to rest of organics treatments. The least number of tillers $hill^{-1}$ was noticed in plot, which received NPK alone.

3.3 Leaf area index

Silicon, organics and their combinations caused significant improvement in leaf area index (LAI) at tillering and panicle initiation stage over control (No silicon and organics) table 3. The highest LAI was noticed with combined application of RDF + 100% (Si + RSC) (T_7) at (3.34) Tillering stage at (9.44) Panicle initiation stage. It was significantly followed by T_8 and T_6. With respect to organics alone application of RDF + RSC (T_4) recorded highest LAI at both stages but compared to rest of the organics alone treatments.

3.4 Root architecture (Root length and dry weight)

Addition of silicon, organics and their combinations caused a significant influence on root length and dry weight at both the stages of crop growth over control (Table 4). Root length and dry weight increased with stages of crop growth. Root length and dry weight enhanced with addition of combined application organics and silicon. The highest root lengthand dry weight at tillering stage (24.85 cm and 4.70 g $plant^{-1}$) and panicle initiation stage (28.02 cm and 15.73 g $plant^{-1}$) was noticed with application of RDF + 100% (Si + RSC) (T_7). It was significantly followed by T_8 and T_6. Percent increase in root length and dry weight due to application of RDF + 100% (Si + RSC) over control and silicon alone treatments was to the tune of at tillering stage (58.68 and 34.36: 30.56 and 16.67) and at panicle initiation stage (57.12 and 33.12: 16.67% and 5.18%).With respect to organics alone, application of RDF + RSC (T_4) recorded maximum root length and dry weight at both stages but superior to rest of the organics alone treatment. The Root length and dry weight was the shortest which did not receive silicon and organics (T_1).

4. Discussion

4.1 Rice yield

Addition of graded dose of silicon or organics or combined application of silicon and rice straw compost cause a significant increase in grain and straw yield over control. The highest grain yield and straw yield was obtained with application RDF + 100% (Si + RSC). Grain yield response varied from 14.50 and 23.77 g pot^{-1} due to RDF + Silicon and RDF + 100% (Si + RSC) doses over control (Fig 1). The per cent increase in grain yield varied 24.86 and 40.75 and per cent increase in straw yield varied 20.63 and 33.63 due to RDF + Silicon and combined application of RDF + 100% (Si + RSC) over control (Fig 2). This increase in grain and straw yield might be attributed to the increase in growth and yield characteristics of rice and also due to the stimulating effect of Si in reducing biotic and abiotic stress. Results also revealed that Si helped plant growth, which might be due to the increased photosynthetic efficiency upon Si addition, and it was exerted through the number of productive tillers, panicle length, the percentage of filling grains, 1000 grain weight, and the reduction of pest and disease infestation. This corroborated the findings[13]. [14]Reported that application of Si was increased the grain yield 19-43% over the control in experiment 1 and 2-14% over the control in experiment 2. In the present study, addition of silicon through soil enhanced the leaf Si concentration and silicon in the soil which would have contributed to higher grain yield. This was supported by significant positive correlation between grain yield with Si content (r = 0.985**), Si uptake (r = 0.998**) and available Si (r = 0.997**). With respect to organics, application of RDF + RSC recorded highest grain (69.63 g pot^{-1}) and straw yield (94.66 g pot^{-1}) respectively and was superior rest of the organics treatments. The grain yield response due to organics 11.30 g pot^{-1}(Fig. 1). The per cent increase in grain yield 19.37 due to addition of RDF + RSC over control (Fig. 2). Enhanced grain and straw yield could be due to supply of nutrients especially macro and micronutrients which induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency, regulation of water to cells, conducive physical environment, facilitating to better aeration, root activity and nutrient absorption leading to higher rice yield [15].

4.2 Tiller production

Tillering capacity is one of the most important components responsible for increased crop production. Tiller production was significantly influenced by addition of silicon and organics over control. Maximum number of tillers was noticed in rice plants which received RDF + 100% (Si + RSC) (T_7). Tillering in the production of expanding auxiliary bud, which is clearly association with nutritional condition of the mother clump because tillers reserve carbohydrate and nutrients from the mother clump during early growth period and this was improved by silicon application [16] reported higher number of tillers count on silicon fertilization. The present result was confirmed by significant positive correlation existed between tiller count with available Si (r = 0.606**), Si content (r = 0.595**) and

Si uptake (r = 0.589**). Maximum number of tillers was noticed in rice plants which received RDF + rice straw compost @ 14.5 t ha^{-1}. Organic manures offers more balanced nutrition to the plant especially micronutrients which has caused better influence on tillering in plants grown with poultry manure and vermicompost. [17]reported increase in number of tillers in rice with organic manure application.

4.3 Leaf area index (LAI)

Addition of silicon or organics or both significantly enhanced the Leaf area index at tillering stage and panicle initiation stage over control. LAI was maximum with combined application of RDF + 100% (Si + RSC) (T_7). With respect to organics RDF + RSC @ 14.5 t ha^{-1} recorded maximum LAI compared to other treatment. Higher concentration of silicon either through soil increased Leaf areaindex. Higher leaf area index could be due to erectness of leaves. Silicon improves high interception of light by keeping leaves erect thereby stimulating canopy photosynthesis in rice [18], agreed with result of the present study. The present result was confirmed by significant positive correlation existed between LAI with available Si (r = 0.657**), Si content (r = 0.993**) and Si uptake (r = 0.999**). Balanced and gradual release of nutrients facilitated the plants to have maximum cell elongation or cell division rendering better size of leaves and also increased nutrient uptake to support growth has increased LAI on addition of different organics [19]. Reported increase in LAI on addition of organics.

4.4 Root architecture

Root length and weight improved significantly on addition of silicon or organics or both over control. Root length improved to the extent of 57 per cent over control while root weight increased by 30 per cent (tillering stage). Increase Root length and dry weight recorded with RDF + 100% (Si + RSC). Silicon nutrition, however, enhanced plant growth parameters and led to the prevention of lignin and the Na^+ accumulation in shoots, reduced levels of lipid peroxidation in the roots and higher levels of chlorophyll [20]. Showed that application of Si significantly increased the root dry mass of both maize cultivars under saline regimes. With respect organics, RDF + RSC recorded increase root length and dry weight. This may be associated with the improvement of biological activity in crop rhizosphere by amino acid and some physiological active substances in the organic sources [21]. In addition, plant root growth is greatly affected by soil environment. The incorporation of organic manure into soil can bring beneficial effects on crop root growth by improving physical and chemical environments of rhizosphere soil [22].

Table 1: Effect of silicon and organics on grain and straw yield of the rice crop (g pot^{-1})

Treatments	Grain Yield	Straw Yield
T_1 - Control (RDF)	58.33	81.42
T_2 - RDF + Silicon (Si) @ 200 kg ha^{-1}	72.83	98.22
T_3 - RDF + Poultry manure (P.M) @ 6.5 t ha^{-1}	63.23	87.52
T_4 - RDF + Rice straw compost (R.S.C) @ 14.5 t ha^{-1}	69.63	94.66
T_5 - RDF + FYM @ 12.5 t ha^{-1}	66.43	91.10
T_6 - RDF + 100% (Si + P.M)	75.92	101.74
T_7 - RDF + 100% (Si + R.S.C)	82.10	108.80
T_8 - RDF + 100% (Si + FYM)	79.02	105.30
SEd	1.29	1.79
CD @ 5%	2.77	3.30

Table 2: Effect of silicon and organics on the No. of tillers hill^{-1} at different growth stages

Treatments	Tillering stage	Panicle initiation stage	No.of productive tillers hill^{-1}
T_1 - Control (RDF)	6.33	10.10	9.60
T_2 - RDF + Silicon (Si) @ 200 kg ha^{-1}	8.08	12.90	12.70
T_3 - RDF + Poultry manure (P.M) @ 6.5 t ha^{-1}	6.84	10.80	11.60
T_4 - RDF + Rice straw compost (R.S.C) @ 14.5 t ha^{-1}	7.67	12.20	12.40
T_5 - RDF + FYM @ 12.5 t ha^{-1}	7.26	11.50	12.00
T_6 - RDF + 100% (Si + P.M)	8.55	13.60	13.10
T_7 - RDF + 100% (Si + R.S.C)	9.40	14.90	13.80
T_8 - RDF + 100% (Si + FYM)	8.98	14.20	13.40
SEd	0.10	0.12	0.14
CD @ 5%	0.20	0.24	0.28

Table 3: Effect of silicon and organics on the leaf area index at different growth stages

Treatments	Tillering stage	Panicle initiation stage
T_1 - Control (RDF)	2.07	6.05
T_2 - RDF + Silicon (Si) @ 200 kg ha^{-1}	2.82	8.01
T_3 - RDF + Poultry manure (P.M) @ 6.5 t ha^{-1}	2.28	6.58
T_4 - RDF + Rice straw compost (R.S.C) @ 14.5 t ha^{-1}	2.65	7.54
T_5 - RDF + FYM @ 12.5 t ha^{-1}	2.45	7.06
T_6 - RDF + 100% (Si + P.M)	3.01	8.50
T_7 - RDF + 100% (Si + R.S.C)	3.34	9.44
T_8 - RDF + 100% (Si + FYM)	3.17	8.97
SEd	0.07	0.16
CD @ 5%	0.15	0.36

Table 4: Effect of silicon and organics on the root length (cm) and dry weight (g) at different growth stages

Treatments	Tillering stage		Panicle initiation stage	
	Root length	Root dry weight	Root length	Root dry weight
T_1 - Control (RDF)	15.66	3.60	17.85	14.17
T_2 - RDF + Silicon (Si) @ 200 kg ha^{-1}	21.04	4.20	23.74	14.90
T_3 - RDF + Poultry manure (P.M) @ 6.5 t ha^{-1}	17.31	3.90	19.47	14.00
T_4 - RDF + Rice straw compost (R.S.C) @ 14.5 t ha^{-1}	19.79	4.10	22.32	14.60
T_5 - RDF + FYM @ 12.5 t ha^{-1}	18.55	4.00	20.89	14.30
T_6 - RDF + 100% (Si + P.M)	22.36	4.40	25.21	15.20
T_7 - RDF + 100% (Si + R.S.C)	24.85	4.70	28.02	15.73
T_8 - RDF + 100% (Si + FYM)	23.61	4.50	26.62	15.45
SEd	0.50	0.08	0.67	0.10
CD @ 5%	1.00	0.16	1.35	0.20

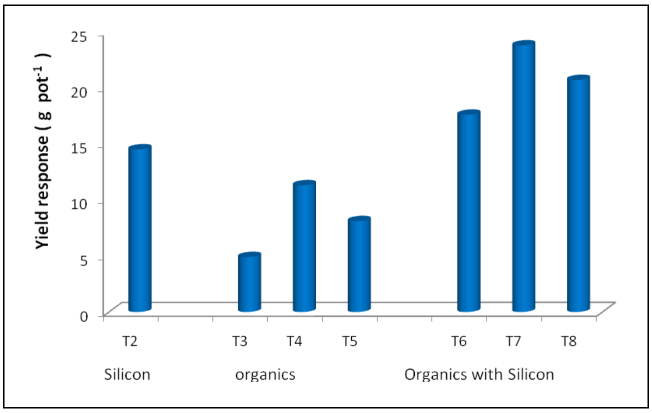

Fig 1: Grain yield response due to silicon, organics and silicon with organics

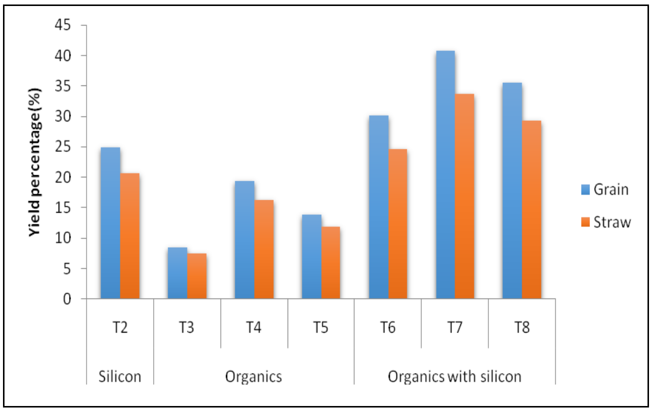

Fig 2: Percentage increase in Grain and straw yield due to silicon, organics and organics with silicon

5. Conclusion

The present investigation clearly indicated the beneficial role of silicon and organics applications in improving the yield of rice in coastal salt affected soils.

6. References

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