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EFFECT OF DIFFERENT SILICON SOURCES ON GROWTH AND YIELD OF RICE UNDER DIFFERENT ESTABLISHMENT METHODS

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Abstract

Field experiment was conducted during Kuruvai season (July-Nov., 2019) at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamilnadu, India to study the effect of different silicon sources on growth and yield of rice under different establishment methods. The experiment was laid out in split plot design with two replications. The main plots comprised of M_1- Dry Seeded Rice (DSR), M_2- Wet Seeded Rice (WSR) and M_3- Transplanted Rice (TR) and sub plots are S_1- RDF, S_2 **-** S_1 + 100 kg Si ha^{-1} through Calcium Silicate + SSB, S_3 - S_1 + 200 kg Si ha^{-1} through Calcium Silicate + SSB, S_4 - S_1 + 100 kg Si ha^{-1} through Diatomaceous Earth, S_5 - S_1 + 200 kg Si ha^{-1} through Diatomaceous Earth, S_6 - S_1 + 100 kg Si ha^{-1} through Fly ash + SSB and S_7 - S_1 + 200 kg Si ha^{-1} through Fly ash + SSB. Among the methods of establishments, transplanted rice recorded significantly higher growth (plant height, number of tillers hill^{-1}, chlorophyll content, leaf area index, root length, root volume and dry matter production) yield attributes (no. of panicles, no. of grains panicle^{-1} and test weight) and yield (grain and straw) of rice, which was followed by wet seeded rice, With regards to silicon sources, application of 200 kg Si ha^{-1} through Diatomaceous Earth along with RDF recorded higher values for growth and yield of rice. The Diatomaceous earth performed better than Fly ash + SSB (Silicate solubilising bacteria) and Calcium silicate + SSB. This was closely followed by S_4. The interaction effect between establishment methods and sources of silicon was significant. The treatment combination of diatomaceous @ 200 kg Si ha^{-1} earth along with RDF and transplanting method registered its superiority over others and recorded higher growth, yield attributes and yield of rice. Therefore it can be concluded that rice planted 15 × 10 cm and fertilized with Diatomaceous Earth @200 kg Si ha^{-1} + RDF is a viable practice to enhance the growth and yield of rice.

Key words: silicon sources, establishment methods, Rice, growth, yield.

Introduction

Rice is one of the most important cereal crops of the word. Rice is an excellent source of carbohydrate and provides protein to a certain extent to human diet. Hence it is used as a staple food for about half of the total world population. In Asia, 60-70 percent of people are getting their energy from rice and its derived products. As per USDA Global Market Analysis; 2018/19, Rice is cultivated worldwide in area of 162.41 million ha^{-1} with the production of 496.46 million tonnes, having the productivity of 4.56 tonnes ha^{-1}. In India, rice is grown about 44.16 million hectares having the annual production of 116.48 million tonnes with the productivity of 3.96 tonnes ha^{-1} (USDA, 2020) Rice production in India became vulnerable due to scarcity of farm labourers, changing climatic conditions coupled with frequent drought & flood, deteriorating soil health, unavailability of irrigation water during critical stages and inadequate supply of mineral nutrients.

In India, Rice cultivation is practiced predominantly under transplanting method that involves raising the seedlings in nursery, uprooting it and transplanting in the main field. Transplanting is a labour intensive, expensive operation and it consumes a large quantity of standing water for puddling (Bouman and Tuong, 2001). Climate change and depletion of ground water table rapidly causes scarcity of irrigation water and there is a threat to Asian rice growers to access adequate irrigation water in the future (Mahajan *et al*., 2013). This scarcity of irrigation water, threatens the sustainability of rice production in irrigated environments (Chauhan *et al*., 2012). Shortage of farm labourers during the peak season of rice transplanting in many rice growing regions of the Asia was also observed (Mahajan *et al*., 2013) which is aggravating the problem for rice production in irrigated

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environment. Shortage of the labourers at the time of transplanting results in delays in transplanting, lower grain yield and delays in sowing/planting of the next crop. Scarcity of irrigation water and shortage of farm labourers triggers the search for such alternative rice crop establishment methods having high water productivity than conventional puddled transplanting.

Direct seeding is an alternative method of growing rice instead of conventional transplanting. This can be done by sowing of pre-germinated seed into a puddled soil (wet seeding) or prepared seedbed (dry seeding). Direct seeding can be done either by hand broadcasting or by line sowing. Improved short duration and high yielding varieties, nutrient and weed management techniques encouraged the farmers to shift from traditional system of transplanting to direct seeded rice culture. It could reduce labour need by more than 20% in terms of working hour and 20% less water as compared to transplanted rice (Satter and Khan, 1994). Direct seeding eliminates the need for seedbed preparation, seedling uprooting and transplanting and the associated cost and energy, direct seeded rice reduced production cost and increased net return by 37 percent, in addition direct seeded rice mature about 8-10 days earlier (Isvilanonda, 2002). It reduces emission of greenhouse-gases and better growth of succeeding crops (Jagmohan Kaur and Avtar Singh, 2017). Therefore, it is imperative to identify the profitable rice establishment method for the current water and labour scarcity condition.

Silicon is a second most abundant element in the earth and fourth most important element for rice production in rice-growing countries of Southeast Asia, following N PK (Gong *et al*., 2012). Si has also been proven to be an "agronomically essential element" in Japan and silicate fertilizers have been applied to paddy soils (Ma *et al*., 2001) which could improve the yields and qualities of a large group of crops. Sufficient Si supply enhances the plants' strength and rigidity and improves defence against abiotic stresses (such as strong rain, wind, salinity and drought) and biotic stresses (such as attacks by insect pests and fungi (Guntzer *et al*., 2012). Plants with lower than the optimum supply of Si exhibit poor growth, development and reproduction with varying degrees depending on plant species and plants belonging to poaceae family are better accumulator of Si compared with other families (Ahmad *et al*., 2007). Rice is a higher Si accumulator, mainly in the form of amorphous Si dioxide particles (Ma and Takahashi, 2002). Si application produces more biomass which helps to improves light interception and photosynthetic efficiency. Addition of silicon strengthens the root canal and supply efficient oxygen to roots and also prevents water loss by evapotranspiration (Malav *et al*., 2018). Recently Si has been regarded as quasi-essential element for the growth of higher plants (Epstein, 2002). Reduced amount of silicon in plant produces necrosis, disturbance in leaf photosynthetic efficiency, growth retardation and reduces grain yield in cereals especially rice (Shashidhar *et al.,* 2008). Hence, Silicon nutrition might be an option to increase rice yields (Marxen *et al.,* 2016). At present silicon is supplemented through calcium silicate, potassium silicate, silica gel, basic slag and diatomaceous earth to rice crop. Even though they are all the effective source of silicon, which are costly. At the same time, an industrial waste like fly ash is used as a source of silicon and enhances the crop productivity (Jawahar and Vaiyapuri, 2009) and is beneficial to the poor farming community. Hence, it is essential to study the effect of certain traditional silicon fertilizers and fly ash as a source of silicon on rice crop. Keeping the above facts in consideration, the present investigation was carried out to study the effect of different silicon sources on growth and yield of rice under different establishment methods.

Materials and Methods

Field experiment was conducted in the northern block of Experimental Farm, Annamalai University during Kuruvai season (July-Nov., 2019) to study the effect of different silicon sources on growth and yield of rice under different establishment methods. The soil of the experimental field is clay loam in texture with moderate fertility. The experiment was laid out in split plot design with two replications. The main plots comprised of M_1- Dry Seeded Rice (DSR), M_2- Wet Seeded Rice (WSR) and M_3- Transplanted Rice (TR) and sub plots are S_1- RDF, S_2 - S_1 + 100 kg Si ha^{-1} through Calcium Silicate + SSB, S_3 - S_1 + 200 kg Si ha^{-1} through Calcium Silicate + SSB, S_4 - S_1 + 100 kg Si ha^{-1} through Diatomaceous Earth, S_5 - S_1 + 200 kg Si ha^{-1} through Diatomaceous Earth, S_6 - S_1 + 100 kg Si ha^{-1} through Fly ash + SSB and S_7 - S_1 + 200 kg Si ha^{-1} through Fly ash + SSB. Rice variety Co-51 was used for this study and was fertilized with 120:40:40 kg NPK ha^{-1}. Entire dose of P_2O_5 was applied as basal. N and K were applied in four equal splits at basal, tillering, panicle initiation and heading stages. Silicon sources and SSB were applied as basal as per the treatments. Biometric observations were recorded at critical stages. The data's were statistically analyzed as suggested by Gomez, (1979).

Results and Discussion

Growth attributes

Silicon sources and establishment methods significantly influenced the growth attributes of rice (Table 1). Among the establishment method, transplanted rice registered it superiority over wet and dry seeded rice and recorded

Table 1: Effect of silicon sources and establishment methods on Plant height, No. of tillers hill^{-1}, Chlorophyll content, LAI, Root length, Root volume and DMP of Rice.

Treatmetns	Plant height at harvest (cm)	No. of tillers hill^{-1}	Chlorophyll content at flowering stage (mg g^{-1})	LAI at flowering	Root length (cm)	Root volume (cm^3)	DMP at harvest (kg ha^{-1})
Main Plot (M)							
M1	85.55	11.74	4.25	3.87	17.26	22.7	10840.8
M2	92.23	12.60	4.95	4.47	23.06	28.9	11459.8
M3	94.98	12.91	5.14	4.74	25.2	30.9	11695.97
MEAN	90.92	12.41	4.78	4.36	21.84	27.50	11332.2
S.Ed	0.84	0.10	0.05	0.62	0.65	0.64	77.33
CD (p=0.05)	2.56	0.30	0.13	1.96	1.95	1.92	232
Sub Plot (S)							
S1	83.87	11.26	4.63	3.69	20.21	24.34	10312.3
S2	86.32	11.65	4.68	3.93	20.78	25.32	10705.59
S3	91.32	12.40	4.78	4.37	21.85	27.55	11343.31
S4	95.35	13.15	4.87	4.81	22.89	29.64	11954.36
S5	97.63	13.55	4.93	5.05	23.53	30.6	12367.65
S6	89.4	12.16	4.75	4.19	21.43	26.62	11147.77
S7	92.59	12.67	4.8	4.52	22.20	28.44	11494.4
MEAN	90.92	12.41	4.78	4.36	21.84	27.50	11332.2
S.Ed	0.68	0.08	0.014	0.12	0.15	0.31	62.33
CD (p=0.05)	1.98	0.25	0.04	0.43	0.44	0.94	187
M × S							
CD (p=0.05)	4.54	0.55	0.17	2.39	2.39	2.86	419
S × M							
CD (p=0.05)	3.46	0.32	0.20	0.27	2.00	2.00	266.64

significantly higher values for plant height (94.98 cm), number of tillers hill^{-1} (12.91), chlorophyll content (5.14 mg g^{-1}), leaf area index (4.74), root length (25.20 cm), root volume (30.90 cm^3) and dry matter production (11695.97 kg ha^{-1}). This could be due to transplanting in puddle soil ensures optimal spacing for proper plant growth and good spacing can enhance the root growth and uptake of applied nutrients resulted in tiller plant, increase tiller numbers and LAI. Therefore seedlings planted in puddle soil produced more dry matter production (Mazid, *et al*., 2003). This was followed by wet seeded rice and recorded the plant height of 92.23 cm, number of tillers hill^{-1} of 12.60, chlorophyll content of 4.95 mg g^{-1}, leaf area index of 4.47, root length of 23.06 cm, root volume of 28.90 cm^3 and dry matter production of 11459.8 kg ha^{-1}. Dry seeded rice produced lesser growth attributes of rice among the establishment method. Regarding to silicon sources, Diatomaceous Earth showed better results over Fly Ash and Calcium Silicate.

Among the levels of silicon, application of 200 kg Si ha^{-1} through Diatomaceous Earth along with recommended dose of fertilizers registered its superiority over others. It recorded higher plant height (97.63 cm), number of tillers hill^{-1} (13.55), chlorophyll content (4.93 mg g^{-1}), leaf area index (5.05), root length (23.53 cm), root volume (30.6 cm^3) and dry matter production (12367.65 kg ha^{-1}), which was followed by 100 kg Si ha^{-1} through Diatomaceous Earth along with recommended dose of fertilizers. Higher growth attributes with 200 kg Si ha^{-1} through Diatomaceous Earth along with recommended' dose of fertilizers could be due to increased availability of silicon and other nutrients in the soil, enhanced root growth and uptake of mineral nutrients by the crop. Silicon helps in increase the erectness of leaves thereby increasing photosynthetic capacity which results in higher plant height (Fallah, 2012). Tillering is the production of expanding auxiliary bud which is clearly associated with nutritional condition of the mother clump during early growth period arid this was improved by silicon application (Liang *et al*., 1994). The highest leaf area index (LAI) and chlorophyll content of rice due to erectness of leaves and synthesis of chloroplast resulted in higher concentration of chlorophyll per unit area of leaf tissue. Highest root length and root volume of rice due to increased cell division, elongation and expansion caused by silicon. The 'maintenance of high photosynthetic activity and higher utilization of light and translocation of assimilated product to sink this could be the possible reasons for increased dry matter production (Rani and Narayanan, 1994). Application of 200 kg Si ha^{-1} through

Table 2: Effect of silicon sources and establishment methods on yield attributes and yields of Rice.

Treatments	Yield attributes			Yield (kg ha^{-1})	
	No. of panicles m^{-2}	No. of grains $panicle^{-1}$	Test Weight (g)	Grain	Straw
Main Plot (M)					
M1	385.27	97.93	17.55	4568.93	7967.86
M2	463.26	101.38	17.57	5278.36	8726.64
M3	490.26	105.14	17.58	5564.64	9030.93
MEAN	446.26	101.48	17.57	5131.31	8575.14
S.Ed	8.42	0.96	NS	89.33	101.
CD (p=0.05)	25.27	2.8	NS	268	303
Sub Plot (S)					
S1	389.21	94.83	17.48	4473.83	7596.33
S2	408.05	97	17.51	4745.67	8004.5
S3	449.15	101.57	17.56	5132.17	8426.83
S4	481.95	105.67	17.63	5585.5	9368.83
S5	499.94	107.67	17.65	5745.83	9819.33
S6	433.60	100.33	17.54	4988.17	8245.17
S7	461.94	103.33	17.60	5248	8565
MEAN	446.26	101.48	17.57	5131.31	8575.14
S.Ed	5.42	0.67	NS	48.33	60.67
CD (p=0.05)	16.28	1.92	NS	145	183
M × S					
CD (p=0.05)	41.55	4.72	NS	413	486
S × M					
CD (p=0.05)	27	4	NS	160	187

Fly ash + SSB along with recommended dose of fertilizers was next in order which recorded the plant height of 92.59 cm, number of tillers $hill^{-1}$ of 12.67, chlorophyll content of 4.8 mg g^{-1}, leaf area index of 4.36, root length of 21.84 cm, root volume of 27.50.84 cm^3 and dry matter production of 11332.2 kg ha^{-1}. This was on par with 200 kg Si ha^{-1} through Calcium Silicate + SSB plus recommended dose of fertilizers. Slow release of silicon nutrition and minimum availability of plant available Si to rice plant during critical stages causes somewhat lesser growth attributes Fly ash and Calcium Silicate applied plots over Diatomaceous Earth. The lesser values for growth attributes rice was recorded under recommended dose of fertilizers alone due to lack of availability of silicon nutrition. Among the interaction effect between establishment methods and sources of silicon, the treatment combination of diatomaceous @ 200 kg Si ha^{-1} earth along with RDF and transplanting method recorded higher values for growth attributes of rice due to the favourable soil condition and adequate supply of silicon and other nutrients during the critical stages of crop growth.

Yield attributes and yield

Yield attributes and yield of rice was significantly increased with Silicon sources and establishment methods (Table 2). Rice seedling planted in puddle soil recorded significantly higher yield attributes (no. of panicles- 490.26, no. of grains $panicle^{-1}$ -105.14) and test weight-17.58 g) and yields (grain- 5546.64 and straw-9030.93 kg ha^{-1}) of rice over other establishment methods (wet and dry seeding). Higher yield attributes and yields in transplanted rice might be due to the Optimal plant spacing, ensure air circulation, adequate availability of water and nutrients and also better light interception and higher photosynthetic efficiency of rice. (Baloch *et al*., 2002). Similar finding was also reported by earlier researchers (Kundu, *et al*., 1993). Wet seeded rice was next in order and recorded the no. of panicles 463.26, no. of grains $panicle^{-1}$ of 101.38 and test weight of 17.57 g. It also recorded the grain yield of 5275.57 kg ha^{-1} and straw yield of 8731.79 kg ha^{-1}. Seeds sown on the dry pulverized soils recorded lesser yield attributes (no. of panicles-385.27, no. of grains $panicle^{-1}$-97.93 and test weight-17.55 g) and yields (grain-4568.93 and straw-7967.86 kg ha^{-1}) of rice. Among the silicon sources, Diatomaceous Earth recorded higher yield attributes and yield of rice, followed by Fly Ash and Calcium Silicate. Application of Diatomaceous earth @ 200 kg Si ha^{-1} along with recommended dose of fertilizers recorded higher number of panicles m^2 (499.94), number of grains $panicles^{-1}$ (107.67), Test weight (17.65 g), grain (5745.83kg ha^{-1}) and straw yield (9819.33kg ha^{-1}) of rice. Panicle formation is directly related to number of productive tillers $plant^{-1}$, application silicon enhanced the number of productive tillers which resulted in more panicle number per unit area (Chaudhary and Bodiuzzaman, 1992). Increased growth attributed enhanced the photosynthetic activity of rice and caused higher number of filled grains. Application of silicon through Diatomaceous Earth increased the availability soil nutrient, enhanced uptake which improved the growth of plants and production of photosynthetic materials and translocation of photosynthate from source to sink. The cumulative effect of these parameters together with improved translocation led to higher grain yield and straw yield of rice. This treatment was followed by 100 kg Si ha^{-1} through Diatomaceous Earth along with recommended dose of fertilizers. Application of 200 kg Si ha^{-1} through Fly ash + SSB along with recommended dose of fertilizers was next in order. This was on par with 200 kg Si ha^{-1} through Calcium Silicate + SSB plus recommended dose of fertilizers. The lesser yield attributes (no. of panicles-389.21, no. of grains panicle^{-1}-94.83 and test weight-17.48 g) and yields (grain- 4473.83 and straw- 7596.33 kg ha^{-1}) of rice was recorded with recommended dose of fertilizers alone. Among the interaction effect between establishment methods and sources of silicon, the treatment combination of diatomaceous @ 200 kg Si ha^{-1} earth along with RDF and transplanting method recorded higher values for yield attributes and yields of rice. It could be due to higher availability of nutrients and water in the soil and increased growth components resulted in higher and yield attributes and yields of rice. Based on the results of this present study, it can be concluded that rice planted 15 × 10 cm and fertilized with Diatomaceous Earth @200 kg Si ha^{-1} + RDF is a viable practice to enhance the growth and yield of rice.

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