Zn Management in Calcareous Soils of Bihar

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Among different micronutrients, Zn deficiency is widespread in Bihar soils and is adversely affecting crop productivity especially in calcareous soils. If Zn deficiency is not diagnosed and rectified, the problem will become alarming in the future because land has to be cultivated more intensively to produce extra food, fiber, fuel, fodder, fruits etc. to meet the requirements of an increasing population. Continuous cropping of cereal after cereal in cropping systems such as rice-wheat is magnifying the Zn depletion in soils.

Soil analysis is a useful and convenient diagnostic tool for a quick and timely assessment of Zn availability. The DTPA-$CaCl_2$ extractable Zn is the most widely used soil test since it works well in most soils. This test also responds well to fertilizer applications and can assess residual effects of Zn fertilization. However, the critical limit varies with soil and crop types. The critical limit of DTPA-$CaCl_2$ extractable Zn in Bihar soils ranged from 0.50 to 0.90 mg kg^{-1} with 0.78 mg kg^{-1} for calcareous soils below which profitable responses to a Zn application can be expected. The magnitude of Zn deficiencies in calcareous soils on a district level are given in Table 1.

Table 1. Zinc deficiencies in calcareous soils on a district level.

District	No. of Samples	% soil samples deficient
E. Champaran	429	60
Muzaffarpur	1309	75
Samastipur	1195	57
Begusarai	715	54
Vaishali	331	48
Saran	1094	77
Gopalganj	599	78
Siwan	1015	79
Overall	6687	68

The magnitude of Zn deficiency, based on a critical limit of 0.78 ppm in young alluvium calcareous soils, ranged from 48 to 79% (average 68%) with more than 70% Zn deficiency in soils of Muzaffarpur, Saran, Siwan and Gopalganj districts. A minimum Zn deficiency (48%) was recorded in soils in the Vaishali districts.

The extent of Zn response varies widely from crop to crop, between varieties of a crop and on different soils for the same crop. The soils inherently high in available Zn may have lower yield responses or even no responses to a Zn application. On the contrary, soils classified low in Zn will produce an invariably higher magnitude in yield response. Hence, the dose of Zn varies according to the soil status of available Zn, the nature of crops in cropping systems and the methods of Zn application. The Zn-use efficiency of $ZnSO_4$ hardly exceeds 2–5% in calcareous soils; its dose has been fixed at a higher rate, i.e. soil application of 5-10 kg Zn ha^{-1} although the crop requirement hardly exceeds 200g ha^{-1}.

The response of crops to soil-applied Zn in field trials had an average of 3.4 to 7.3 q ha^{-1} in cereals, 0.50 to 4.5 q ha^{-1} in pulse, 0.90 to 4.7 q ha^{-1} in oilseeds, 72.5 q ha^{-1} in onion, 58.5 q ha^{-1} in potato and 193 q ha^{-1} in sugarcane. The maximum yield response was found in rice followed by maize and was least in wheat. The yield response data for different crops show that there is an ample scope to enhance crop productivity by Zn application in Zn-deficient soils. The application of Zn to soils based on soil analysis is more profitable. A maximum benefit can only be derived from Zn treatments if the supply of NPK is maintained at optimum levels.

Different methods of Zn application were tested to identify an alternative Zn application method. The response to Zn applications using different methods was variable.

(i) Soil Application

The application of Zn to soil is the most satisfactory way to cure Zn deficiency. Zinc is applied by broadcasting or placed beside and below the seeds. When broadcasted, Zn fertilizers should be incorporated into the soil. In calcareous soils, the application of Zn at 0, 5 and 10 kg Zn ha^{-1} using $ZnSO_4$ or ZnO in winter maize proved equally effective with respect to grain yield response. However, the lower Zn level irrespective of Zn carriers placed below the seeds appeared to be slightly better than the broadcasting method. This might be due to a more efficient utilization of Zn by plants because their roots are closer to the Zn carriers. Increasing Zn levels progressively increased Zn concentration and its uptake by crops.

A split application of 25 kg $ZnSO_4$ ha^{-1} (12.5 kg at rice transplanting and 12.5 kg at tillering as a top-dress) appeared to be similar to an application of 25 kg $ZnSO_4$ once at transplanting on the sites Pusa and Dholi Farms. Two equal splits of 25 kg $ZnSO_4$ at transplanting and panicle initiation produced a significantly lower yield. The application of Zn in three splits (10 kg at transplanting + 10 kg at tillering + 4 kg at panicle initiation stage) was also similar to a single application at transplanting. This indicates that rice crops require only 20 kg $ZnSO_4$ ha^{-1} at transplanting and tillering, whereas 5 kg $ZnSO_4$ at panicle initiation is not useful. The application of 25 or 50 kg $ZnSO_4$ ha^{-1} is similar with respect to yield response of rice.

Considering the variation in the soil status of available Zn, intensive cropping systems, such as rice-wheat rotation and crop genotypic differences in mining soil-Zn, it is recommended to apply 25 kg $ZnSO_4$ ha^{-1} annually to the soil as a basal treatment or 50 kg $ZnSO_4$ ha^{-1} in alternate years.

(ii) Foliar spray

Zinc deficiency is more often corrected by Zn applications to soil than to standing crops. Foliar spray of 0.5% $ZnSO_4$ solution neutralized with slaked lime is applied to combat Zn deficiency. In the majority of the cases, foliar spray was found inferior to soil applications because considerable crop damage has already occurred when Zn deficiency can be observed. Therefore, foliar spray should be considered as a supplement rather than a substitute for soil application. The results of foliar-spraying $ZnSO_4$ solution (0.5% $ZnSO_4$ solution + 0.25% slaked lime) resulted in grain yield responses ranging from 4-9 q ha^{-1} in rice, 8-9 q ha^{-1} in maize and 2-10 q ha^{-1} in wheat.

(iii) Roots dipping

Dipping of rice and onion seedling roots into 3% ZnO suspension before transplanting was effective in controlling Zn deficiency and in enhancing crop yield. Yield responses after dipping roots into 3% ZnO suspension was 16 q ha^{-1} for rice grains and 66 q ha^{-1} for onion bulbs. The soils adhering to the root surface should be washed off with water before dipping the roots into suspension. The bundles of seedlings should be kept in the shade after the treatment for some time before transplanting to allow the solution to dry and to stick to the root surface.

Incorporation of Zn-amended organic manures in soils was found effective in increasing the Zn-use efficiency. The application of moderate doses of organic manures as a FYM/ compost/biogas-slurry with Zn may result in extra yield and raise the soil status of available Zn from deficiency to sufficiency levels. The direct effect of Zn and Zn-amended FYM was evaluated in rice and the residual effect in winter maize in a field experiment on calcareous soil. Results indicated that mixing 12.5 kg $ZnSO_4$ with 5t FYM ha^{-1} produced rice-grain yield responses up to 13.9 q ha^{-1} while an application of 25 kg $ZnSO_4$ ha^{-1} resulted in 12.6 q ha^{-1}. This would result in a saving of 12.5 kg $ZnSO_4$ ha^{-1} compared to the recommended dose of Zn due to the combined application with FYM. Zinc uptake ranged from 56 to 247 g ha^{-1}. The residual effect of 5t FYM + 12.5 kg $ZnSO_4$ ha^{-1} produced a maize-grain yield response of 8 q ha^{-1} while 25 kg $ZnSO_4$ ha^{-1} resulted in a 6.9 q ha^{-1} response. This indicated an increase in Zn-use efficiency by 50%. In another experiment, mixing 12.5 kg $ZnSO_4$ with 5 or 10 t ha^{-1} FYM/compost produced a similar magnitude in yield responses in rice, namely 15.5 or 16.8 q ha^{-1}, respectively, compared to 13.8 q ha^{-1} obtained with an application of 25 kg $ZnSO_4$ ha^{-1}. residual effects of 12.5 kg $ZnSO_4$ + 5 t FYM/compost produced grain yield responses of 4.4 q ha^{-1} in barley and 5.3 q ha^{-1} in rice.

A field experiment with Zn and biogas slurry (BGS) mixed in different ratios was conducted to evaluate the proper ratio to enhance the productivity of crops in a rice-wheat system. The combined application of Zn and BGS was effective in augmenting crop yield, Zn-uptake, Zn-use efficiency and available Zn in the post harvest soil. Application of 10 t ha^{-1} BGS was as effective as 5 kg Zn ha^{-1} (25 kg $ZnSO_4$ ha^{-1}) in increasing grain yields in four crops. However, the application of 2.5 kg Zn + 1.5 t ha^{-1} BGS was superior to the 5 kg Zn ha^{-1} application. It was further observed that a Zn:BGS ratio of 1:500 was suitable for a better utilization of applied and native Zn.

In a long-term experiment, crop yields reduced with times after the 10th cropping cycle at four fertility levels tested and available soil-Zn decreased below the threshold value in treatments receiving 100% NPK fertilizers with each crop. However, in all superimposed treatments (Zn, FYM, Zn + FYM) after the 10th cycle, the available soil-Zn status was adequate reaching a maximum value in 10 kg Zn + 10t FYM ha^{-1} treatments. Thus, results indicate that crop yields can be sustained on a long-term basis with an application of Zn-amended organic manure to Zn-deficient soils.

The effect of crop residue recycling in rice-wheat systems on calcareous soils indicated that an application of 5 kg Zn ha^{-1} with the first crop and 50% crop residue of every crop was as effective as 100% crop residue alone. This indicates a saving in crop residues of 50%. The magnitude of yield increase and Zn-uptake was higher in rice than in wheat, which indicates that rice benefited more than wheat from crop residue incorporation. The soil status of available Zn progressively improved with rising levels of crop residues.