Agric. Rev., 24 (2) : 136 - 141, 2003

ZINC NUTRITION IN RICE - A REVIEW

S. Mythili, K. Natarajan and R. Kalpana

Tamil Nadu Agricultural University,
Coimbatore - 641 003, India

ABSTRACT

Micronutrient deficiencies are becoming serious because of escalated nutrient demand from more intensive and exploitative agriculture, coupled with use of single-nutrient fertilizers and low amounts of organic manures. In rice ecosystems, crop residue management by recycling wastes and manures is the prime factor that controls the long- term micronutrient balance of the soil. Micronutrient cycling in soils is closely associated with organic matter turnover because it is intricately related with trace elements. Green manures, being succulent and fast degrading under submerged condition, might act as effective electron acceptor and this property may influence the chemical reduction of all metallic cations thereby favouring the utilization of nutrients in general and Zn in particular, by rice. Keeping these points in view, the literature pertaining to the beneficial effects of added zinc either in the presence or absence of green manure on rice yield, Zn availability in soil and its uptake by rice for establishing integrated nutrient supply system in lowland rice have been reviewed.

Zinc deficiency - Occurrence and amelioration

The concentration of water-soluble Zn is lower in the lowland soils, and Zn deficiency is a wide spread nutritional disorder of wetland rice (Neue and Latin, 1994). Analyses of more than 1,00,000 soil samples from different agro-ecological zones of India showed marked Zn deficiency (41.7%) (Singh and Saha, 1995). Continuous rice cultivation over centuries in certain tracts depleted available Zn and Cu and increased Fe and Mn. Old Cauvery Delta soils of Thanjavur district, Tamil Nadu, which have been cultivated for centuries, exhibit Zn deficiency in more than 80 per cent of the area (Nagarajan, 1983). It is difficult for a farmer to identify Zn deficiency symptoms, which are described as Khaira in India, Hadda in Pakistan, Taya-Taya in Philippines, Akagare type II in Japan and bronzing in USA.

Since, lowland rice experiences widespread Zn deficiency in India, fertilization is common for Zn than for other micronutrients (Bansal and Nayyar, 1989). Many sources of Zn can be applied by different methods. Well-tested application methods for Zn include broadcast/band application, foliar spray, soaking or dusting the seed in Zn solution/dust, and dipping the seedling roots in Zn suspension/slurry. Zn deficiency is effectively controlled by field application of $ZnSO_4$ (Takkar and Walker, 1993). Trials in different agro-ecological zones of India showed that soil application of 25-50 kg ha^{-1} of $ZnSO_4$ is optimum for rice (Rajagopalan and Palanisamy, 1986).

To alleviate the Zn deficiency, different commercially available Zn sources used are $ZnSO_4$, ZnO, ZnS, Zn frits and Zn chelates. Maskina *et al.* (1979) studied various sources of Zn for lowland rice and found that all of them increased the yield. Krishnamurthy (1979) ascertained that Zn-EDTA at very low dose was as efficient as $ZnSO_4$. Ram and Raman (1984) stated that zinc complexes were superior to inorganic zinc as they provide zinc in an available form for a longer time, leading to higher mobilization of this element, which resulted in an enhanced plant growth, dry matter production and grain yield.

Rice was grown in an Inceptisol at Delhi with different Zn sources ($ZnSO_4$, zincated urea and ZnO) (Deb, 1990). The highest grain yield was obtained with $ZnSO_4$ and zincated urea. The highest utilization of Zn was however, observed with $ZnSO_4$ in both rice and the subsequent residual wheat crop. Rashid (1999) studied the methods of alleviating Zn deficiency in transplanted flooded rice grown in alkaline soils and reported that considering the effectiveness, economics and adaptability at farm level, the only viable alternative to the $ZnSO_4$ application to soil is seedling enrichment or application of $ZnSO_4$ to nursery beds.

Zinc concentration increased significantly in grain and straw of rice with 30 days of application of green manure (*S. aculeata*) leaves and gypsum to sodic soil, but remained less than the critical value of 10 ppm in a green house experiment (Swarup, 1991). The cultivation of zinc efficient varieties under zinc stress conditions is another alternative to combat zinc deficiency. A number of cultivars of different crops have been identified to be tolerant to zinc stress conditions (Nayyar and Chhibba, 1991).

Zinc application on dry matter production and rice yield

With the application of Zn, Sinha *et al.* (1985) observed a progressive increase in the dry matter production of rice at critical growth stages of crop while a significant increase in the dry matter production and total Zn content of rice was noticed by Deb (1990). Increase in rice grain yield due to Zn fertilization varied from 0.14 to 6.5 t ha^{-1} with a five-fold variation (0.29 - 1.4 t ha^{-1}) in average response (Takkar *et al.*, 1989).

The beneficial influence of Zn fertilization was evidenced by Balasundaram *et al.* (1981) at 30 kg $ZnSO_4$ ha^{-1} for rice grown in sandy soil of Srivilliputhur. Das and Singh (1982) appraised that Zn application favoured the root growth with mobilization of plant nutrients at optimum level and thereby increased the grain yield of rice. In calcareous silt loam soil, application of 5 kg Zn ha^{-1} as $ZnSO_4$ amended with compost at 10 t ha^{-1} significantly increased the Zn uptake and rice yield (Sakal *et al.*, 1985). Muralidharadu (1991) reported that the rice grown in Zn deficient soils of Tarai region (U.P) responded well to the application of chelated forms of Zn *viz.*, Zn-humate and Zn-fulvate.

Singh *et al.* (1995) reported that when Zn accompanied N, significant increase in grain yield was observed upto 150 kg N ha^{-1}. Yields obtained with 150 kg N ha^{-1} alone were statistically at par with those at 100 kg N ha^{-1} with Zn. The addition of Zn at all four N levels (0, 50, 100, 150 kg N ha^{-1}) increased Zn uptake and chlorophyll content significantly over the corresponding N levels without Zn. Hence to get higher yields, Zn should accompany N rather than applying only higher N doses.

Hasan (1997) studied the response of rice to Zn application to soil as $ZnSO_4$ and found that application of Zn with recommended NPK resulted in significant increase in grain yield over control. Application of Zn at 9 kg ha^{-1} yielded 5.8 t ha^{-1} compared to 4.6 t ha^{-1} with NPK alone, which was attributed to improved fertilizer NUE from Zn application.

Zinc application on zinc uptake by rice

Significant correlation between grain yield and Zn uptake at tillering stage, under flooded conditions with greater per cent recovery of fertilizer Zn as compared to moist soil was shown by Kaur *et al.* (1985). The main reason attributed for this increase was the pattern of root distribution and/or the physiological or morphological characteristics of rice roots growing in the moist or flooded soil conditions (Giordano and Mortvedt, 1973). According to Balakrishnan *et al.* (1985), $ZnSO_4$ application at 25 kg ha^{-1} to soil improved the N, P and K uptake, however at 50 kg ha^{-1}, the uptake of these nutrients was lowered. Increased concentration of zinc might have inhibited the utilization of these nutrients to a higher proportion.

Giordano and Mortvedt (1973) studied the effect of different Zn sources (ZnO, $ZnSO_4$ and Zn-EDTA) on Zn uptake by rice under flooded soil conditions and found that the uptake of Zn to be in the order of ZnO>$ZnSO_4$>Zn-EDTA. On the contrary, EDTA-Zn registered the highest concentration and uptake of Zn followed by $ZnSO_4.7H_2O$ and ZnO in a calcareous soil (Singh and Singh, 1980). Trivedi *et al.* (1997) studied the effect of dose of Zn application on yield and uptake of rice and found a quadratic relationship between Zn levels and pooled yield and pooled total Zn uptake, which indicated a continuation of Zn uptake upto 14.3 kg Zn ha^{-1} and a yield increase upto 13.6 kg Zn ha^{-1}. Thus the need to increase Zn application to about 12 kg ha^{-1} was felt.

Zinc availability in rice soils

Zinc availability per unit of Zn addition is more from Zn chelates than the other inorganic sources since they provide a better distribution of this nutrient in the soil due to their solubility (Brown, 1965). Results of a five years study, comparing the sources and methods of Zn application for rice in nine countries showed that 5 kg ha^{-1} of Zn as $ZnSO_4$ satisfied the Zn requirement of atleast two successive crops (IAEA, 1981). Chelated Zn (Zn-EDTA) was however equal to $ZnSO_4$ at the usual Zn rates as evidenced in these studies but was inefficient at low Zn rates.

The main factors affecting Zn availability in soil are pH, organic matter, $CaCO_3$ content and clay minerals. Misra and Pandey (1977) obtained a highly significant negative correlation between organic carbon and DTPA extractable zinc and indicated that high $CaCO_3$ content made Zn unavailable due to formation of insoluble $CaZnO_2$ in saline and alkali soils of Central Uttar Pradesh. The Zn deficiency is normally expected owing to pH; however, under submerged conditions, the pH tends to attain neutrality and hence, Zn availability is likely to be increased (Swarup, 1985). Contrary to this, Ponnamperuma (1977) observed a decrease in Zn availability with time lag when the soil was under submergence.

^{65}Zn studies confirmed the low availability and use efficiency of soil applied Zn (1-2 per cent) (Rajarajan, 1991). The soluble inorganic Zn, when added to soil, is readily adsorbed, fixed and converted into less soluble compounds. Rajarajan (1993) studied the retention and movement of applied Zn in rice soils as influenced by organic matter, N and P. He reported that more than 90 % Zn applied as $ZnSO_4$ remained in the top 0-5 cm layer and very little Zn reached the lower layers. Treatments of FYM, N and P at various levels had no effect on Zn movement. Applied Zn was not prone to leaching but was prone to fixation.

Zinc and Phosphorus interaction

Katyal (1972) investigated on the possible formation of zinc phosphate and its role in controlling zinc solubility. Of the 10 submerged soils investigated, zinc phosphate existed in 6 soils. Based upon transitory existence, zinc phosphate did not appear to exert a dominant control on zinc availability. In a subsequent study, application of P upto 500 mg kg^{-1} soil could hardly depress tissue zinc concentration to deficiency level. In the finding of Takkar *et al.* (1989), P application did not reduce zinc availability. On the contrary they noted a favourable effect on P application on zinc availability.

Mythili (1992) reported that the highest translocation of P to grain with the application of $ZnSO_4$ and green manure was due to the indirect influence of green manure in the reduction of iron and release of P from the insoluble ferric phosphate in rice soils. (Islam and Elahi, 1954 and Ponnamperuma, 1972). Further the straw P uptake was found to be increased with EDTA-Zn, the chelated form of zinc. The synergistic influence of Zinc on P uptake might be due to the formation of $ZnNH_4PO_4$ in soils under submergence, which favoured the increased availability of both zinc and phosphorus and increased their translocation in the plant system (Singh and Mittal, 1983; Balakrishnan *et al.*, 1985; Ilangovan, 1985; Katyal *et al.*, 1992, Nagarajan, 1983).

Influence of green manure on rice

Green manure has been recognized as an important source of N for wetland rice, as its application improves the physical condition of the soil and water retention, besides reducing the leaching loss of nutrients. Green manuring may also favourably alter the availability of several plant nutrients including Zn and S through its impact on chemical and biological properties of soils (Yadvinder Singh *et al.*, 1991). Bouldin (1988) observed yield increase with 60 days old green manures *viz.*, Sesbania aculeata and *S.rostrata* applied on equivalent basis of 60 kg N ha^{-1}. Ramasamy *et al.* (1988) reported that dhaincha at 12.5 t ha^{-1} produced significantly better grain yield than the yield with 40 kg N ha^{-1} application alone and when it was applied along with 40 kg ha^{-1}, the yield was even better than that obtained with 80 kg N ha^{-1}. Application of 30 kg N ha^{-1} as *S. rostrata* with 70 kg N ha^{-1} as urea produced the highest grain yield (5.2 t ha^{-1}) of rice compared to 100 kg N ha^{-1} (4.5 t ha^{-1}) as urea and no N (2.4 t ha^{-1}) (Rabindra *et al.*, 1989). Use of organics such as farmyard manure and green manure is a common practice, particularly in sodic soils, as green manures improve the crop growth and yield by amending the problems of sodicity (Swarup, 1987).

Green manure on zinc availability in soil

Organic manures supply Zn and other micronutrients to plants. They mobilize the native Zn through chelation and complex formation with organic ligands. Fractionation of Zn in the Zn-enriched organic manures reflected in an increase in the content of complexed Zn (Dravid and Goswami, 1987). The effect of organic manures such as green manure, poultry manure and farmyard manure in increasing the availability of plant nutrients in general, particularly availability of micronutrients was evidenced (Duraisamy *et al.*, 1981). Dhaincha (*S. aculeata*) as a green manure applied to black alkali soil improved the availability of Zn from 0.28 to 0.41 ppm (ICAR, 1977). The effect of Zn availability, uptake of Zn and rice grain yield was more with *dhaincha* than with lignocellular coir pith (Channel, 1992).

The Zn deficiency is also frequently reported in saline and/or sodic soils because of the increased pH and E.C. (Ponnamperuma, 1977). As a consequence of green manure addition under submergence, the water soluble Fe^{2+} and Mn^{2+} ions are liberated at higher proportion due to reduction, which in turn lowered the concentration of Zn^{2+} in the soil solution. Whereas, in sodic soils (pH 10.2), the green manure addition enhanced the availability of Zn due to the reduction in soil pH (Swarup, 1987). The Zn concentration in green manure amended soils was lowered during the initial stages with subsequent increase at later stages as compared to the soils not amended (Thind and Chandal, 1987). Mythili *et al.* (1993) evaluated the effect of *S. aculeata* on translocation of Zn and S to the grain, straw and roots of short duration rice variety ADT 36. $ZnSO_4$ + gypsum + green manure recorded the highest per cent translocation of total Zn absorbed to the grain.

Swarup (1991) reported that the zinc requirement rice crop in a sodic soil could also be met through organic sources like green manure, which contained 20 ppm of zinc and this might have also contributed to its enhanced availability in soil. Similarly only in a sodic soil having a pH of 10.2, green manure could increase the availability of applied zinc (Swarup,

1987) possibly due to reduction in soil pH brought about by green manuring under submerged conditions. Several workers (Katyal, 1977; Iu *et al.*, 1981; Katyal *et al.*, 1992; Khind *et al.*, 1987) have reported that water-soluble or DTPA-extractable zinc declined with the duration of flooding whether or not the soil was green manured. As liberation of water soluble Fe^{2+} and Mn^{2+} was enhanced by green manuring, it helped in the further lowering of soil solution zinc concentration in most of the investigations.

Combined effect of green manure and zinc on zinc availability, uptake and rice yield

Under submerged conditions, microbial reduction caused by anaerobic bacteria might bring about many chemical and electrochemical changes in the soil (Watanabe and Furusaka (1980). The intensity of microbial reduction is increased by green manures and thus the activity of Zn^{2+} in the ambient soil solution is much affected by a shift in the chemical equilibria of such soils (Rinaudo *et al.*, 1983). The beneficial effect of organic manures on Zn availability in rice soils was reported by several workers (Gupta *et al.*, 1983; Gupta and Raj, 1983; Singh *et al.*, 1983; Sakal *et al.*, 1985).

Soil application of $ZnSO_4$ with green manure results in greater Zn availability. In sodic soils, the yield of rice and Zn uptake were significantly higher when $ZnSO_4$ was applied along with green manure (Duraisamy *et al.*, 1981). Krishnamurthy *et al.* (1985) compared the effect of different organic and inorganic amendments with graded levels of Zn in a sodic soil (clay loam) having a pH of 8.95 and ESP of 24. Results indicated the superiority of green manure applied along with Zn at 2.5 ppm over other amendments by improving the soil environment and grain yield of rice. Soil application of Zn as Zn-DAP with green manure increased the grain yield of rice (Ilangovan, 1986). The water soluble or DTPA-extractable Zn declined with the duration of flooding both in the presence and absence of green manure (Khind *et al.*, 1987). Zn enriched green manures increased the availability of soil applied Zn to rice (Sharma and Mittra, 1990).

REFERENCES

Balakrishnan, K. *et al.* (1985). *Madras Agric. J.* 72: 25-30.

Balasundaram, C.S. *et al.* (1981). In: Proc. National Sem. "Micronutrients in Agriculture", Tamil Nadu Agricultural University, Coimbatore, 7-8, Jan. pp. 99-111.

Bansal, R.L. and Nayyar, V.K. (1989). *IRRN.* 14: 24-25.

Bijay Singh *et al.* (1992). *Fertil. News.* 37: 41-45.

Bouldin, D.R. (1988). Proc. Sym. Sustainable Agric., IRRI, Philippines, pp. 155-172.

Brown, A.L. (1965). *Crops and Soils*, 18: 10-13.

Channel, H.T. (1992). Ph.D Thesis, Tamil Nadu Agricultural University, Coimbatore.

Das, D.K. and Singh, M.P. (1982). *Oryza.* 19: 84-87.

Deb, D.L. (1990). *J. Nuclear Agric. Biol.*, 19: 236-241.

Dravid, M.S. and Goswami, N.N. (1987). *J. Nuclear Agric. Biol.* 16:201-205.

Duraisamy, P. *et al.* (1981). In: National Seminar on Micronutrients in Agriculture, Tamil Nadu Agricultural University, Coimbatore. pp. 248-254.

Giordano, P.M. and Mortvedt, J.J. (1973). *Agron. J.*, 65: 51-53.

Gupta, V.K. and Raj, H. (1983). *H.A.U. J. Res.*, 13: 249-253.

Gupta, V.K. *et al.* (1983). *Indian J. Agric. Sci.*, 53: 826-830.

Hasan, B. (1997). *IRRN.* 22: 34-35.

IAEA (1981). Intern. Atomic Energy Agency, Vienna, Tecdoc. pp. 242.

ICAR (1977). Annual Report, New Delhi, India.

Ilangovan, R. (1986). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Islam, M.A. and Elahi, M.A. (1954). *J. Agric. Sci.*, 45: 1-10.

Iu, K.L. *et al.* (1981). *Pl. Soil*, 59: 327-333.

Katyal, J.C. (1977). *Soil Biol. Biochem.*, 9: 259-266.
Katyal, J.C. *et al.* (1972). Technical Report IRRI, LosBanos, Laguna, Philippines, 115.
Katyal, J.C. *et al.* (1992). *Fertil. News*, 37: 27-33.
Kaur, P.N. *et al.* (1985). *Indian J. Agric. Sci.*, 55: 485-486.
Khind, C.S. *et al.* (1987). *IRRN.* 12: 42.
Krishnamurthy, V.S. *et al.* (1985). In: Proc. National Seminar on Salt affected Soils., Soil Salinity Res. Centre, Tiruchirapalli, Tamil Nadu.
Krishnamurthy, V.S. (1979). Ph.D Thesis, Tamil Nadu Agricultural University, Coimbatore.
Maskina, M.S. *et al.* (1979). *Indian J. Agric. Sci.*, 49: 367-370.
Misra, S.G. and Pandey, G. (1977). *J. Indian Soc. Soil Sci.*, 24: 336.
Muralidharadu, Y. (1991). *J. Indian Soc. Soil Sci.*, 39: 114-117.
Mythili, S. (1992). M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
Mythili, S. *et al.* (1993). *IRRN.* 18: 27.
Nagarajan, R. (1983). Ph.D Thesis, Tamil Nadu Agricultural University, Coimbatore.
Nayyar, V.K. and I.M. Chhibba. (1991). *Indian Fertil. Scene Annual*, 1: 4.
Neue, H.V. and Latin, K.S. (1994). *Monogr. Theor. Appl. Genet.* 21: 175-200.
Ponnamperuma, F.N. (1977). *IRRI Res. Paper Ser.*, 8: 1-15.
Ponnamperuma, F.N. (1972). *Adv. Agron.*, 24: 29-96.
Rabindra, B. *et al.* (1989). *IRRN*, 13: 28.
Rajagopalan, S. and Palanisamy, S. (1986). *IRRN.* 11: 26.
Rajarajan, A. (1991). Ph.D. Thesis, Tamil Nadu Agricultural University, Coimbatore.
Rajarajan, A. (1993). *IRRN.* 18: 26.
Ram, N. and Raman, K.V. (1984). *Agrochemica.* 28: 96-101.
Ramasamy, S. *et al.* (1988). *IRRN*, 13: 28.
Rashid, A. (1999). *IRRN.* 24: 32-33.
Rinaudo, G. *et al.* (1983). *Soil Biol. Biochem.*, 15: 111-113.
Sharma, A.R. and Mittra, B.N. (1990). *Fertil. News.* 35: 43-51.
Singh, A.K. *et al.* (1995). *IRRN.* 20: 16-17.
Singh, A.P. *et al.* (1983). *Indian J. Agric. Sci.*, 53: 918-921.
Singh, M. and Mittal, S.B. (1983). *J. Indian Soc. Soil Sci.*, 31: 132-134.
Singh, M. and Singh, S.P. (1980). *Pl. Soil*, 56: 81-92.
Singh, M.V. and Saha, J.K. (1995). In: 26th Progress Report of All India Coordinated Res. Project of Micro and secondary nutrients, IISS, Bhopal, pp. 145.
Sinha, M. *et al.* (1985). *J. Indian Soc. Soil Sci.*, 33: 933-934.
Swarup, A. (1985). *J. Indian Soc. Soil Sci.* 33:352.
Swarup, A. (1987). *Biol. Fertil. Soils.* 5: 203-208.
Swarup, A. (1991). *J. Indian Soc. Soil Sci.*, 39: 530-536.
Takkar, P.N. and Walker, C.D. (1993). In: Zinc in Soils and Plants. Kluwer Academic Publishers, pp. 151-165.
Takkar, P.N. *et al.* (1989). In: Twenty Years of Coordinated Research on Micronutrients. Bull. No. 1., IISS, Bhopal. Pp. 114.
Thind, H.S. and Chandai, D.S. (1987). *Biol. Fertil. Soils.* 3: 179-182.
Trivedi, B.S. *et al.* (1997). *IRRN.* 22: 37.
Watanabe, I. and Furusaka, C. (1980). Adv. *Microbiol. Ecol.* 4: 125-168.
Yadvinder Singh *et al.* (1991). *Adv. Agron.*, 45: 135-189.