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Effect of zinc and silicon fertilization on growth and yield of rice

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Abstract
Field experiment was conducted at Annamalai university Experimental farm, Annamalainagar, Tamil Nadu, India during kharif 2015 to study the effect of zinc and silicon fertilization on growth and yield of rice. The results indicated that the treatment which received 10 kg Zn ha^{-1} and 150 kg Si ha^{-1} alone recorded a yield increase of 19.5 and 11 percent, respectively over control. The highest rice and straw yield (5178.5 and 6732.0 kg ha^{-1}) and (4951 and 6477 kg ha^{-1}) was achieved in treatment 10 kg Zn ha^{-1} and 150 kg Si $ha^{-1.}$ On the other hand, 10 kg Zn ha^{-1} in combination with 150 kg Si ha^{-1} produced 31.9 percent more rice yield over control. The addition of 10 Zn ha^{-1} plus 150 kg Si ha^{-1} resulted in significant increase in higher value for growth (plant height, number of tillers $hill^{-1}$ and dry matter production). The study revealed zinc and silicon fertilization as a suitable material for improving crop yield as well as soil fertility.

Keywords: Zinc, silicon, rice

Introduction
Rice (*Oryza sativa*) the prince among cereals is the premier food crop not only in India but world too (Chhabra, 2002). In Asia, India has the largest area under rice, which is cultivated round the year in one (or) other part of the country in diverse ecological spread of 44.8 Mha accounting for 29.4 percent of the global rice area with a production of 132 million tonnes of rice with an average productivity of 2.98 t ha^{-1} (Rai, 2006). Among the rice growing countries of the world, India has the largest rice acreage and ranked second in production (Anonymous, 2006) [3]. The burgeoning population of our country may stabilize around 1.4 and 1.6 billion by 2025 and 2050, requiring annually 380 and 450 mt of food grains respectively (Yadav *et al*., 2009). In Tamil Nadu, it is cultivated in an area of 1.79 m ha with the production of 5.04 mt and a productivity of 2.82 t ha^{-1} (Anonymous, 2010) [2]. For achieving sustainability in food production, rate of nutrient supply to crop plants should keep pace with rate of nutrient removal of the crops. Balanced fertilizers use in food grain crops including rice is one of the important considerations in providing food security to the burgeoning Indian population and promoting soil fertility in sustainable intensive agriculture. Balancing the micronutrients along with macronutrients for rice cultivation enhanced the quality and yield (Ma *et al*., 2007) [12]. Among major constraints of quality and paddy yield in rice, imbalanced micronutrients in soil are the most important variables. Silicon is one of the most important micronutrients for sustainable rice production. Silicon has a key role in plant environment relationship because it can improve plant abilities to withstand edaphic climatic and/ or biological adversities by acting as a “Natural antistress” mechanism that enables higher yields and better quality end product (Brunings *et al*., 2009; Regina and Katarzyna, 2011) [4, 19]. Zinc plays an important role in the nutrition of rice. Zinc deficiency was first diagnosed in rice on calcareous soils of Northern India (Nene, 1966) [17]. It was subsequently found to be widespread phenomenon in lowland rice areas of Asia, next to N and P deficiencies. Zinc deficiency in rice appears right from seedling stage in nursery and three weeks after transplanting in main field. Zinc deficiency is considered the most widespread disorder in lowland rice (Quijano-Guerta *et al.,* 2002; Fageria *et al.*, 2002) [18, 5]. The present investigation was carried out to determine the effect of zinc and silicon on rice growth and productivity.

Materials and methods

Field experiment was conducted at Annamalai university Experimental farm, Annamalainagar, Tamil Nadu, India during kharif 2015 to study the effect of zinc and silicon fertilization on growth and yield of rice. The experimental soil was deep, moderately drained, clay loam in texture with pH 8.20, EC 0.69 dSm^{-1}, organic carbon 3.5 g kg^{-1} (low), medium in available nitrogen 328 kg ha^{-1}, high in available phosphorus 31.1 kg ha^{-1}, high in available potassium 322 kg ha^{-1}, low in available zinc 0.80 mg kg^{-1}, medium in available silicon 39.2 mg kg^{-1}.The experiment was laid out in randomized block design. The experiment consisted of sixteen treatments viz., zinc levels (0, 5, 7.5 and 10 kg ha^{-1}) and silicon levels (0, 75, 150 and 225 kg ha^{-1}) and their combinations. The recommended dose of 150:50:50 N, P_2O_5, K_2O ha^{-1} through urea, superphosphate and muriate of potash was added uniformly to all the plots. The amount of zinc and silicon based on treatment was calculated and was applied through zinc sulphate and potassium silicate respectively. The amount of potassium supplied through potassium silicate was taken in to account while applying recommended dose of potassium to all plots. The entire quantity of P was applied basally while nitrogen was applied in three split doses. The plant samples were collected at tillering, panicle initiation and harvest stage. The biometric observations on plant height, tiller count and dry matter production were recorded at different stages of crop growth. At harvest, grain and straw yield were recorded and expressed as kg ha^{-1}.

Results and Discussion

Plant height

Addition of graded levels of zinc and silicon significantly increased the plant height at all stages of crop growth over control (Table 1). Plant height progressively increased with zinc levels and the tallest plant was noticed with 10 kg Zn ha^{-1}, it was superior to rest of zinc levels. Similarly plant height also progressively increased with Si levels and the tallest plant was noticed with 150 kg Si ha^{-1} and declined at 225 kg Si ha^{-1}. Combined application of 150 kg Si ha^{-1} and 10 kg Zn ha^{-1} registered the tallest plant at all stages of crop growth compared to other combinations. This treatment recorded 76.4, 103.4 and 113.3 cm at tillering, panicle initiation and harvest stage, respectively. However irrespective of Zn levels, addition of 225 kg Si ha^{-1} caused reduction in plant height at all stages of crop growth. Zinc application significantly increased the plant height which might be attributed to the adequate supply of zinc contributed to accelerate the enzymatic activity and auxin metabolism in plants. These result are in agreement with the findings of Khan *et al.* (2007) [12]. This was confirmed by positive correlation of DTPA-Zn with plant height ($r=0.912^{**}$). Variation in plant height due to nutrient sources was considered to be variation on the availability of major nutrients. Application of silicon was effective in preventing lodging in rice by increasing the thickness of the clum and size of the vascular bundles thereby enhancing the strength of clum. Increase in plant height might owe to increased cell division elongation and expansion caused by silicon. Increase in plant height could be due to deposition of silicon on the plant tissue causing erectness of the leaves and stem. The finding on the positive effect of silicon on plant height is harmony with those obtained by Fallah (2012) [6] and Jawahar *et al.* (2015) [11]. Ahmad *et al.* (2013) [1] reported maximum plant height with 1% Si foliar spray.

Number of tillers hill^{-1}

Effect of zinc, silicon or their combinations was significant on number of tillers $hill^{-1}$ in both the stages over control (Table 2). The number of tillers $hill^{-1}$ at all stages progressively increased with zinc level up to 10 kg Zn ha^{-1}. It was superior to rest of zinc levels. This treatment registered 20.3 and 25.1 number of tillers $hill^{-1}$ at tillering and panicle initiation stage respectively. With respect to silicon, addition of 150 kg Si ha^{-1} recorded the highest number of tillers $hill^{-1}$ of 18.3 and 22.3 at tillering and panicle initiation stage respectively. Increased tiller production can be attributed to Zn induced enzymatic activity and auxin metabolism in plant. Similar effect was noticed by Hafeez *et al.* (2013) [10] and Waleed Khaliq Rana and Saifur Rehman Kashif (2014) [20] reported in highest effective tillers $hill^{-1}$. The significant positive correlation between DTPA-Zn and productive tillers ($r=0.884^{**}$) confirmed the role of zinc on tiller production. 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. Gerami *et al.* (2012) [7] and Jawahar *et al.* (2015) [11] 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 ($r=0.901^{**}$), Si content ($r=0.952^{**}$) and Si uptake ($r=0.977^{**}$).

Dry matter production

Addition of zinc and silicon caused significant effect on dry matter production at all stages of crop growth over control (Table 3). The dry matter production increased with advancement of crop growth and was lowest in plots which did not receive zinc and silicon. Throughout the crop growth, DMP increased with zinc levels and the maximum DMP was noticed with 10 kg Zn ha^{-1} (2689, 5552 kg ha^{-1}) at tillering and panicle initiation stages, respectively. It declined thereafter with decreased in zinc levels. With respect to silicon application of 150 kg Si ha^{-1}, registered the highest DMP of (2642 and 5311 kg ha^{-1}) at tillering and panicle initiation stages, respectively. Combined application of zinc and silicon caused higher DMP over their individual application at both stages of crop growth, but to the significant level. Addition of 150 kg Si ha^{-1} and 10 kg Zn ha^{-1} registered the highest DMP. Irrespective of zinc levels, 225 kg Si ha^{-1} application caused reduction in DMP. Similarly, at all levels of silicon, addition of 5 and 7.5 kg Zn ha^{-1} caused reduction in DMP. Increased in DMP might be due to adequate supply of zinc that might have increased the availability and uptake of other essential nutrients thereby improvement in crop growth. Increase in DMP due to zinc was reported by earlier workers (Fageria *et al.*, 2011). Addition of 150 kg Si ha^{-1} caused 36.89 percent at tillering stage, 18.49 percent at panicle initiation stage over control. Optimization of silicon nutrients increases mass and volume of roots increases total and absorbing surfaces there by silicon fertilization increased the dry weight of the plants. Korndorfer and Lapsch (2001) [14] reported that maintenance of photosynthetic activity alone to silicon addition could have also contributed to higher DMP. Gerami *et al.* (2012) [7] and Jawahar *et al.* (2015) [11] reported higher DMP with silicon addition.

Rice yield

On close examination of data on grain and straw yield furnished in (Table 4). Showed the grain and straw yield graded dose of zinc, silicon or in combination over control. Grain and straw yield increased with Zn levels and the highest grain yield (5178 kg ha^{-1}) and straw yield (6732 kg ha^{-1}) was noticed with 10 kg Zn ha^{-1} in respectively. Grain and straw yield decreased at rest of zinc levels. The percentage increase in grain yield (19.5) and straw yield (17.0) over no Zn was noticed at 10 kg Zn ha^{-1} tried. With respect to silicon levels, maximum grain yield (4951 kg ha^{-1}) and straw yield (6477 kg ha^{-1}) in respectively was noticed at 150 kg Si ha^{-1}. Further increase in Si level caused reduction in grain and straw yield. This was comparable with 225 kg Si ha^{-1} but superior to the rest of silicon levels. The percent increase in grain and straw yield due to 150 kg Si ha^{-1} over control was (11.0) and (10.0) in respectively. With respect to interaction effect between zinc and silicon, the highest grain and straw yield was noticed with 150 kg Si ha^{-1} and 10 kg Zn ha^{-1}. This treatment recorded the grain yield (5363 kg ha^{-1}) and straw yield (6970 kg ha^{-1}). This treatment caused 31.9 percent increase in grain yield and 28.4 percent increase in straw yield over control. In the absence of silicon, the percent increase in grain yield due to various levels of Zn ranged from 6.3 to 20.1 respectively. Similarly, the percent increase in straw yield due to various levels of Zn ranged from 5.1 to 17.5 respectively. Application of zinc has been reported to correct the efficiency of different Zn requiring enzymes leading to higher yield (Hacisalihoglu *et al.*, 2003) [9]. The enhancement in the zinc efficiency of seedling by zinc application might have resulted in the increased uptake of zinc in different plant parts leading to higher yield. These results are in line, Khan *et al.* (2012) [13] reported maximum yield at 9.0 kg Zn ha^{-1} and reduced at 12 and 15 kg Zn ha^{-1}. Muthukumararaja and Sriramachandrasekharan (2012) [16] reported maximum grain and straw yield with 5 mg Zn kg^{-1} in zinc deficient soils. This increase in grain and straw yields might be attributed to the increase in growth and yield characteristics of rice and also 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 (Gholami and Falah 2013) [8]. Wattanapayapkul *et al.* (2011) [21] reported that application of Si grain yield was increased 19-43% over the control in experiment 1 and 2-14% over the control in experiment 2.

Table 1: Effect of zinc and silicon levels on plant height (cm) at different growth stages

Zinc levels (Kg ha^{-1})	Tillering stage					Panicle initiation stage					Harvest stage				
	Silicon levels (kg ha^{-1})														
	0	**75**	**150**	**225**	**Mean**	**0**	**75**	**150**	**225**	**Mean**	**0**	**75**	**150**	**225**	**Mean**
Zn-o	37.5	48.0	56.7	55.3	49.3	58.4	70.0	78.5	75.3	70.5	68.2	78.4	86.4	85.9	79.7
Zn-5.0	46.8	57.0	64.5	63.1	57.8	71.0	80.6	88.0	84.8	81.1	79.6	88.8	96.4	95.7	90.1
Zn-7.5	54.3	63.7	70.6	69.2	64.4	77.9	88.5	95.9	93.6	88.9	86.9	96.9	104.5	103.2	97.8
Zn-10	61.2	69.6	76.4	75.3	70.6	86.3	97.0	103.4	101.9	97.1	94.6	105.7	113.3	111.7	106.3
Mean	49.9	59.5	67.0	65.7		73.4	84.0	91.4	88.8		82.3	92.4	100.1	99.1	
		Zn	Si	Zn × Si			Zn	Si	Zn × Si			Zn	Si	Zn × Si	
SEd		1.27	1.27	2.54			1.42	1.42	2.85			1.17	1.17	2.34	
CD (p=0.05)		2.60	2.60	5.20			2.92	2.92	5.84			2.39	2.39	4.79	

Table 2: Effect of zinc and silicon levels on number of tillers hill^{-1} and productive tillers hill^{-1} at different growth stages

Zinc levels (Kg ha^{-1})	Tillering stage					Panicle initiation stage					Productive tillers hill^{-1}				
	Silicon levels (kg ha^{-1})														
	0	**75**	**150**	**225**	**Mean**	**0**	**75**	**150**	**225**	**Mean**	**0**	**75**	**150**	**225**	**Mean**
Zn-o	6.3	9.4	12.5	12.4	10.1	6.7	11.7	15.2	15.2	12.2	3.0	6.6	9.0	8.7	6.8
Zn-5.0	9.5	14.3	17.5	17.4	14.7	13.0	17.3	21.0	20.9	18.0	6.7	9.1	12.8	12.1	10.1
Zn-7.5	12.5	17.9	20.6	20.2	17.8	16.8	24.0	24.9	24.0	22.4	9.7	13.9	16.3	16.0	13.9
Zn-10	15.4	20.8	22.8	22.5	20.3	19.1	25.5	28.0	27.7	25.0	12.9	17.3	19.4	19.1	17.1
Mean	10.9	15.6	18.3	18.1		13.9	19.6	22.2	21.9		8.0	11.7	14.3	13.9	
		Zn	Si	Zn × Si			Zn	Si	Zn × Si			Zn	Si	Zn × Si	
SEd		0.24	0.24	0.49			0.61	0.61	1.22			0.32	0.32	0.64	
CD (p=0.05)		0.50	0.50	1.01			1.24	1.24	2.49			0.66	0.66	1.32	

Table 3: Effect of zinc and silicon levels on dry matter production (kg ha^{-1}) at different growth stages

Zinc levels (Kg ha^{-1})	Tillering stage					Panicle initiation stage				
	Silicon levels (kg ha^{-1})									
	0	**75**	**150**	**225**	**Mean**	**0**	**75**	**150**	**225**	**Mean**
Zn-o	1618	2057	2293	2204	2043	3970	4339	4672	4608	4397
Zn-5.0	1830	2294	2562	2487	2293	4290	4802	5143	5061	4824
Zn-7.5	2039	2451	2763	2689	2485	4679	5174	5541	5441	5208
Zn-10	2235	2691	2950	2881	2689	4992	5543	5888	5786	5552
Mean	1930	2373	2642	2565		4482	4964	5311	5224	
		Zn	Si	Zn × Si			Zn	Si	Zn × Si	
SEd		40.23	40.23	80.47			42.02	42.02	84.04	
CD (p=0.05)		82.18	82.18	164.36			85.82	85.82	171.64	

Table 4: Effect of zinc and silicon levels on grain and straw yield of rice (kg ha^{-1})

Zinc levels (Kg ha^{-1})	Tillering stage					Panicle initiation stage				
	Silicon levels (kg ha^{-1})									
	0	75	150	225	Mean	0	75	150	225	Mean
Zn-o	4062	4289	4507	4468	4331	5425	5700	5984	5910	5754
Zn-5.0	4320	4600	4833	4800	4638	5700	6058	6327	6296	6095
Zn-7.5	4631	4883	5101	5090	4926	6071	6370	6627	6590	6414
Zn-10	4891	5142	5363	5318	5178	6372	6670	6970	6916	6732
Mean	4476	4728	4951	4919		5892	6199	6477	6428	
		Zn	Si	Zn × Si			Zn	Si	Zn × Si	
SEd		45.66	45.66	91.32			25.87	25.87	51.75	
CD (p=0.05)		93.25	93.25	186.50			52.85	52.85	105.70	

Conclusion

The experimental soil which was deficient in zinc and medium in silicon responded well to combined application of zinc and silicon than individual application. It is concluded from the present study that addition of 10 kg Zn ha^{-1} plus 150 kg Si ha^{-1}could be sufficient to realise the maximum growth and yield of rice through market improvement in efficiency.

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