



Influence of zinc and silicon through fly ash along with silicate solublizing bacteria on yields, NPKSi uptake and economics of rice

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Abstract

Field experiments were carried out during kuruvai (July,2019) and Navarai (March,2020) to study the influence of zinc and silicon through fly ash along with silicate solublizing bacteria on yields, NPKSi uptake and economics of rice. The treatments comprised of T₁-RDF, T₂- T₁ + 25 kg ZnSO₄ ha⁻¹, T₃- T₂ + 50 kg Si ha⁻¹, T₄- T₂ + 100 kg Si ha⁻¹, T₅- T₂ + 150 kg Si ha⁻¹, T₆- T₂ + Silicate Solublizing Bacteria, T₇- T₃ + Silicate Solublizing Bacteria, T₈- T₄ + Silicate Solublizing Bacteria and T₉- T₅ + Silicate Solublizing Bacteria. The experiments were laidout in randomized block design and replicated thrice. Among the various treatments tried, T₉ (25 kg ZnSO₄ ha⁻¹ +150 kg Si ha⁻¹+ Silicate Solublizing Bacteria) recorded higher yields (grain and straw), NPKSi uptake and economics of rice. The treatment T₈ (25 kg ZnSO₄ ha⁻¹ +100 kg Si ha⁻¹+ Silicate Solublizing Bacteria) was next order. Based on two season experiment, it concluded that rice applied with RDF + 25 kg ZnSO₄ ha⁻¹ +150 kg Si ha⁻¹+ Silicate Solublizing Bacteria is economically viable practice to enhance the productivity, NPKSi uptake and profitability of rice.

Keywords: ZN, SI, rice, yield, nutrient uptake, economics

Introduction

Rice is known as highly essential staple foods for more than 50% of global population and its yearly population holds the key to world food security. At present, the global population is 7.6 billion and they are getting energy from 2817.20 million tonnes of cereals grains and their derived products. Among them rice alone contributes 496.40 million tonnes which is grown in 162.06 million hectares. The expected world population in 2050 will be 10 billion. Therefore, there is need to enhance the rice production by 30% to meet the demand. In India, rice occupies 44.16 million hectares and produced 116.48 million tonnes of grains with the productivity 3.96 tonnes ha⁻¹ (USDA, 2020). Rice productivity is greatly affected by different factors such as, flood, drought, salinity, alkalinity, intensive cropping, soil degradation, pests, diseases and macro & micro nutrient deficiency and their toxicity (Hollier *et al.*, 1993). Among the factors, inadequate application of macro & micro nutrients significantly affects the rice productivity.

An effective nutrient management practices are much essential for increasing and sustaining crop yields at high levels (Gruhn *et al.*, 2000) [5]. In recent years, scientists started focusing their attention on Zn and Si nutrition due to their beneficial role on crops especially on rice. In India, zinc is considered as the fourth major yield governing nutrient next to nitrogen, phosphorus and potassium (Singh and Singh, 2019) [17]. Zinc deficiency in rice soils has been reported widely in many regions of the world. In India, 47% soils are found deficiency in Zinc, whereas 57% in Tamilnadu (Muthukumaraja and Sriramachandrasekharan, 2012). Soil application of zinc increased the grain yield and foliar zinc application increased the grain zinc concentration (Yerokun and Chirwa, 2014) [24]. When rice was grown in different types of soil, up to 90% difference was found in grain Zn concentration in the same rice varieties. Rice is extremely sensitive to Zinc deficiency and Zinc limits the growth, yield and quality of rice crop (Graham *et al.*, 1999) [4].

Silicon (Si) is the second most abundant element in the earth's crust and it is considered as beneficial element for crop production, especially for the crops belongs to poaceae family (Savant *et al.*, 1997) [16]. Silicon is the only element known that does not damage plants with excess accumulation. Rice is a higher silicon accumulating plant. Silicon supply is much essential for healthy growth and economic yield of the rice crop (Epstein, 1999) [2]. Silicon interacts with other nutrients in the soil and improved their agronomic performance, efficiency and yield response, it also improved the tolerance of rice under abiotic and biotic stresses (Singh *et al.*, 2020). In India, about 80-million metric tons of Fly Ash is generated from195 thermal power stations annually, but a smaller portion of ash is used for preparation of bricks, cements and ceramics (Mishra *et al.*, 2007). Fly Ash has been used widely as a source of plant nutrients especially silicon and enhanced the yields of many crops (Manisha

Basu *et al.*, 2009). The beneficial role of fly ash as silicon source was reported by Jawahar and Vaiyapuri (2010) and Balasubramaniam (2019). When Silicon is applied through fly ash along with silicate solublizing bacteria (SSB) which improved the soil fertility, nutrients uptake and higher up rice yield by releasing more amount of silicon available to crops which also offered defence against biotic stresses (Han and Lee, 2005 and Pedda Ghouse *et al.*, 2016) [6, 14]. As far as rice crop is concerned, a very few works has been done on the combined effect of Zinc and Silicon nutrition on the productivity of rice especially nil when silicon applied through lignite fly ash along with SSB. Keeping the above facts in consideration, the present experiments were carried out to study the influence of zinc and silicon through fly ash along with silicate solublizing bacteria on yields, NPKSi uptake and economics of rice.

Materials and Methods

Field experiments were carried out during kuruvai (July,2019) and Navarai (March,2020) at Department of Agronomy, Annamalai University, Tamilnadu State, India to study the influence of zinc and silicon through fly ash along with silicate solublizing bacteria on yields, NPKSi uptake and economics of rice. There were nine treatments viz., T₁-RDF, T₂- T₁ + 25 kg ZnSO₄ ha⁻¹, T₃- T₂ + 50 kg Si ha⁻¹, T₄- T₂ + 100 kg Si ha⁻¹, T₅- T₂ + 150 kg Si ha⁻¹, T₆- T₂ + Silicate Solublizing Bacteria, T₇- T₃ + Silicate Solublizing Bacteria, T₈- T₄ + Silicate Solublizing Bacteria and T₉- T₅ + Silicate Solublizing Bacteria. The experiments were laidout in randomized block design and replicated thrice. Rice variety CO51 was used for this study. The recommended dose of 120:40:40 kg N, P₂O₅, K₂O ha⁻¹ was applied uniformly to all the treatment plots. Entire P₂O₅ was applied at the time of transplanting as basal and N and K were applied in four equal splits at basal, tillering, panicle initiation and heading stages. Zinc and Silicon were basally applied as per treatment through Zinc Sulphate and Fly Ash, respectively. SSB was applied by mixing with sand as per treatment. Biometric observations were recorded at harvest. The total cost of cultivation and prevailing market price of grain and straw were taken into consideration to work out gross and net income per hectare. The BCR was worked out for various treatments by dividing the gross income by cost of cultivation. The data's were statistically analyzed as suggested by Gomez (1979) [3].

Results and Discussion

Yields

The perusal of the data furnished in Tables 1 showed the influence of Zinc and Silicon through Fly ash along with SSB on yields of rice. Among the treatment imposed in this study, the higher rice grain (4745 & 5210) and straw (8280 & 8989) yields (kg ha⁻¹) were obtained under RDF + 25 kg ZnSO₄ ha⁻¹ +150 kg Si ha⁻¹ through Fly ash + Silicate Solublizing Bacteria during both kuruvai and navarai seasons. When Zinc alone applied along with RDF (T₂), it recorded the per cent increase in grain yield of 7.15 and 7.82 % over RDF during both kuruvai and navarai seasons, respectively and when silicon was applied along with RDF, it recorded the per cent increase in grain yield of 14.0 and 15.60 % under T₃, 20.16 and 21.79 % under T₄, and 30.52 and 31.84 % under T₅ during kuruvai and navarai seasons, respectively. Similarly, When Zinc was applied along with SSB + RDF (T₆), it recorded the per cent increase in grain yield of 25.37 and 25.98 % over RDF during both kuruvai and navarai seasons, respectively. However, when Zinc and Silicon through Fly ash along with SSB were applied together, it recorded the per cent increase in grain yield of 41.30 and 37.15 % under T₇, 49.13 and 41.90 % under T₈, and 54.30 and 45.53 % under T₉ during kuruvai and navarai seasons, respectively. The same trend of results were observed for straw yield in both kuruvai and navarai seasons. The higher yield at RDF + 25 kg ZnSO₄ ha⁻¹ +150 kg Si ha⁻¹ through Fly ash + Silicate Solublizing Bacteria could be due to involvement of zinc fertilization in several metallic and enzymatic systems, regulatory functions in the plant system and production of auxin (Sachdev *et al.*, 1988) [15], it also improved carbohydrates synthesis and its transport to the grains (Pedda Babu *et al.*, 2007) [13]. Higher zinc content in in the rhizosphere supplies more of Zn to the plant and enhanced the number of effective tillers hill⁻¹ and improved grain filling resulted higher grain yield (Jena *et al.*, 2006) [8]. Similarly, Increase in grain and straw yield due to Silicon could be attributed to beneficial role of silicon on higher growth and yield attributing characteristics of rice and also due to lesser biotic and abiotic stresses (Jawahar *et al.*, 2015 and Sowbika, 2018) [7, 19]. This is accordance with the results of Muthukumararaja *et al.* (2019) [11]. Further application of application SSB solubilized more of silicon from from flyash and improved the availability of silicon to the plant and caused higher grain as well as straw yield.

Table 1: Influence of zinc and silicon through fly ash along with silicate solublizing bacteria on grain and straw yield (kg ha⁻¹) of rice

Treatments	Yields (kg ha ⁻¹)			
	Kuruvai Season		Navarai Season	
	Grain	Straw	Grain	Straw
T ₁	3075	6624	3580	7415
T ₂	3295	6894	3860	7665
T ₃	3505	7124	4130	7885
T ₄	3695	7339	4360	8074
T ₅	4075	7725	4720	8450
T ₆	3855	7510	4510	8235

T ₇	4345	7926	4910	8660
T ₈	4595	8117	5080	8835
T ₉	4745	8280	5210	8989
S. Ed	81.68	88.61	75.24	81.63
CD (P=0.05)	165	179	152	165

Nutrient Uptake

On close examination of the data furnished in the Tables 2 and 3 showed that the combined application of Zinc and Silicon through Fly ash with SSB significantly improved nutrient uptake (N,P,K and Si) of rice. Among the treatment, application of RDF + 25 kg ZnSO₄ ha⁻¹ +150 kg Si ha⁻¹ through Fly ash + Silicate Solublizing Bacteria recorded the highest nutrient uptake (N,P,K and Si) in both seasons. It recorded the N,P,K and Si uptake of 116.16,21.51,108.21 and 196 kg ha⁻¹ during kuruvai season and 129.90,24.35,112.05 and 207.0 kg ha⁻¹ during navarai season, respectively. The treatment T₈ was next in order for nutrient uptake which recorded the N,P,K and Si uptake of 112.96,20.66,104.92 and 185 kg ha⁻¹ during kuruvai season and 126.70,23.60,109.55 and 190.0 kg ha⁻¹ during navarai season. This result was conformity with the findings of Sudha and Stalin (2015) [21], who reported that Zn application increased the accumulation of amino acids and nutrient metabolism in plant tissue and enhanced their uptake by rice plant. Further, Silicon application enhanced the nutrient uptake due to fertilized plant gained maximum benefits of ample N uptake (Singh *et al.*, 2005) [18]. Subrahmanian and Gopalswamy (1991) [20] reported that increased phosphorous uptake with silicon application could be due to release of absorbed P by anion exchange and also the enhancing P availability with addition of silicon, thereby elevating P uptake. Higher K uptake due to Si could be due to the positive response of higher silicon application towards potassium can be linked to silicification of cell wall (Singh *et al.*,2005) [18]. This is in line with Chanchhareonsook *et al.* (2002) who stated that combined application of NPK and Si to rice significantly improved the total NPK uptake. Application of flyash along with SSB released more amount of plant available silicon to crop there by higher Si uptake was observed under application of RDF + 25 kg ZnSO₄ ha⁻¹ +150 kg Si ha⁻¹ through Fly ash + Silicate Solublizing Bacteria. This was agreement with the results of Pedda Ghouse *et al.* (2016) [14]. This is also due to increased root growth and enhanced soil silicon availability. These findings are in agreement with the earlier reports of Kalyan Singh *et al.* (2006) [9]

Table 2: Influence of zinc and silicon through fly ash along with silicate solublizing bacteria on NPK and Si uptake (kg ha⁻¹) of rice during Kuruvai season

Treatments	Nutrient Uptake (kg ha ⁻¹)			
	N	P	K	Si
T ₁	92.99	15.59	87.38	120
T ₂	95.91	16.41	90.10	130
T ₃	98.76	17.20	92.95	142
T ₄	102.02	18.11	95.15	159
T ₅	106.87	19.26	99.77	149
T ₆	104.22	18.66	97.27	164
T ₇	109.46	19.94	102.12	176
T ₈	112.96	20.66	104.92	185
T ₉	116.16	21.51	108.12	196
S.Ed	1.10	0.28	1.06	2.97
CD (P=0.05)	2.23	0.57	2.15	6.0

Table 3: Influence of zinc and silicon through fly ash along with silicate solublizing bacteria on NPK and Si uptake (kg ha⁻¹) of rice during Navarai season

Treatments	Nutrient Uptake (kg ha ⁻¹)			
	N	P	K	Si
T ₁	106.44	17.81	90.0	126
T ₂	109.56	18.73	92.96	135
T ₃	112.71	19.60	95.84	147
T ₄	115.56	20.42	99.04	168
T ₅	120.59	21.86	103.98	158
T ₆	117.61	21.07	101.02	175
T ₇	123.49	22.75	106.80	187
T ₈	126.70	23.60	109.55	190
T ₉	129.90	24.35	112.05	207
S.Ed	1.02	0.33	0.99	3.71
CD (P=0.05)	2.07	0.67	2.0	7.5

Economics

Among the different treatments imposed on rice (Tables 4 and 5), addition of RDF + 25 kg ZnSO₄ ha⁻¹ + 150 kg Si ha⁻¹ through Fly ash + Silicate Solublizing Bacteria registered more gross return (Rs. 69965 and Rs. 76719), net return (Rs. 32742 and Rs. 39496) and BCR (1.88 and 2.06) of rice. This might be due to higher biological yield (grain and straw) of the rice with lesser cost of cultivation. This was followed by RDF + 25 kg ZnSO₄ ha⁻¹ + 100 kg Si ha⁻¹ through Fly ash + SSB which recorded the gross return of Rs. 67852 and Rs. 74875, net return of Rs. 30678 and Rs. 37702 and BCR of 1.83 and 2.01 during kuruvai and navarai season, respectively. The least economics were recorded with an application of RDF alone.

Table 4: Influence of zinc and silicon through fly ash along with silicate solublizing bacteria on economics of rice during Kuruvai season

Treatments	Cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	BCR
T ₁	35930	46599	10669	1.30
T ₂	36623	49729	13106	1.36
T ₃	36673	52689	16016	1.44
T ₄	36723	55374	18651	1.51
T ₅	36773	60700	23927	1.65
T ₆	37073	57625	20552	1.55
T ₇	37123	64411	27288	1.79
T ₈	37173	67852	30679	1.83
T ₉	37223	69965	32742	1.88

Table 5: Influence of zinc and silicon through fly ash along with silicate solublizing bacteria on economics of rice during Navarai season

Treatments	Cost of cultivation (Rs.)	Gross income (Rs.)	Net income (Rs.)	BCR
T ₁	35930	53955	18025	1.50
T ₂	36623	57845	21222	1.58
T ₃	36673	61575	24902	1.68
T ₄	36723	64754	28031	1.76
T ₅	36773	69810	33037	1.90
T ₆	37073	66865	29792	1.80
T ₇	37123	72490	35367	1.95
T ₈	37173	74875	37702	2.01
T ₉	37223	76719	39496	2.06

Conclusion

Hence, it can be concluded that combined application of RDF + 25 kg ZnSO₄ ha⁻¹ + 150 kg Si ha⁻¹ through Fly ash + Silicate Solublizing Bacteria significantly improved the yields, NPKSi uptake and BCR of rice and it can be recommended as a viable practice to boost the overall productivity of rice.

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