Silicon Sources on Yield and Economics of Rice under Different Methods of Establishment

Phurailatpa Pooja Sharma[1] & *S.Jawahar[2]
[1]Ph.D. Scholar & [2]Assistant Professor in Agronomy,
Faculty of Agriculture, Annamalai University,
Annamalainagar, Tamilnadu- 608002, India.
*Corresponding author Email: jawa_au@yahoo.com

ABSTRACT

Field experiment was carried out to study the effect of different silicon sources on yield and economics of rice under different methods of establishment during Kuruvai season (July – Nov,2019) at Department of Agronomy, Annamalai University, Tamilnadu, India. The treatments were arranged in split plot design, having two replications. The main plots are 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 highest yield attributes and yield 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 highest values for yield attributing characters and yield of rice. Diatomaceous Earth performed better than application of Fly ash + SSB (Silicate solubilising bacteria) and Calcium Silicate with SSB. Addition of Diatomaceous Earth @ 200 kg Si ha^{-1} along with RDF was closely followed by S_4. Among the interaction, the treatment combination of diatomaceous earth @ 200 kg Si ha^{-1} along with RDF and transplanting method registered its superiority over others and recorded higher values for no. of panicles m^{-2} 487.94, no. of grains panicle^{-1} - 111.7, test weight - 17.83g) and yields (grain - 6392 and straw - 9591 kg ha^{-1}) of rice. Regarding economics, rice fertilized with 200 kg Si ha^{-1} through Diatomaceous Earth along with RDF (M_3S_5) under transplanting method recorded higher gross income (Rs. 92680) followed by M_3S_4 which recorded the gross income of Rs. 88460. However, fertilization of 100 kg Si ha^{-1} through Diatomaceous Earth along with RDF in wet seeded (M_3S_4) rice recorded the highest net income of Rs. 46894 and BCR of 2.22. Therefore it can be concluded that cultivation of rice under wet seeded method and fertilized with 100 kg Si ha^{-1} through Diatomaceous Earth along with RDF will be a recommend practice to rice growers under water and labour deficit condition.

Key words: silicon sources, establishment methods, Rice, yield attributes, yield, economics

INTRODUCTION

Rice is the highly essential staple foods for nearly fifty per cent of the world's population. It is mostly grown in Asian continent. Rice produces higher grain yield than wheat and maize. Rice is deeply engraved in the rich tradition and culture of India. India stood second ranked in production, lagging behind China. In India, the overall production of rice is 115.60 million tonnes during 2018-19. Rice has certainly increased about 2.69 million tonnes production in 2018-2019 than comparing the production of 112.91 million tonnes in 2017-2018 (Anonymous, 2019). Transplanting of rice seedling is practiced predominantly in India due to higher productivity. Due to increasing water scarcity for agriculture as well as higher inputs cost, transplanting of rice leads to major problem in some countries like India and China (Choudhary *et al.,*2010).Therefore, direct seeded rice is the only method to reduce the water flows. Direct seeding is the age old method of rice cultivation and offers several advantages such as low-input demand like it saves more of labour cost, requires lesser amount of water, formation of less drudgery, early growth and maturity, low input cost, good soil conditions, lesser emission of methane and better growth of succeeding crops etc (Ramesh and chandrasekaran, 2007). At present, direct seeding of rice has been widely adopted by rice farmers in Asia as an alternative crop cultivation method to transplanting for better economic and technical reasons

(Choudhary *et al*., 2010). Therefore, it is necessary to identify the profitable rice establishment method for the current water and labour scarcity condition.

Rice crop respond well to mineral nutrients especially silicon under stress conditions. Silicon (Si) is a major constituent of Earth crust and second abundant element after oxygen. Silicon offers multiple stress resistance to crop plant such as biotic (pest and diseases) and abiotic stresses (salt stress, drought stress, nutrient imbalance, metal toxicity, radiation damage, high temperature and freezing) (Meharg and Meharg, 2015). Si application to plant increases the thickness layer of plant cell walls. Addition of silicon would improve the yield of crops and deposition of the silicon under the leaf epidermis offer defence from physical mechanism, reduces lodging, increases photosynthesis capacity, decreases transpiration losses and also offer resistance against pests and diseases (Korndörfer et al., 2004). Rice accumulates more amount of silicon as amorphous Si dioxide particles (Ma and Takahashi 2002). Since 20th century Si has been recognized as an agronomically essential element and silicate fertilizers has been applied to paddy soils in Japan. Depletion of silicon in plant leads plant cell death, disturbance in leaf photosynthetic efficiency, reduces in growth and reduction in rice grain yield (Shashidhar *et al.,* 2008). Lesser quantity of plant available form of Si in the soil leads to declining yields. Hence, Si fertilization is beneficial for sustainable rice production and also for getting higher income (Ning *et al*., 2014). Therefore, the present experiment was aimed to study the effect silicon sources on yield and economics of rice under different methods of establishment.

MATERIALS AND METHODS

Field experiment was conducted at Department of Agronomy , Annamalai University, Tamilnadu, India during Kuruvai season (July – Nov2019) to study the effect of different silicon sources on yield attributes (No. of panicles m^{-2}, No. of grains panicle^{-1} and test weight), yield (grain and straw) and economics of rice under different methods of establishment. The treatments were arranged in split plot design and replicated thrice. The main plots are 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 grown as test variety for this study. Rice crop 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 4 equal splits at basal, maximum tillering stage, panicle initiation stage and heading stage. Silicon sources and SSB were applied as basal as per the treatments. Biometric observations were recorded at harvest and economics were worked out based on the inputs cost, labour charges and market value of the produces. The data's were statistically analyzed as suggested by Gomez (1979).

RESULTS AND DISCUSSION

Yield attributes and Yield

Silicon sources and methods of rice establishment significantly influenced the yield attributing characters and yield of rice (Table 1 and 2). Among the methods of establishment, transplanted rice registered the higher yield attributes (number of panicles m^{2}- 430.14, number of grains panicles^{-1} - 105.26, test weight-17.74g) and yields (grain-5632 and straw-8842 kg ha^{-1}) of rice. This is due to proper plant spacing makes uniform growth of plants, better availability nutrients in the soil and uptake of those essential elements by the crop as well as effective translocation of photosynthates from the source to sink resulted in more panicle numbers m^{-2}, number of filled grains panicles^{-1} and test weight which improved the grain and straw yield of rice (Vinay Kumar *et al.,* 2018). This is in agreement with Mazid, *et al*.(2003) who reported that the higher panicle no. m^{-2} in transplanting method could be due to optimum plant spacing, which help the crop for proper growth and increased the tillers numbers hill^{-1} over other planting methods. Higher photosynthetic activities and assimilate partitioning enhanced the filled grains panicle^{-1} and test weight of rice (Kundu, *et al*., 1993). Higher grain and straw yield in transplanting after puddling also due to optimal plant spacing ensure air circulation, water and light which are basic factors necessary for photosynthesis (Baloch *et al*., 2002). This was followed by wet seeded rice and recorded the number of panicles m^{2} of 402.42, number of grains panicles^{-1} of 102.56, test weight of 17.73g, grain yield of 5337 and straw yield of 8617 kg ha^{-1}. The lowest yield attributes (number of panicles m^{2} - 361.47, number of grains panicles^{-1} 96.1, test weight - 17.71g) and yields (grain - 4612 and straw 7852 kg ha^{-1}) were observed in direct seeded rice. It could be due to lesser availability of water throughout the cropping period, exposure of seeds to pest destruction, higher weed infestation and lesser utilization of applied nutrients resulted in poor growth attributes which caused lowest yield attributes and yield in dry seeded rice. This is lined with the results of Vinay Kumar *et al.*(2018).

Among the silicon sources, diatomaceous earth @200 kg Si ha^{-1} + RDF registered its superiority over other levels and recorded highest yield attributes (number of panicles m^{2} - 458.16, number of grains panicles^{-1} - 107.5, test weight - 17.82g) and yields (grain – 5931 and straw - 9161 kg ha^{-1}) of rice (Table 1 and 2). This might be due to higher solubility and availability of silicon in diatomaceous earth compared to other silicon sources (Fraysse *et al.*, 2009) which increased the uptake of silicon and other elements by the crop resulted in higher yield attributes and yield of rice. Increased availability and sustained supply of silicon in the soil in the plant available form of ortho silicic acid to the crop and its synergistic effect with other nutrients which ultimately lead to better photosynthetic activity by the crop and resulted in higher yield attributes and yield of rice (Berthelsen *et al*.,2003). Similar results were earlier reported by Sandhya *et al.* (2018). Panicle formation is directly depends on number of productive tillers hill^{-1}. Application silicon through diatomaceous earth significantly enhanced the productive tillers hill^{-1}, which caused more number of panicles per m^{2}. Better assimilation of carbohydrate in panicles may enhance the filled grains number. Higher test weight was attributed to better availability and translocation of nutrients as well as photosynthates from the source to sink. These results are accordance with the findings of Jawahar and Vaiyapuri (2013) and Pati *et al.* (2016). Addition of diatomaceous earth as Si source increased the availability of NPK&Si in the soil and improved their uptake by rice which enhanced the growth attributes and improved the photosynthetic activity of the plant resulted in increased biomass production and these factors coupled with efficient translocation of photosynthates resulted in more number of filled grains and increased test weight which ultimately led to higher grain and straw yield of rice (Bharathiraja, 2014). This was followed by diatomaceous earth @100 kg Si ha^{-1} + RDF. Application of 200 kg Si ha^{-1} through Fly ash + SSB plus RDF was next in order with was on par with 200 kg Si ha^{-1} through Calcium Silicate + SSB + RDF. The lowest yield attributes (no. of panicles m^{-2} - 341.49, no. of grains panicle^{-1} - 94.7, test weight - 17.64g) and yields (grain- 4436 and straw -7680 kg ha^{-1}) were recorded under recommended fertilizers alone due to lack of availability and uptake of silicon nutrition. Among the interaction between rice establishment methods and silicon sources, transplanted rice applied with diatomaceous earth @ 200 Si kg ha^{-1} along with RDF registered its superiority over other treatment combinations, which recorded highest yield attributes (no. of panicles m^{-2} - 487.94, no. of grains panicle^{-1} - 111.7, test weight - 17.83g) and yields (grain - 6392 and straw - 9591 kg ha^{-1}) of rice. It was followed by wet seeded rice applied with diatomaceous earth @ 100 Si kg ha^{-1} + RDF. The lowest yield attributes and yields were recorded under dry seeded rice. This could be due to improper arrangements of plants in row, lesser availability water and higher weed growth and also due to reduced availability silicon and other nutrients resulted in minimum yield attributes and yield of rice.

Economics

Silicon sources and rice establishment methods greatly influenced the economics of rice (Table 3). Among the treatment combinations, transplanted rice applied with diatomaceous earth @ 200 Si kg ha^{-1} + RDF recorded higher gross income (Rs 92680) of rice due to highest grain and straw yield over others. This was followed by application of silicon @ 100 kg ha^{-1} through diatomaceous earth in transplanted rice and registered the gross income of Rs 88460. However, the higher net income of Rs. 46894 was recorded in wet seeded rice fertilized with diatomaceous earth @ 100 Si kg ha^{-1} + RDF followed by diatomaceous earth @ 200 Si kg ha^{-1} + RDF in wet seeded rice and recorded the net income of Rs 46546. Regarding BCR, the highest BCR of 2.22 was registered under diatomaceous earth @ 100 Si kg ha^{-1} + RDF in wet seeded rice which was followed by wet seeded rice fertilized with 200 kg Si ha^{-1} through Fly ash + SSB + RDF which registered the BCR of 2.19. The highest net income and BCR at wet seeded rice + diatomaceous earth @ 100 Si kg ha^{-1} + RDF might be due to lesser cost of cultivation over transplanted rice applied with diatomaceous earth @

200 Si kg ha^{-1} + RDF. Though Fly ash@200 kg ha^{-1} + SSB+RDF in wet seeded rice recorded lesser yields over diatomaceous earth @ 200 Si kg ha^{-1} in transplanted rice, the BCR is comparable or almost equal to diatomaceous earth @ 100 Si kg ha^{-1} + RDF in wet seeded rice. This could be due to very lesser cost of cultivation, in particular the input cost for fly ash (Jawahar, 2011). The lesser net income (Rs. 21735) was recorded in dry seeded rice fertilized with100 kg Si ha^{-1} through Calcium Silicate + SSB +RDF, whereas the least BCR of 1.5 was observed in 200 kg Si ha^{-1} through Calcium Silicate + SSB+RDF due to higher cost of cultivation over RDF alone, fly ash and diatomaceous earth applied plot . Hence it can be concluded that cultivation of rice under wet seeded method and fertilized with 100 kg Si ha^{-1} through Diatomaceous Earth along with RDF is a viable practice to rice growers under water and labour deficit condition.

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Table 1. Effect of Silicon Sources on Yield Attributes of Rice under Different Methods of Establishment

Treatments	No. of panicles m^{-2}				No. of grains $panicle^{-1}$				Test weight (g)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	297.89	359.95	366.62	341.49	91.50	95.50	97.10	94.70	17.62	17.64	17.65	17.64
S_2	319.96	369.95	389.95	359.95	92.70	97.50	99.40	96.53	17.65	17.67	17.68	17.67
S_3	359.95	399.28	429.95	396.39	94.50	103.50	106.50	101.50	17.71	17.73	17.74	17.73
S_4	404.62	432.61	476.61	437.95	100.30	106.50	109.60	105.47	17.77	17.79	17.80	17.79
S_5	426.61	459.94	487.94	458.16	102.30	108.50	111.70	107.50	17.8	17.82	17.83	17.82
S_6	346.62	386.62	413.28	382.17	93.30	102.20	105.20	100.23	17.68	17.70	17.71	17.70
S_7	374.62	408.61	446.61	409.95	98.10	104.20	107.30	103.20	17.74	17.76	17.77	17.76
Mean	361.47	402.42	430.14		96.10	102.56	105.26		17.71	17.73	17.74	
	M	S	S x M	M x S	M	S	S x M	M x S	M	S	S x M	M x S
S.Ed	8.89	5.00	9.33	13.89	0.90	0.57	1.10	1.47	NS	NS	NS	NS
CD (P=0.05)	26.67	15.00	28.00	41.67	2.69	1.72	3.20	4.41	NS	NS	NS	NS

Table 2. Effect of Silicon Sources on Grain and Straw Yield of Rice under Different Methods of Establishment

Treatments	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1	3861	4605	4843	4436	7060	7823	8156	7680
S_2	4152	4866	5182	4733	7242	8198	8528	7989
S_3	4523	5290	5650	5154	8004	8616	8833	8484
S_4	5123	5874	6100	5699	8270	9094	9160	8841
S_5	5365	6020	6392	5926	8478	9414	9591	9161
S_6	4453	5226	5504	5061	7849	8374	8654	8292
S_7	4807	5460	5758	5342	8066	8800	8971	8612
Mean	4612	5334	5633		7852	8617	8842	
	M	S	S x M	M x S	M	S	S x M	M x S
S.Ed	98	63	118	161	74	64	59	139
CD(P=0.05)	294	188	354	482	223	193	177	416

Table 3. Effect of Silicon Sources on Economics of Rice under Different Methods of Establishment

Treatment combinations	Total cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	BCR
M_1S_1	34033	57253	23220	1.68
M_1S_2	39483	61218	21735	1.55
M_1S_3	44483	66803	22320	1.50
M_1S_4	36833	74869	38036	2.03
M_1S_5	39633	78223	38590	1.97
M_1S_6	34583	65738	31155	1.90
M_1S_7	34683	68776	34093	1.98
M_2S_1	35755	67688	31933	1.89
M_2S_2	41205	71450	30245	1.73
M_2S_3	46205	77386	31181	1.67
M_2S_4	38555	85450	46895	2.22
M_2S_5	41355	87674	46319	2.12
M_2S_6	36305	76312	40007	2.10
M_2S_7	36405	79780	43375	2.19
M_3S_1	44130	71115	26985	1.61
M_3S_2	49580	75894	26314	1.53
M_3S_3	54580	82283	27703	1.51
M_3S_4	46930	88460	41530	1.88
M_3S_5	49730	92687	42957	1.86
M_3S_6	44680	80206	35526	1.79
M_3S_7	44780	83825	39045	1.87