EFFECT OF SOURCES AND LEVELS OF ZINC ON GROWTH, YIELD AND MINERAL COMPOSITION OF RICE IN ALKALI SOIL

H.P. SINGH AND T.N. SINGH*

Directorate of Research, N.D. University of Agriculture & Technology, Faizabad-224229, U.P.

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SUMMARY

Zinc application was found to have ameliorative effects on rice (*Oryza sativa* L.) in alkali soil. The increase in growth and yield attributes were dose-dependent. Soil application of 10 kg Zn ha^{-1} was adequate in partially reclaimed alkali soil with initial pH 10.3, exchangeable sodium percentage 85 and electrical conductivity of soil solution (1:2) 2.1 dS m^{-1}. Zinc sulphate proved decidedly superior source of zinc over zinc frits. Zinc application increased chlorophyll and raised the tissue concentration of Zn, Ca, Mg, K and P, whereas Na content decreased. Thus, zinc modified elemental composition of plant tissues favourably and thereby accelerated plant growth and yield.

Key words: **Alkali soil, chlorophyll, sodic soil, soil amendment, zinc, zinc frit, zinc sulphate.**

INTRODUCTION

Until recently zinc sulphate has been the main source of zinc for correcting Zn-deficiency or fulfilling zinc requirements of field crops (Milapchand *et al.* 1980, Singh 1982, 1983). However, there has been some concern in the past about the low efficiency of applied zinc to the soils in general and alkali or sodic soils in particular. In order to enhance the agro-economic efficiency of applied zinc, use of various forms of zinc, *i.e.* chelated zinc, zincated superphosphate, fritted zinc etc. have been advocated (Kanwar and Randhawa 1978). It was in this context that the present experiments were conducted in semi-reclaimed alkaline soil under field conditions to evaluate the comparative effectiveness of these products vis-a-vis commonly used source of zinc, *i.e.* zinc suphate.

MATERIALS AND METHODS

A piece of highly alkaline land having pH 10.3, exchangeable sodium 85% and electrical conductivity (1:2) 2.1 dS m^{-1} in 0-15 cm depth of soil (Richards 1954) was chosen for experimentation at the research farm of N.D. University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). To lower down the initial high pH, soil was pre-treated with pyrites (8.5 t / ha) having 21% sulfur, in a manner as described by Singh (1977). The pH and exchangeable sodium percentage (ESP) after adding chemical amendment came down to 9.1 and 40, respectively. Various quantities of zinc, i.e. 5, 7.5 and 10 kg Zn ha^{-1} were made available by three sources of zinc, i.e. DMCC zinc frit (22.2% Zn), Ferro zinc frit (19% Zn) and zinc sulphate (23% Zn) as basal application. The experiment consisted of randomized block design with 4 replications having plot size 5x4 m each. NPK nutrients were applied @ 120 kg N, 50 kg p_2O_5 and 30 kg k_2O ha^{-1} as per normal schedule of fertilizer application in the form of urea, diammonium phosphate and muriate of potash, respectively. Five-week-old seedlings of rice var. Sarjoo-52 were transplanted @ 4 seedlings per hill at 15x15 cm distance. Efforts were made to keep the supply of water normal during crop season. At maturity,

* Corresponding author's present address: Associate Director of Research, Crop Research Station, Masodha, P.O. Dabhasemar, Distt. Faizabad - 224133, U.P.

observations were recorded on plant height, tiller production, bio-mass accumulation (all based on five tiller randomly selected from each replication), yield and yield components. Composite sample of leaves were analysed for Zn, Ca, Mg, Na, K and P contents, Total chlorophyll was estimated two weeks after transplanting (Yoshida *et al.* 1976) and at the same time plants were also scored for zinc-deficiency symptoms (IRRI 1980). Results were subjected to statistical analysis (Li 1968).

RESULTS AND DISCUSSION

Scores for Zn-deficiency symptoms ranged from 2 to 5 depending upon sources and levels of zinc applied. Since, height of plant is an easy measure of plant growth, it was measured at three levels of zinc supplied by three sources in alkali soil. The effect of zinc sulphate and that of DMCC zinc frit were much similar and slightly superior to Ferro zinc frit (Table 1). Higher doses (7.5 or 10 kg ha^{-1}) of zinc had more positive effect and plants supllied with 10 kg/ha were taller by 81 to 93% than those of control plants. Thus, zinc application (10kg/ha) almost doubled the plant height increasing it from 40 cm up to 77 cm. Tiller porduction under Zinc application was around 17-21, whereas under zinc-deficiency it was restricted only to 11 tillers per hill demonstrating the process being dose-dependent. Zinc sulphate was superior to other zinc carriers. Similarly, biomass accumulation was much less (19.2g) in plants not supplied with any amount of zinc than those adequately fed with it (28.7 to 34.5g) favouring root over shoot growth. This is clear from shoot: root ratio being highest (1.37) in control plants. Zinc application hastened the process of heading by 5 to 10 days (Table 2). Thus, the growth of panicle and the rachis branch production were very extensively inhibited by Zn-deficiency. The length of panicle of Zn-deficient plant was shorter by 6 to 7 cm than those of adequately fertilized with zinc (18 to 19cm). Similarly, the rachis branch production doubled on account of zinc application (Table 2). It is known that high pH and high contents of $CaCO_3$ in the soil greatly inhibit zinc availability to plants (Singh and Sekhon 1977, Kanwar and Randhawa 1978). This could probably be the reason for good response of rice to zinc application under alkali soil conditions as the inherent zince status of the experimental field was only 0.55 ppm and the $CaCO_3$ was high (1.5%). Stimulation in these growth parameters is understandable as zinc application increased the chlorophyll content, which might have enhanced photosynthetic activities resulting in greater dry matter accumulation (Davi *et al.* 1997, Tripathi *et al.* 1999).

Table 1. Effect of sources and levels of zinc on plant growth attributes and chlorophyll of rice grown in alkali field conditions.

Sources of zinc	Levels of zinc (kg/ha)	Plant height (cm)	Productive tiller/hill	Non-productive tiller/ hill	Total tiller/ hill	Shoot weight (g/hill)	Root weight (g/hill)	Total weight (g/hill)	Shoot: root ratio	Chlorophyll (mg/g fw)
1. DMCC zinc frit	5.0	65.8	6.4	10.1	16.5	14.8	12.2	27.0	1.21	5.2
2. DMCC zinc frit	7.5	71.6	7.0	9.5	16.5	17.2	13.4	30.6	1.28	6.7
3. DMCC zinc frit	10.0	76.1	8.6	8.9	17.5	18.5	15.0	33.5	1.23	7.8
4. Ferro zinc frit	5.0	61.9	5.9	7.8	13.7	12.8	9.6	22.4	1.33	5.4
5. Ferro zinc frit	7.5	69.0	6.8	9.6	16.4	13.9	10.9	24.8	1.28	6.1
6. Ferro zinc frit	10.0	72.3	7.7	10.3	18.0	16.1	12.6	28.7	1.28	7.0
7. Zinc sulphate	5.0	65.4	7.5	5.2	12.7	15.5	11.9	27.4	1.30	6.1
8. Zinc sulphate	7.5	72.1	9.1	9.3	18.4	16.9	14.2	31.1	1.19	7.1
9. Zinc sulphate	10.0	77.2	10.7	10.0	20.7	18.9	15.6	34.5	1.21	9.3
10. Control	Nil	39.9	4.6	6.1	10.7	11.1	8.1	19.2	1.37	4.9
LSD (0.05)		2.4	0.3	1.9	1.6	1.2	0.6	0.7	0.08	0.2

Zinc application increased the number of filled grains by 10-12 per panicle raising them from 50 grains in Zn-deficient plants to 62 grains in plants adequately fed with zinc supply. The proportion of chaffy grains decreased on account of zinc application. However, the total number of spikelets (filled + chaffy grains) did not fluctuate much (70 to 75) under conditions of Zn-deficiency or Zn-adequacy. On an average the application of $ZnSO_4$ resulted in the boldest grains (25.3g / 1000 grains) followed by those of DMCC zinc frit (19.4g) and Ferro zinc frit (16.6g) in that order. These enhancements amounted to 6, 24 and 62 per cent respectively over control. The results also indicated less effectiveness of zinc frit-superphosphate mixture compared to $ZnSO_4$ on the calcareous soils, while the two sources were equally effective on neutral soils (Singh and Sekhon 1977). Large variations in the size and number of grains accompanied by panicle numbers due to soil alkalinity and zinc application resulted in large variations in grain yield (Table 2). Sources and levels both had significant effect on grain yield. $ZnSO_4$ proved most beneficial followed by those of DMCC zinc frit and Ferro zinc frit in that order. The grain yield without zinc was only 12.8q ha^{-1}, whereas it increased to 26.3 q/ha when zinc was applid @ 10kg/ha in the form of $ZnSO_4$. The superiority of $ZnSO_4$ over other zinc carriers has also been reported with respect to yields of rice, wheat and maize (Puri and Dev 1979, Singh and Choudhari 1996). The quantum of yield enhancement due to zinc application suggests that, in addition to application of soil amendments (Abrol and Bhumbla 1973, Singh 1977) zinc application in appropriate quantities in highly alkaline soils is also essential (Singh *et al.* 1987).

The elemental analysis of leaf tissues revealed very significant changes in the concentration of Zn, Ca, Mg, Na, K and P by zinc application in alkali soil (Table 3). Zinc level of leaf tissues increased from 12.4 ppm to 23.8 ppm when alkali soil was fertilized with zinc @ 10kg/ha. Zinc accumulation in leaf tissues was found to be dose-dependent. Calcium, magnesium, phosphorus and potassium contents also increased by zinc application. However, sodium content decreased by 28% when zinc was supplied @ 10kg/ha as zinc sulphate. The maximum increase was recorded in zinc level (200%) followed by potassium (58%), calcium (38%), magnesium (27%) and phosphorus (24%). The magnitudes of these changes were dependent upon sources and levels of zinc applied to the soil with DMCC and Ferro zinc frits being relatively less effective. These elemental changes, therefore,

Table 2. Effect of sources and levels of zinc on heading, yield and yield components of rice grown in alkali field conditions.

Sources of zinc	Levels of zinc (kg/ha)	Earliness in heading (days)	Panicle length (cm)	Rachis branches/ panicle	Filled grains/ panicle	Chaffy grains/ panicle	Total spike-lets / panicle	Spikelet sterility (%)	Grain wt. (g/1000 grains)	Grain yield (q/ha)
1. DMCC zinc frit	5.0	7.3	14.5	5.0	52.8	19.5	72.3	27.0	18.3	18.4
2. DMCC zinc frit	7.5	7.5	15.5	7.0	57.0	17.5	74.5	23.5	19.2	21.3
3. DMCC zinc frit	10.0	8.5	17.2	9.0	60.8	13.5	74.3	18.2	20.7	25.1
4. Ferro zinc frit	5.0	5.8	14.2	5.5	53.5	18.8	72.3	26.0	15.7	15.6
5. Ferro zinc frit	7.5	8.3	16.0	7.5	56.5	17.3	73.8	23.4	16.5	18.5
6. Ferro zinc frit	10.0	9.3	18.5	9.0	60.5	12.5	73.0	17.1	17.6	23.0
7. Zinc sulphate	5.0	5.0	14.4	5.5	54.5	18.8	73.3	25.6	24.6	19.0
8. Zinc sulphate	7.5	6.5	16.5	7.5	57.5	17.5	75.0	23.3	25.6	22.1
9. Zinc sulphate	10.0	9.5	18.9	10.0	62.0	12.0	74.0	16.2	25.7	26.3
10. Control	Nil	Nill	11.5	4.5	49.8	20.5	70.3	29.2	15.6	12.8
LSD (0.05)		1.1	1.3	1.1	5.6	0.3	4.0	3.2	0.5	2.1

Table 3. Effect of sources and levels of zinc on changes in mineral composition of leaf tissues of rice grown in alkali field conditions.

Sources of zinc	Levels of zinc (kg/ha)	Zinc (ppm)	Calcium (ppm)	Magnesium (ppm)	Sodium (ppm)	Phosphorus (%)	Potassium (%)
1. DMCC zinc frit	5.0	16.3	1559	1753	1733	0.204	2.22
2. DMCC zinc frit	7.5	18.4	1708	1830	1652	0.215	2.63
3. DMCC zinc frit	10.0	21.4	1882	1932	1557	0.228	2.77
4. Ferro zinc frit	5.0	15.8	1438	1707	1773	0.201	2.15
5. Ferro zinc frit	7.5	16.9	1694	1732	1706	0.211	2.48
6. Ferro zinc frit	10.0	20.7	1791	1871	1651	0.223	2.67
7. Zinc sulphate	5.0	17.5	1588	1759	1677	0.207	2.34
8. Zinc sulphate	7.5	19.7	1729	1893	1548	0.231	2.71
9. Zinc sulphate	10.0	23.8	1974	1937	1469	0.240	2.90
10. Control	Nil	12.4	1430	1526	1885	0.193	1.83
LSD (0.05)		0.5	32.4	30.4	34.5	0.004	0.11

appeared to be indicative of improvement in plant health and metabolism brought about by zinc application (Abrol and Bhumbla 1979, Shukla and Mukhi 1980, Tripathi *et al.* 1999).

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