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# Effect of different rates and methods of zinc application on the yield and nutritional qualities of rice cv. BR11

**M. A. Hossain, M. A. Hannan, N. M. Talukder[1] and M. A. Hanif**
Department of Biochemistry, Bangladesh Agricultural University, Mymensingh-2202,
[1]Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

**Abstract:** An experiment was carried out at the main farm of Bangladesh Agricultural University, Mymensingh to study the influence of different rates and methods of zinc application on yield and nutrient content of rice cv. BR11 and also the nutrient status of post-harvest soil. The experiment was laid out in randomized complete block design with three replications using zinc for soil application @ 0, 5, 10 and 15 kg $ZnSO_4$ $ha^{-1}$ and foliar application @ 0.1 %, 0.3 %, 0.5 % and 0.7 % $ZnSO_4$ solution along with basal dose of urea, triple super phosphate (TSP), murate of potash (MP) and gypsum. The study revealed that most of the yield and yield attributing characters except a few were significantly influenced by the soil and foliar application of zinc. The highest grain yield was recorded with the foliar application of 0.5 % $ZnSO_4$ solution; while the lowest was recoded in no zinc treatment. Among the nutrient contents, phosphorus, potassium, magnesium, sulphur, and zinc in grains varied significantly due to different zinc applications; but nitrogen content was not significantly changed. Different rates and methods of zinc application significantly affected the starch content in grains and straw but protein content did not vary significantly. The highest percentage of protein and starch was found in the treatment of 0.5 % $ZnSO_4$ solution. Results on post-harvest soil analyses revealed that zinc application had an agonistic effect on N, Mg, S and Zn contents, but antagonistic effect on P and K contents. The overall results suggest that foliar application of zinc at 0.5 % $ZnSO_4$ solution showed the best performance in respect to yield and nutritional qualities of rice.
**Key words:** Yield, nutritional qualities, soil and foliar application, Zinc sulphate, rice cv. BR11

## Introduction

Zinc was recognized as an essential element for rice cultivation from long ago (Sommer and Lipman, 1926). Zinc plays an important metabolic role on plant as a component of a variety of enzymes such as dehydrogenases, proteinases, peptidases, carbonic anhydrases and phosphohydrolases. Zinc is also involved in auxin metabolism, synthesis of cytochrome C and stabilization of ribosomal fraction (Shkonik, 1974). About 1.74 million hectares of land in Bangladesh are suspected to be potentially zinc deficient (Anonymous, 1980). Zinc deficiency is considered to be the third most important nutrient element after nitrogen and phosphorus limiting the growth and yield of rice (Katyal and Ponnamperuma, 1973). In some regions of Bangladesh, yield loss due to zinc deficiency ranged from 10-80% (Choudhury and Choudhury, 1990). Although there were some reports on the application of zinc in soil, information on the optimum dose of zinc and comparative studies of the soil application versus foliar application of zinc particularly on rice is meagre in Bangladesh. Keeping the above facts in view, the present research was undertaken to explore the effect of different rates and methods of zinc application on the yield and nutritional qualities of rice.

## Materials and Methods

The field experiment was carried out in a typical rice growing soil to the North-West corner of the main farm of Bangladesh Agricultural University, Mymensingh. Chemical analyses of the initial soil sample of the experimental plots showed the basic soil properties like pH, organic carbon, organic matter, total N, exchangeable K, Mg, available P, S and Zn were 6.51, 0.73 %, 1.26 %, 0.13 %, 0.06 meq/100 g soil, 2.29 meq/100 g soil, 12.29 ppm, 9.21 ppm and 2.51 ppm respectively. The basal doses of TSP, MP and gypsum were applied during the land preparation and urea was applied in three splits. The experiment was laid out in randomized complete block design with three replications. There were eight treatments comprising 3 levels of soil applied zinc treatment, viz. 5, 10 and 15 kg $ZnSO_4$ $ha^{-1}$ and 4 levels of foliar application, viz., 0.1 %, 0.3 %, 0.5 % and 0.7% $ZnSO_4$ solution along with a control (no zinc treatment). The unit plot was 10 $m^2$ (4 m × 2.5 m). Thirty days old seedlings of Aman rice cv. BR 11 (Mukta) were transplanted on August with a spacing of 15 cm from hill to hill and 25 cm from row to row (BARC, 1997). Intercultural operations like irrigation, weeding, insect pest control were done whenever required. The crop was harvested at 114 days after transplantation at full maturity. Plot-wise yield and yield attributes were recorded. Samples (grain, straw and post-harvest soil) were analyzed physically and chemically following the standard procedures. All data were statistically analyzed using the MSTATC. Duncan's Multiple Range Test (DMRT) was used to compare variation among the treatments.

## Results and discussion

Application of zinc at various levels and methods had noticeable influence on the yield and nutritional qualities of transplant rice (Tables 1-4). The maximum plant height (99.81 cm) was obtained from the plant receiving 0.5% $ZnSO_4$ solution by foliar application. The highest plant height, filled grain per panicle, 1000-grains weight, grain yield, length of rice grains, length/breadth ratio were obtained from the plant receiving 0.5% $ZnSO_4$ solution by foliar application and minimum were from control plant. Similar observation were also made by Asaduzzaman *et al.* (1996) who reported the beneficial effect of zinc application in relation to increase plant height of BR11 rice. Significant effect of $ZnSO_4$ on grain yield was reported by Prasad *et al.* (1989), Shah and De-Datha (1991), Prasad and Bid (1993), Das *et al.* (1993), Ranjan (1993), Room-Singh *et al.* (1994) and Haloi (1998). On the contrary, highest number of non-effective tillers $hill^{-1}$ and sterile grains $panicle^{-1}$ obtained in the control and the lowest was obtained with foliar application of Zinc at 0.5 % $ZnSO_4$ solution. Plant receiving 10 kg $ZnSO_4$ $ha^{-1}$ by soil application showed highest number of fertile tillers $hill^{-1}$ and the lowest was recorded in control. The result showed that both in soil and foliar application of Zinc at the highest level used reduced the number of fertile tiller $hill^{-1}$ while in both the methods of Zn application up to 10 kg $ZnSO_4$ $ha^{-1}$ and 0.5 % $ZnSO_4$ solution, it decreased the number of fertile tillers $hill^{-1}$.

The result further indicated that soil application of Zn promoted the number of effective tiller $hill^{-1}$as compared to foliar applied Zn. However the second highest number of fertile tillers $hill^{-1}$ (10.58) was observed in 0.5 % $ZnSO_4$ solution treatment. The present finding is in agreement with the result of Babiker (1986) and Hussain *et al.* (1988).

**Table 1. Effect of different levels of zinc on yield and yield attributing characters of rice cv. BR11**

| Treatments | Plant height (cm) | Panicle length (cm) | non-effective tillers $hill^{-1}$ (no.) | Fertile tillers $hill^{-1}$ (no.) | Filled grains $panicle^{-1}$ (no.) | Sterile grains $panicle^{-1}$ (no.) | 1000-grains weight | Grain yield (t $ha^{-1}$) | Straw yield (t $ha^{-1}$) | Biological yield |
|---|---|---|---|---|---|---|---|---|---|---|
| $Zn_0$ | 80.98b | 22.16 | 2.57a | 8.25d | 83.60e | 14.22a | 22.77b | 4.15b | 6.15b | 10.30e |
| $Zn_1$ | 92.16a | 22.80 | 1.99b | 9.19cd | 98.66d | 10.76b | 24.95b | 4.75ab | 7.21a | 11.96d |
| $Zn_2$ | 94.02a | 23.01 | 1.50d | 10.91a | 106.7ab | 9.65bc | 25.65b | 5.26a | 8.12a | 13.37ab |
| $Zn_3$ | 95.23a | 22.50 | 1.75c | 9.71abc | 102.7bcd | 9.86bc | 25.50b | 4.93ab | 7.67a | 12.62bcd |
| $Zn_4$ | 92.75a | 22.31 | 1.93b | 9.34bcd | 101.90cd | 9.91bc | 25.15b | 4.82ab | 7.27a | 12.09cd |
| $Zn_5$ | 95.95a | 23.87 | 1.87bc | 9.68abc | 103.3bc | 9.46bc | 25.73b | 5.23a | 7.61a | 12.86abc |
| $Zn_6$ | 99.81a | 24.73 | 1.22e | 10.58a | 110.0a | 7.537c | 28.89a | 5.56a | 8.05a | 13.60a |
| $Zn_7$ | 93.97a | 23.91 | 1.53d | 9.98abc | 107.50a | 9.50bc | 25.75b | 5.43a | 7.83a | 12.20cd |
| CV % | 4.37 | 9.36 | 5.01 | 7.22 | 4.22 | 14.44 | 6.03 | 8.83 | 6.66 | 4.74 |

$Zn_0$ =0 kg $ZnSO_4$ $ha^{-1}$; $Zn_1$ =5.0 kg $ZnSO_4$ $ha^{-1}$; $Zn_2$ =10.0 kg $ZnSO_4$ $ha^{-1}$; $Zn_3$ =15.0 kg $ZnSO_4$ $ha^{-1}$; $Zn_4$ =0.1 % $ZnSO_4$ solution; $Zn_5$ =0.3 % $ZnSO_4$ solution; $Zn_6$ =0.5 % $ZnSO_4$ solution and $Zn_7$ =0.7 % $ZnSO_4$ solution

**Table 2. Effect of different levels of zinc on physical characteristics of rice cv. BR11**

| Treatments | Grain length (mm) | Grain breadth (mm) | Grain-breadth ratio |
|---|---|---|---|
| $Zn_0$ | 8.40 | 2.93 | 2.87 |
| $Zn_1$ | 8.46 | 2.90 | 2.92 |
| $Zn_2$ | 8.76 | 2.92 | 3.00 |
| $Zn_3$ | 8.69 | 2.91 | 2.981 |
| $Zn_4$ | 8.57 | 2.92 | 2.98 |
| $Zn_5$ | 8.73 | 2.85 | 3.06 |
| $Zn_6$ | 8.90 | 2.87 | 3.11 |
| $Zn_7$ | 8.79 | 2.86 | 3.07 |
| CV % | 12.46 | 13.15 | 12.38 |

Plants grown with different levels of zinc applied in soil and foliage did not show any significant effect on the panicle length. The highest number of non-effective tillers $hill^{-1}$ (2.57) and sterile grains $panicle^{-1}$ (14.22) was obtained in the control and the lowest number (1.22 and 7.357, respectively) was obtained with foliar application of zinc at 0.5% $ZnSO_4$ solution. The highest number of fertile tiller $hill^{-1}$ (10.91) and straw yield (8.12) was recorded in soil application of Zn at 10 kg $ha^{-1}$ and lowest in control. The plant receiving 0.5 % $ZnSO_4$ solution by foliar application showed highest filled grains $panicle^{-1}$ (110.0) and the lowest was recorded in control. The highest 1000-grains weight (28.89 g) was found in 0.5 % $ZnSO_4$ solution by foliar application while the lowest (22.77 g) in control. The highest grain yield (5.56 ton $ha^{-1}$) was found in 0.5 % $ZnSO_4$ solution in foliar application while the lowest (4.15) was recorded in control. The above findings revealed that higher dose of both the soil and foliar application of Zn decreased yield while medium doses seemed to be the best. The reason may be due to the toxicity of that element. Yield attributing characters were affected significantly by the application of zinc. Application of 0.5 % $ZnSO_4$ solution seemed to be the best treatment.

The highest length and length-breadth ratio of rice grain was found in foliar application of 0.5% $ZnSO_4$ solution while the lowest in control (Table 2). On the contrary, the highest breadth was found in the control and lowest in foliar application of 0.3 % $ZnSO_4$ solution.

P, K, Mg and S content in rice grain and straw were significantly influenced by various methods and levels of zinc treatments (Table 3). Zinc treatment showed no significant effect on total N in rice grain and straw. The highest and lowest P content in grain and straw were found in foliage applied 0.1 % $ZnSO_4$ solution and control respectively. This result indicated that Zn fertilizer had positive influence on the P content in rice grain. K content was found highest in rice grain and with 10 kg $ha^{-1}$ by soil application. Zaman *et al.* (1994) in a trial on non-calcareous dark gray flood plain soil reported that Zn application cause decrement of k content in rice grain but when applied in calcareous soil with P influenced the accumulation of N along with P, S and Mn. In the present study, it is assumed that the same phenomenon might also have taken place. The effect of different levels of Zn on magnesium content in rice grain was statistically significant. The highest Mg content (0.039 %) was found in 0.5 %

$ZnSO_4$ solution treatment and lowest (0.195 %) in control. Mg content in straw did not differ significantly among the treatments. Since Mg is a mobile element and is readily translocated from older to younger parts of the plants and is involved in various physiological and biochemical functions (Tisdale *et al.*, 1984), its accumulation in small amounts in grain which we obtained in present study is, therefore, obvious. The sulphur content in rice grain and straw decreased significantly by the different treatments of Zn.

## Table 3. Effect of different levels of zinc on nutrient content of rice cv. BR11

| Treatments | Nitrogen (%) | | Phosphorus (%) | | Potassium (%) | | Magnesium (%) | | Sulphur (%) | | Zinc (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw | Grain | Straw |
| $Zn_0$ | 1.102 | 0.578 | 0.126b | 0.120a | 0.2180d | 1.11cd | 0.195c | 0.459 | 0.171a | 0.151a | 15.19g | 42.06c |
| $Zn_1$ | 1.194 | 0.598 | 0.243a | 0.087b | 0.261bc | 1.27bc | 0.265b | 0.527 | 0.137bc | 0.121b | 25.23c | 50.19ab |
| $Zn_2$ | 1.213 | 0.673 | 0.241a | 0.079b | 0.280a | 1.86a | 0.305a | 0.579 | 0.123c | 0.139ab | 32.65a | 55.15a |
| $Zn_3$ | 1.148 | 0.633 | 0.245a | 0.071b | 0.257bc | 1.05d | 0.294a | 0.563 | 0.128bc | 0.137ab | 29.14b | 52.95a |
| $Zn_4$ | 1.198 | 0.621 | 0.301a | 0.122a | 0.243c | 1.45b | 0.266b | 0.548 | 0.131bc | 0.123b | 19.25f | 43.25c |
| $Zn_5$ | 1.158 | 0.645 | 0.281a | 0.121a | 0.259bc | 1.37b | 0.271b | 0.571 | 0.145b | 0.145a | 21.21e | 45.61bc |
| $Zn_6$ | 1.130 | 0.703 | 0.275a | 0.120a | 0.274ab | 1.24bc | 0.309a | 0.593 | 0.129bc | 0.125b | 32.71a | 55.20a |
| $Zn_7$ | 1.219 | 0.566 | 0.257a | 0.119a | 0.269ab | 1.28bc | 0.307a | 0.569 | 0.123c | 0.149a | 24.15d | 52.53a |
| CV % | 6.14 | 24.30 | 12.85 | 6.57 | 5.46 | 8.62 | 6.80 | 8.99 | 10.14 | 4.59 | 4.41 | 6.64 |

$Zn_0$ =0 kg $ZnSO_4$ $ha^{-1}$; $Zn_1$ =5.0 kg $ZnSO_4$ $ha^{-1}$; $Zn_2$ =10.0 kg $ZnSO_4$ $ha^{-1}$; $Zn_3$ =15.0 kg $ZnSO_4$ $ha^{-1}$; $Zn_4$ =0.1 % $ZnSO_4$ solution; $Zn_5$ =0.3 % $ZnSO_4$ solution; $Zn_6$ =0.5 % $ZnSO_4$ solution and $Zn_7$ =0.7 % $ZnSO_4$ solution

**Table 4: Effect of different levels of zinc on protein and starch quality of rice cv. BR11**

| Treatments | Protein content (%) | | Starch content (%) | |
|---|---|---|---|---|
| | Grain | Straw | Grain | Straw |
| $Zn_0$ | 6.887 | 3.61 | 69.90 | 29.46 |
| $Zn_1$ | 7.467 | 3.69 | 71.14 | 34.53 |
| $Zn_2$ | 7.579 | 4.21 | 72.48 | 35.01 |
| $Zn_3$ | 7.176 | 3.75 | 7.50 | 34.58 |
| $Zn_4$ | 7.475 | 3.88 | 71.41 | 34.68 |
| $Zn_5$ | 7.238 | 4.03 | 71.10 | 34.88 |
| $Zn_6$ | 8.135 | 4.35 | 73.15 | 35.06 |
| $Zn_7$ | 7.618 | 3.54 | 70.62 | 34.40 |
| CV % | 12.43 | 12.85 | 5.29 | 4.96 |

The data presented in table 4 showed that protein content in rice grain and straw was not significantly influenced by the application of different levels of Zn whereas starch content significantly varied with the treatments. Li *et al*. (1999) observed that chlorophyll contents and net photosynthetic rates were significantly decreased and protein synthesis of rice was prevented due to Zn deficiency and also observed that rice quality increased by Zn application. The protein content varied from 6.887 to 8.135 % in grain and 3.54 to 4.35 % in straw. Our present study has produced the same result as that reported by Hussain *et al*. (1979). The maximum starch (73.15 %) found in 0.5 % $ZnSO_4$ solution of foliar application which was similar to 72.5 % as obtained by Chavan and Magar (1977).

Data incorporated in Table 5 presents the effect of different levels of zinc on nutrient status of post-harvest soil. The N content of pre-planting soil was 0.13 % which increased (up to 0.39 %) in all the post-harvest soils to a large extent which might be due to application of nitrogen fertilizer. The data revealed that the higher N present in post-harvest soil was obtained with soil applied Zn. It is evident that Zn is necessary for large number soils of Bangladesh for efficient utilization of nitrogen. The present study also reveals that application of Zn induced the availability of nitrogen in soil.

The available P in post-harvest soil significantly decreased by the addition of Zn. The decrease of P content of post-harvest soil from the pre-planting soil was probably due to uptake of huge amount of P by the plants. Pathak *et al.* (1975) observed that P had an antagonistic effect to the application of Zn.

Results also showed that K content of post-harvest soil was significantly decreased by the addition of Zn. Borhan (1996) also reported that K content was decreased with the increasing rate of Zn. The Mg content in post-harvest soil increased except control. This increase might be due to fixation of soil organic matters.

The S content in post-harvest soil was greater (up to 25.14 ppm) than the pre-planting soil (9.21 ppm). This increase in S content seems to be due to residual effect of S bearing fertilizers like gypsum. Zinc concentration in post-harvest soil was increased significantly with the application of different levels of Zn treatments. It revealed that the higher Zn content in post-harvest soil was obtained with soil application of Zn. Chaudhury (1997), Sharma *et al.* (1982) and Sachdev and Dev (1991) studied the relative utilization of different Zn carriers in soil and found that Zn uptake and Zn content increased with increasing rates of Zn application.

It can be concluded that foliage applied 0.5 % $ZnSO_4$ solution exerted best result regarding yield and nutritional qualities of rice. Finally, it might be suggested that 0.5 % $ZnSO_4$ solution by foliar application be employed with basal doses of other essential nutrients in soil as used in the present study.

**Table 5: Effect of different levels of zinc on nutrient status of post-harvest soil**

| Treatments | Nitrogen (%) | Phosphorus (ppm) | Potassium (me100g$^{-1}$ soil) | Magnesium (me100g$^{-1}$ soil) | Sulphur (ppm) | Zinc (ppm) |
|---|---|---|---|---|---|---|
| $Zn_0$ | 0.26d | 16.37a | 0.085a | 2.13f | 13.15g | 1.143f |
| $Zn_1$ | 0.233e | 8.513d | 0.087a | 4.51d | 15.52ef | 2.268c |
| $Zn_2$ | 0.391a | 7.751d | 0.082b | 6.033a | 25.14a | 2.667b |
| $Zn_3$ | 0.362b | 8.750d | 0.078b | 5.393b | 18.63cd | 3.427a |
| $Zn_4$ | 0.357b | 16.03a | 0.082b | 3.677e | 14.75fg | 1.191f |
| $Zn_5$ | 0.365b | 12.47b | 0.085a | 4.97c | 19.29c | 1.290ef |
| $Zn_6$ | 0.384a | 11.15c | 0.083a | 5.89a | 22.47b | 1.560e |
| $Zn_7$ | 0.339c | 10.21c | 0.082b | 4.83c | 17.23de | 1.890d |
| CV % | 4.67 | 4.90 | 4.36 | 3.14 | 5.85 | 9.68 |

## References


Anonymous. 1980. Zinc deficiency in rice and its remedy. Bangladesh rice Res. Ins. Booklet No. 44, 2nd edition. pp.1-2.

Assaduzzaman, M., Hashem, M.A., Islam, M.R. and Jahiruddin, M. 1996. Contribution of indigenous blue green algae to rice yield in relation to different added nutrients. Thai J. Agric. Sci. 29(2): 157-164.

Babiker, F.S.H. 1986. The effect of zinc sulphate levels on rice. Alexandria J. Agril. Res. 31(2): 480.

BARC. 1997. Fertilizer Recommendation Guide. Bangladesh Agricultural Research Council, Farmgate, Dhaka.

Borhan, U. 1996. Effect of zinc and boron on yield of rice and nutrient concentration in some soils of Bangladesh. M.S Thesis, Department of Agril. Chem., Bangladesh Agricultural University, Mymensingh. p. 47.

Chaudhury, F.M., Kausar, M.A., Rashid, A. and Rahmatullah, M. 1997. Mechanism of nitrogen effect on zinc nutrition of flooded rice. Plant and Soil. 46(3): 649-654.

Chavan, J.D. and Magar, N.G. 1977. Physicochemical characteristics of rice Maharashtra. Indian J. Agric. Sci. 47(9): 456-459.

Choudhury, A.K.M and Choudhury, A.H. 1990. Effects of sulphur and methods of zinc application on the yield of BR11 rice. Pak. J. Sci. Indus. Res. 33 (5 &6): 231-233.

Das, D.K., Singh, A.P. and Sakal R. 1993. Relative performance of some zinc carriers in maize-rice sequence under calcareous soil. Rajandra Agricultural University, India. 14(1): 84-89.

Haloi, B. 1998. Performance of growth promotors on rice crop efficiency and yield components. J. Agric. Sci. Soc. North-East India. 11(2): 226-229.

Hussain, A.K.M., Ahmed, I.U., Fair, S.M.A. and Syed, M.A. 1988. Growth and yield parameters of rice as affected by Zn, P and Mg interactions in acid soils of Bangladesh. Proceedings of the 13th Annual Bangladesh Science Conference. Section 1. p.139.

Hussain, M., Hossain, M.A. and Siddique, M.H.R. 1979. Physicochemical properties of some selected strains of rice. Bangladesh J. Sci. Ind. Res. XIV(3-4): 345-348.

Katyal, J.C. and Ponnanperuma, F.N. (1973). Zinc deficiency-a wide spread nutritional disorder of rice in Gusan del Notre. J. Phili. Agric. 58(3&4): 79-89.

Li, Yan, Qin, Suichu, Li, Y. andQin, S.C. 1999. Effect of rice metabolism and the diagnosis of hidden zinc deficiency in rice. J. Fujian Agric. Univ. 28(1): 66-77.

Pathak, A.N., Tiwari, K.N. and Kalusing, D.R. 1975. Zinc-phosphate interrelationship in rice. J. Ind. Soc. Soil Sci. 23(4): 477-483.

Prasad, B., Kumar, M. and Prasad, J. 1989. Direct effect of organic wastes and zinc sulphate on zinc availability under cropping sequence of wheat and rice. Indian J. Agric. Sci. 59(5): 300-305.

Prasad, J. and Bid, N.N. 1993. Response of crop on zinc in five districts of Uttar Pradesh. Proceeding of the workshop on micronutrients. Hindustan Fert. Crop, Lucknow, India. 57(1): 265-268.

Ranjan, A.R 1993. Relative utilization of different zinc carrier in rice (*Oryza sativa* L.) Ind. J. Agric. Chem. 26(1): 1-4.

Room-Singh, Sharma, M.P and Singh, R. 1994. Response of rice to different zinc carriers and their methods of application in partially reclaimed salt affected oil. Fertilizer News. 39(7): 51-52.

Sachdev, P and Dev, D.L. 1991. Zinc uptake by upland rice in relation to Zn ion activity in soil. Annals Agric. Res. 12(2): 109-114.

Shah, A.L. and De-Datta, S.K. 1982. Evaluation of methods of zinc application to rice in sodic soil. Fert. Res. 32(1): 161-167.

Sharma, B.D., Takkar, P.N. and Salna, V.S. 1982. Evaluation of level and methods of zinc application to rice in sodic soil. Fert. Res. 32(2): 161-167.

Shkolnik, M.J. 1974. Biochemical changes during metabolism of rice. Microelements in plant life. Nauka, Leningrad, 23 (RU).

Sommer, A.L and Lipman, C.B. 1926. *In*: Soil fertility theory and practice. J.S Kanwar, 1976. Ind. Council Agric. Res. New Delhi. p.10.

Tisdale, S.L. Nelson, W.L. and Beaton, J.D. 1984. Soil fertility and fertilizers, Macmillan Pub.Co. Inc. New York. pp.326, 328.

Zaman, M.W, Rahman, S.H., Morzia, B. and Ahmed, S. 1994. Phosphorus and zinc interaction in rice grain. Prog. Agric. 5(2): 273-278.