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Phurailatpa Pooja Sharma and S. Jawahar

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Effect of Zinc and Fly Ash as Source of Silicon in Combination with Silicate Solubilizing Bacteria on Productivity of Rice

Phurailatpa Pooja Sharma[1] and S. Jawahar*[2]

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ABSTRACT

Field experiment were conducted at Annamalai University, Experimental farm, Annamalai University, Tamil Nadu State, India in Kuruvai and Navarai seasons during July 2019 – March 2020 to study the effect of Zn and Fly ash as source of silicon in combination with silicate solubilizing bacteria on productivity of rice. There are nine treatments viz., T_1- Recommended dose of fertilizers (RDF), T_2- T_1 + $ZnSo_4$ @ 25 kg ha^{-1}, T_3- T_2 + Si @ 50 kg ha^{-1} through Fly Ash (FLA) T_4- T_2 + Si @ 100 kg ha^{-1} through FLA, T_5- T_2 + Si @ 150 kg ha^{-1} through FLA, T_6- T_2 + Silicate Solublizing Bacteria (SSB), T_7- T_3 + SSB, T_8- T_4 + SSB and T_9- T_5 + SSB. The treatments were arranged in randomized block design and with three replications. Among the different treatments, T_9- T_5 + SSB registered the higher values for growth attributes (plant height - 105.21 and 115.16 cm , number of tillers hill^{-1}- 13.27 and 15.61, chlorophyll content - 5.34 and 6.74 mg g^{-1}, leaf area index - 7.21 and 8.83 and dry matter production (DMP) - 9436 & 9633 kg ha^{-1}), yield attributes (number of panicles m^{-2}- 544 and 602, number of grains panicles^{-1} - 110 and 121 and test weight - 16.69 and 17.89 g) and yields (grain-4745 and 5210 kg ha^{-1} and straw - 8280 and 8989 kg ha^{-1}) of rice, which was followed by T_8 - T_4 + SSB. Thus, it can be concluded that cultivation of rice fertilized with RDF + $ZnSO_4$ @ 25 kg ha^{-1} + Si @ 150 kg ha^{-1} through FLA + SSB is a viable practice to enhance the growth, yield attributing characters and yield of rice.

Key words**:** Zn, Silicon, SSB, Rice, Growth, Yield

Rice is a most important field crops in the world. It is a main source of calories intake and also the staple food for about 90 per cent of the world. The world population has grown at an exponential rate, so the demand for rice consumption has increased. At present, the global population is 7.6 billion and they are getting energy from 2817.20 m.t of cereals grains and their derived products. Among them rice alone contributes 496.40 m.t which is grown in162.06 m. ha. 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 m. ha^{-1} and produced 116.48 million tonnes of grains with the productivity 3.96 tonnes ha^{-1} [1]. Climate changes such as, unexpected temperature rise, rainfall fluctuations and extreme weather affects the crop productivity including rice at worldwide [2-3]. Rice production is affected by various factors such as drought, flood, salinity, alkalinity, soil degradation, intensive cropping, insect pests, diseases and nutrient deficiency and toxicity. Among them, deficiency of macro and micro nutrients affects the productivity at a greater extent. An effective soil nutrient management is much necessary in crop production, responsible for increasing and sustaining crop yields at high levels [4]. Good nutrient management is a key factor for rice crop. Any deficiency, especially at the critical stages leads to the maximum reduction in the final yield. Now a day's Zinc (Zn) and Silicon (Si) are the essential and beneficial element which gets the attention of the scientist due to their important role in rice production and also their deficiency in the paddy soils all over the world. Intensive cropping, soil degradation, frequent flood, crop residues removals and inadequate application of Zn and Si fertilizers caused their deficiency in soils. Therefore, Zn and Si management is essential for sustainable production of rice.

Zinc (Zn) is a fourth important nutrient after NPK that influences more on crop yields and it plays an important role in rice nutrition [5]. Soil with available Zn of 0.6 mg kg^{-1} is good for rice production which is also the critical limit of Zn [6]. Application of Zinc enhances rice yield ranged from 12 - 180% when compare to control [7]. Rice is more sensitive to Zn deficiency which drastically affects the yields. The availability of Zn in the soil is very low and it has been reported widely in rice growing areas of the world. Zinc deficiency was first diagnosed in rice in the calcareous soils of northern states of India [8] and it is the most deficient micronutrient in Indian soils [9-10]. At present, 47

* S. Jawahar
jawa.au@gmail.com

[1-2] Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar - 608 002, Tamil Nadu, India

per cent of the Indian soils were reported as Zn deficient [11]. Therefore, it causes yield reduction in rice and also causes Zn malnutrition in human beings [12]. Hence, it is essential to supply adequate quantities of zinc to rice to enhance the yield and to overcome malnutrition.

Silicon (Si) is the second most abundant element of the earth's surface and plays a significant role in imparting abiotic biotic, biotic stress resistance and enhancing the crop productivity [13]. Silicon increases vegetative growth, decreases transpiration rate and also improves crop yield and quality of the produces [14]. Silicon is much necessary for stable grain yield in rice [15]. Silicon nutrition showed positive effect on growth of leaves, stems, roots and plants sheaths especially in rice which also improves entry of light inside of crop canopy by keeping the plant erect [16]. Plants absorb silicon as ortho silicic acid from the soil and it is supplemented to crops through various organic and inorganic sources. Fly ash is among the one. Fly ash (FLA) is a waste obtained from thermal power stations. In India, there are 103 thermal power stations all over the country which produces 217 million tonnes of fly ash annually [17]. Disposal of fly ash is a biggest challenge which causes air pollution and hazardous to human being. However, it has been used as a source of plant nutrients especially silicon and enhanced the yields of many crops [18]. The beneficial effect of fly ash as a source of silicon was reported by [19-20]. But the supply of plant available silicon from fly ash is very slow. When fly ash is applied as silicon source along with silicate solubilizing bacteria, it improved the soil fertility and increased the yield by supplying more of plant available silicon also offered defense against various insect pest and diseases [21-22]. As far as rice is concerned, integrated use of Zn and Si through FLA with SSB was not documented widely. Therefore, experiments were carried out to study the effect of Zn and Fly ash as source of silicon in combination with silicate solubilizing bacteria on productivity of rice.

MATERIALS AND METHODS

Field experiments were conducted during July, 2019 - March, 2020 in the Experimental Farm, Annamalai University, India during Kuruvai and Navarai seasons experimental field soil was clay loam with moderate fertility. There are nine treatments viz., T_1- Recommended dose of fertilizers (RDF), T_2- T_1 + $ZnSo_4$ @ 25 kg ha^{-1}, T_3- T_2 + Si @ 50 kg ha^{-1} through Fly Ash (FLA) T_4- T_2 + Si @ 100 kg ha^{-1} through FLA, T_5- T_2 + Si @ 150 kg ha^{-1} through FLA, T_6- T_2 + Silicate Solublizing Bacteria (SSB), T_7- T_3 + SSB, T_8- T_4 + SSB and T_9- T_5 + SSB. The treatments were arranged in randomized block design and with three replications. Rice variety Co-51 was used for this study. The recommended dose of 120:40:40 kg N, P_2O_5, K_2O ha^{-1} was applied uniformly to all the treatment plots. Entire P_2O_5 was applied at the time of transplanting as basal and N&K were applied in four equal splits. The amount of Zinc and Silicon based on treatment was calculated and applied through Zinc Sulphate and Fly Ash, respectively. Biometric observations such as plant height, number of tillers $hill^{-1}$, DMP and yields were recorded at harvest whereas LAI and chlorophyll content were recorded at flowering stage. The data were statistically analyzed as suggested by Gomez [23].

RESULTS AND DISCUSSION

Growth attributes

Integrated application of Zn and Si through FLA with SSB significantly influenced the growth attributes of rice. The highest values on growth attributes were recorded under combined application of $ZnSO_4$ @ 25 kg ha^{-1} + Si @ 150 kg ha^{-1} through FLA + SSB + RDF over control during Kuruvai and Navarai seasons (Table 1-2). This treatment recorded the tallest plant height (105.21 and 115.16 cm), higher tiller numbers (13.27 and 15.61), chlorophyll content (5.34 and 6.74 mg g^{-1}), leaf area index (7.21 and 8.83) and DMP (9436 and 9633 kg ha^{-1}). Increase in growth attributes at $ZnSO_4$ @ 25 kg ha^{-1} + Si @ 150 kg ha^{-1} through FLA + SSB + RDF could be due to supply of adequate amount of Zn and plant available Si from $ZnSO_4$ and FLA, respectively. Application of Zn accelerates the enzymatic activities and auxin metabolism in the plant system [24]. Addition of Zn also enhanced the availability other nutrients in soil due to its synergistic effect, increased its uptake and improved the metabolic process within plants which resulted in more growth attributes [25].

Table 1 Effect of Zn and Fly ash as source of silicon in combination with silicate solubilizing bacteria on growth attributes of rice during Kuruvai season

Treatments	Plant height (cm)	No. of tillers $hill^{-1}$	Chlorophyll content (mg g^{-1})	LAI	DMP (kg ha^{-1})
T_1	87.63	11.24	3.61	5.77	7402
T_2	90.37	11.55	3.92	6.02	7722
T_3	92.63	11.82	4.21	6.25	8022
T_4	94.95	12.07	4.43	6.46	8292
T_5	98.91	12.56	4.80	6.78	8762
T_6	96.10	12.24	4.57	6.57	8452
T_7	101.50	12.87	5.02	6.97	9032
T_8	104.00	13.12	5.21	7.12	9282
T_9	105.21	13.27	5.34	7.21	9436
S.Ed	0.63	0.09	0.07	0.06	84.65
CD (P=0.05)	1.27	0.19	0.15	0.12	171

Application of silicon through Fly ash (FLA) with SSB supplied more ortho silicic acid to rice crop which improved the plant height by preventing lodging, increase the thickness of clum and its size which enhanced the strength of clum and keep the plant more erect [26]. Increase in plant height also due to the deposition of silicon in the plant tissues and caused erectness to rice [27]. Silicon application enhanced the supply of carbohydrate and nutrients to the mother clump which influenced on expanding auxiliary resulted in higher number of tillers [28]. The highest leaf area index (LAI) and chlorophyll content of rice due to more leaf numbers and its growth and synthesis of chloroplast resulted in higher leaf area index and more concentration of chlorophyll in the leaves [29]. The maximum dry matter production (DMP) under Si might be due to the maintenance of high photosynthetic activity, efficient utilization of solar light and higher translocation of photosynthates to the sink [30].

Table 2 Effect of Zn and Fly ash as source of silicon in combination with silicate solubilizing bacteria on growth attributes of rice during Navarai season

Treatments	Plant height (cm)	No. of tillers hill^{-1}	Chlorophyll content (mg g^{-1})	LAI	DMP (kg ha^{-1})
T_1	98.37	12.91	4.41	7.09	7686
T_2	101.00	13.35	4.78	7.40	8006
T_3	103.54	13.76	5.13	7.67	8286
T_4	105.56	14.14	5.46	7.88	8536
T_5	109.55	14.74	5.93	8.31	8986
T_6	107.02	14.39	5.65	8.03	8716
T_7	111.53	15.09	6.28	8.52	9236
T_8	113.75	15.40	6.57	8.71	9456
T_9	115.16	15.61	6.74	8.83	9633
S.Ed	0.74	0.13	0.10	0.08	92.08
CD (P=0.05)	1.47	0.26	0.20	0.16	186

Yield attributes and yield

On close examination of data furnished in (Table 3-4) showed that the combined use of Zn and Si through FLA with SSB significantly improved the yield attributing characters and yield of rice. The highest yield attributes (number of panicles m^{-2} - 544 and 602, grains panicles^{-1} - 110 and 121 and test weight- 16.69 and 17.89 g) and yields (grain- 4745 and 5210 kg ha^{-1} and straw- 8280 and 8989 kg ha^{-1}) were recorded under combined application of RDF + $ZnSO_4$ @ 25 kg ha^{-1} + Si @ 150 kg ha^{-1} through FLA + SSB over control during Kuruvai and Navarai seasons. Increase in panicles number m^{-2} might be due to sustained supply of zinc to rice crop particularly at critical stages which also increased the availability of major nutrients in the soil, enhanced its uptake and caused improvement in crop growth resulted in more panicles [31]. The increase in number of grains panicle^{-1} might be due to zinc fertilizer and its effect on enhancing the physiological functions of the crop, like photosynthesis and translocation of plant nutrients which ultimately increased the filled grains [32]. Increased in test weight with the application of zinc might be due to more efficient participation of Zn in various metabolic processes involved in the production of healthy grains [33]. Increase in yield components, like number of panicles, grains panicles^{-1} and 1000-grain weight produced higher yields of rice [34]. Application of Zinc also increased the efficiency of Zn requiring enzymes for photosynthesis and improved the accumulation food materials in sink and produced more gain and straw yield [35].

Table 3 Effect of Zn and Fly ash as source of silicon in combination with silicate solubilizing bacteria on yield attributes and yields of rice during Kuruvai season

Treatments	Yield attributes			Yield (kg ha^{-1})	
	No. of panicles m^{-2}	No. of grains panicle^{-1}	Test weight (g)	Grain	Straw
T_1	344	74	16.34	3075	6624
T_2	376	81	16.41	3295	6894
T_3	403	87	16.46	3505	7124
T_4	425	92	16.50	3695	7339
T_5	473	99	16.59	4075	7725
T_6	442	95	16.52	3855	7510
T_7	502	104	16.64	4345	7926
T_8	529	108	16.68	4595	8117
T_9	544	110	16.69	4745	8280
S.Ed	8.91	1.98	0.004	81.68	88.61
CD (P=0.05)	18	4	NS	165	179

Silicon application enhanced the number of productive tillers which resulted in more panicle number per unit area [36]. Increased growth attributed enhanced the photosynthetic activity of rice which caused higher number of filled grains. The increase in grain and straw yield might be due to higher growth and yield attributing characteristics of rice and also due to lesser biotic and abiotic stress by Si nutrition [37]. The agronomic characters had positive correlation with rice grain yield which were number of panicles (r = 0.990334), grains panicle^{-1} (r = 0.993274) and test weight (r = 0.998936) during Kuruvai season. In Navarai season, the same had positive correlation with rice grain yield were number of panicle (r = 0.999945), grains panicle^{-1} (r = 0.997917) and test weight (r = 0.998962). Similar kind of positive correlation with rice grain yield was observed by [38-39].

Table 4 Effect of Zn and Fly ash as source of silicon in combination with silicate solubilizing bacteria on yield attributes and yields of rice during Navarai season

Treatments	Yield attributes			Yield (kg ha^{-1})	
	No. of panicles m^{-2}	No. of grains panicle^{-1}	Test weight (g)	Grain	Straw
T_1	372	90	17.47	3580	7415
T_2	413	96	17.54	3860	7665
T_3	450	101	17.60	4130	7885
T_4	483	105	17.67	4360	8074
T_5	533	111	17.76	4720	8450
T_6	502	107	17.70	4510	8235
T_7	560	116	17.81	4910	8660
T_8	585	120	17.87	5080	8835
T_9	602	121	17.89	5210	8989
S.Ed	9.90	1.49	0.005	75.24	81.63
CD (P=0.05)	20	3	NS	152	165

CONCLUSION

The results of the two season's experiments showed that combined application of $ZnSO_4$ @ 25 kg ha^{-1} + Si @ 150 kg ha^{-1} through FLA + SSB along with RDF significantly improved the growth and yield of rice and it can be recommended as a viable practice to enhance the overall productivity of rice.

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