Zinc-Enriched Urea Improves Grain Yield and Quality of Aromatic Rice

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Zinc-deficiency is widespread in the rice-growing tracts of northern India. The use of Zn-enriched prilled urea formulations assures better quality control than with Zn sulfate ($ZnSO_4$), which is being sold to farmers in India, but has quality issues. In this study, we found $ZnSO_4$ to be a better source to enrich prilled urea than Zn oxide (ZnO). For aromatic rice production, 1.0% Zn-enriched urea ($ZnSO_4$) was most effective in realizing higher grain yield and economic return.

In India, rice is the most important food crop, occupying 44 million (M) ha of land and producing 141 million metric tons (M t) of grain annually. But the per hectare yield of rice (3.21 t/ha) for India, though increasing marginally, is still well below the world's average yield of 4.15 t/ha. Furthermore, the aromatic rice varieties occupy a prime position in national and international markets due to their excellent quality characters, namely, aroma, fineness, and kernel length for cooking.

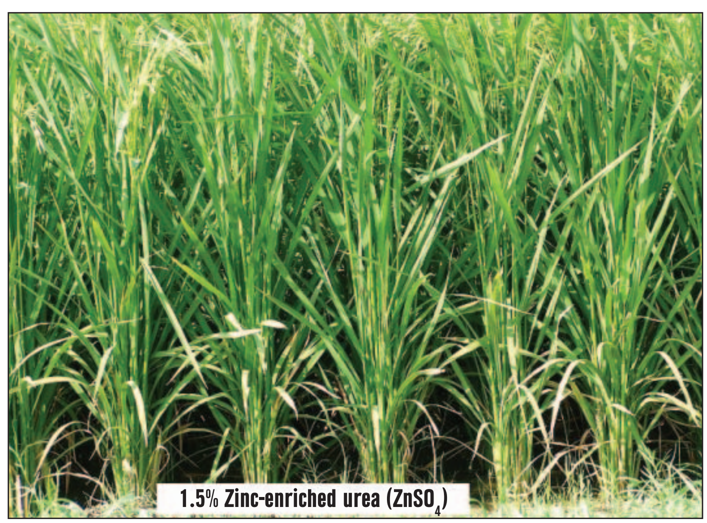
The use of macronutrients and micronutrients is important to increase aromatic rice yields and improve the quality of grains. Besides N, P, K, and S, Zn has gained maximum attention of late. The apparent reason for this is the overwhelming dominance of Zn deficiency in Indian soils and crops compared to other nutrients (Rattan et al., 1997). Increasing cropping intensity and accompanying changes in the soil and fertilizer management practices have lowered the Zn status of soils and its availability, especially in the Indo-Gangetic plains of India where rice-wheat cropping system is being practiced on a large-scale (Prasad, 2005).

The recommendation for Zn, which is generally marketed as Zn sulfate heptahydrate ($ZnSO_4 \bullet 7H_2O$), varies from 10 to 25 kg/ha/season, depending upon the crop, environmental, and soil conditions. One of the major issues that farmers in India are facing is the availability of good quality $ZnSO_4$. Therefore, a good quality Zn-enriched urea (ZEU) manufactured by a fertilizer company would be ideal. Government of India's Fertilizer Control Order (FCO) has a provision for manufacturing and coating of 2.0% Zn onto urea. But very limited scientifically-valid data are available on the evaluation of Zn-coated urea in aromatic rice. We conducted a field experiment at the Indian Agricultural Research Institute (IARI), New Delhi, during *kharif* (summer monsoon) seasons (July-October) of 2005 and 2006 to evaluate the effectiveness of Zn-enriched urea formulations on grain yield and quality of aromatic rice in a sandy clay loam soil. The experimental soil had low levels of available Zn (0.68 ppm). The critical level of DTPA extractable Zn for rice grown on alluvial soils in the rice-wheat belt of North India varies from 0.38 to 0.90 ppm soil (Takkar et al., 1997). The soil contained 0.53% organic C, 0.05% total N, 14.5 kg/ha available P and 247 kg/ha available K at the start of the experiment. The initial soil pH was 8.2. New Delhi has a semi-arid and sub-tropical climate with hot and dry summers and cold winters. The mean annual rainfall is about 710 mm, most of which (about 84%) is received between July and September.

View of research plots.

In our experimental layout, there were a total of 10 treatments. Basic treatments consisted of eight combinations of two Zn-enrichment materials ($ZnSO_4$ and ZnO) and four levels of Zn-enrichment (0.5, 1.0, 1.5, and 2.0% w/w of prilled urea). In addition, there were two other treatments including a no Zn control (only PU) and $ZnSO_4$ at 5 kg Zn/ha (soil application)

Abbreviations and notes for this article: PU = prilled urea (common urea); Zn = zinc; ZEU = zinc-enriched urea; ZnO = zinc oxide; $ZnSO_4$ = zinc sulfate; DAT = days after transplanting; HRR = Head rice recovery; N = nitrogen; P = phosphorus; K = potassium; S = sulfur; C = carbon; CD = Critical Difference, equivalent to Least Significant Difference; ppm = parts per million.



Plot showing rice with 1.5% Zn-enriched urea treatment ($ZnSO_4$).

Table 1. Grain yield, agronomic efficiency, and economic return of Zn use in aromatic rice as affected by Zn-enriched urea formulations.

Treatment	Zn rate, kg/ha	Grain yield across two years, t/ha	Agronomic efficiency of Zn, kg grain increase/kg Zn	Economic return,[1] Rs/Re invested in Zn
PU	0	3.98	–	–
0.5% ZEU (ZnO)	1.3	4.25	208	13.3
0.5% ZEU ($ZnSO_4$)	1.3	4.44	353	22.7
1.0% ZEU (ZnO)	2.6	4.46	185	11.9
1.0% ZEU ($ZnSO_4$)	2.6	4.66	261	16.8
1.5% ZEU (ZnO)	3.9	4.68	179	11.5
1.5% ZEU ($ZnSO_4$)	3.9	4.96	251	16.1
2.0% ZEU (ZnO)	5.2	4.95	186	11.9
2.0% ZEU ($ZnSO_4$)	5.2	5.14	223	14.3
PU + 25 kg $ZnSO_4$/ ha soil application	5.3	5.18	226	14.5
CD (p=0.05)	–	0.47	–	–

[1]Taking GOI procurement price of fine paddy at Rs.6.10 per kg, and cost of Zn at Rs.95/kg. Minor changes in price of these commodities will not change the conclusion.
US$1 is approximately equal to Rs.46.

Table 2. Effect of Zn-enriched urea formulations on grain quality of aromatic rice in second year of experimentation

Treatment	Zn rate, kg/ha	Hulling, %	Milling, %	Head rice recovery, %	Protein content, %
PU	0	70.2	63.7	52.4	6.6
0.5% ZEU (ZnO)	1.3	73.7	64.8	53.8	6.7
0.5% ZEU ($ZnSO_4$)	1.3	74.6	65.2	54.3	6.8
1.0% ZEU (ZnO)	2.6	74.8	65.6	54.5	6.9
1.0% ZEU ($ZnSO_4$)	2.6	75.6	66.3	55.1	7.0
1.5% ZEU (ZnO)	3.9	75.9	66.5	55.3	7.1
1.5% ZEU ($ZnSO_4$)	3.9	76.2	67.2	56.1	7.2
2.0% ZEU (ZnO)	5.2	76.3	67.8	57.2	7.3
2.0% ZEU ($ZnSO_4$)	5.2	78.5	69.3	58.3	7.6
PU + 25 kg $ZnSO_4$/ha soil application	5.3	75.8	66.2	55.2	7.2
CD (p=0.05)	-	2.6	2.7	2.1	0.6

+ prilled urea. In the soil application treatment, $ZnSO_4$ was applied on the soil surface (broadcast and incorporated), which is the general recommendation for rice in India (Rattan et al., 1997). The treatments were replicated thrice in a randomized block design. All plots received 120 kg N/ha as ZEU or PU. At final puddling, 60 kg P_2O_5/ha as single superphosphate and 40 kg K_2O/ha as KCl were broadcast. Nitrogen at 120 kg N/ha as PU or ZEU was band-applied in two equal splits – half at 10 DAT and the other half at panicle initiation (40 DAT). The ZEU supplied 1.3, 2.6, 3.9, and 5.2 kg Zn/ha for the 0.5, 1.0, 1.5, and 2.0% coatings, respectively. To make up for the short fall of N in ZEUs, calculated amounts of additional N as PU were added in plots receiving ZEUs. Two to three 25 day-old seedlings of basmati (aromatic) rice variety 'Pusa Sugandh 5' were transplanted on hills at a row x plant spacing of 20 cm x 10 cm in the second week of July during 2005 and 2006.

The increase in grain yield in ZEU treatments over prilled urea ranged from 7.7% (0.5% ZEU-ZnO) to 35.9% (2.0% ZEU-ZS). A 0.5% Zn-enrichment of PU through $ZnSO_4$ or ZnO did not give a significant increase in grain yield over PU **(Table 1)**. However, a significant increase in grain yield over PU was obtained with 1.0, 1.5, and 2.0% Zn-enrichment either with $ZnSO_4$ or ZnO-enriched ureas and with soil application of $ZnSO_4$. Among the three higher levels of Zn enrichment (1.0, 1.5 and 2.0%), the highest grain yield was obtained at the 2.0% level. But the economic return was highest at the 1.0% level in the case of $ZnSO_4$, and at the 2.0% level in case of ZnO. Further, 1.0% ZEU ($ZnSO_4$) gave much higher economic return than 2.0% ZEU (ZnO).

In general, $ZnSO_4$-enriched urea was a better source than ZnO-enriched urea at the same level of Zn enrichment. This could be due to better solubility of $ZnSO_4$-enriched urea than of ZnO-enriched urea at the same level of Zn enrichment as observed by Nayyar et al. (1990). Slaton et al. (2005) also observed that Zn fertilizer source, averaged over application times, significantly affected grain yield of rice at all sites with Zn fertilization increasing yields by 12 to 180% compared with the unfertilized control.

Grain quality parameters were studied in year 2 of the study **(Table 2)**. Application of ZEUs improved the grain quality of rice significantly. In general, $ZnSO_4$-enriched urea had a higher percentage of hulling, milling, and head rice recovery (HRR) than ZnO-enriched urea at a same level of Zn-enrichment. For example, protein content and other quality parameters improved significantly with 1.5% ZEU ($ZnSO_4$), 2.0 % ZEU ($ZnSO_4$ or ZnO), and soil application of $ZnSO_4$. The lower levels of Zn-enrichment (0.5% or 1.0%) did not improve grain quality over the PU.

Conclusion

In this study, $ZnSO_4$ was a better source than ZnO for Zn-enrichment of prilled urea. A 1.0% coating may be sufficient for rice, with higher economic return per rupee invested in Zn. For improved grain quality, 1.5% Zn-enriched urea ($ZnSO_4$) may be more appropriate than other Zn formulations. BC

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