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Zinc fertilization effect on productivity and nutritional status of rice (*Oryza sativa*) in North-east India

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The productivity of rice (*Oryza sativa* L.) in North Eastern hill (NEH) region is about 2.0 t/ha (Das *et al*. 2020) which is lower than the national average, leading to production deficit of 9.53% in the region (Roy *et al*. 2015). The problems of drought and flood, improper crop management, and nutrient imbalances are some of the important concerns of rice cultivation in NEH region. The nutrient imbalance is basically due to soil inherent nutrient status and soil acidity as well as changes in soil reaction and nutrient availability due to heavy rainfall and puddled soil conditions. Among the nutrients, concentration of iron (Fe), manganese (Mn), zinc (Zn), nitrogen (N) and phosphorus (P) are affected significantly due to change in *p*H (Fageria *et al*. 2011). The reducing conditions prevalent in periodically waterlogged soils leads to increased concentrations of divalent ferrous (Fe^{++}) and manganese (Mn^{++}) ions, from the dissolution of their hydrous oxides, and these could compete with Zn ions for uptake into roots (Alloway 2008). Hence, lowland rice fields having medium to adequate status of available Zn could become Zn deficient under waterlogged conditions. Considering the role of Zn in human nutrition (Palmgren *et al.* 2008), widespread Zn deficiency (Tandon 2013) and response of rice to Zn fertilization even on soils with high Zn status (Wissuwa *et al*. 2008), an experiment was conducted to study the effect of various options of Zn fertilization for their effectiveness in rice.

A field experiment was conducted during the *kharif* season (June–November) of 2015 at the research farm of ICAR Research Complex for NEH Region, Umiam, Meghalaya, India located at 25°41' N latitude, 91°54' E longitude and at an altitude of 980 m amsl. The climatic condition of Umiam is sub-tropical type. The total rainfall at experimental site during crop growing season was 1954.1 mm. The soil texture of the experimental site was clayey loam with 278.8 kg/ha, 18.9 kg/ha, 125.4 kg/ha, 12.4 kg/ha and 2.06 mg/kg soil of available N, P (Bray's-1), K (NH_4AOC-extractable), sulphur and DTPA-extractable Zn, respectively. The soil pH and organic carbon content were 4.51 and 2.8%, respectively. Field experiment involving rice variety Shahsarang 1 was laid out in a completely randomized block design involving 10 treatments under three replications. Treatments consisted of three Zn coated urea (ZnCU), i.e. T_1-1% ZnCU, T_2-2% ZnCU, T_3-3% ZnCU, two rates of soil Zn application through Zn sulphate heptahydrate ($ZnSO_4.7H_2O$), i.e. T_4- 2.5 kg Zn/ha and T_5-5 kg Zn/ha and three foliar Zn application treatments, i.e. T_6- one spray at panicle initiation (PI) stage, T_7- two spray at PI and flowering stage and T_8- three spray at PI, flowering and grain filling stages, these treatments were compared with two control, viz. T_9- prilled urea application and T_{10}- absolute control (no urea application). The quantity of Zn supplied through 1%, 2% and 3% ZnCU were 2.6 kg Zn/ha, 5.2 kg Zn/ha and 7.8 kg Zn/ha, respectively. For all these three treatments half dose of ZnCU was applied to soil as basal and the remaining half was applied in two equal split doses at 30 and 60 days after transplanting (DAT). In case of foliar application, $ZnSO_4.7H_2O$ at the rate of 0.1% Zn (in 1000 l of water/ha) was sprayed at the required stages as per the treatment. For each foliar spray one kg Zn/ha was used every time. For example, in case of T_6, T_7 and T_8, one, two and three kg Zn was used for respective treatments.

The 23 days old rice seedlings were transplanted in puddled field at 20 cm × 20 cm spacing using two-three seedlings/hill. The recommended rate of N, P and K (80:26.2:33.3 kg/ha) was applied as per treatments. The N was split applied as 50% at transplanting, 25% at 30 DAT and 25% at 60 DAT; while complete dose of P and K was applied as basal dose. The leaf area meter was used to determine leaf area (cm^2) and was expressed as leaf area index (LAI).

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Table 1 Effect of zinc (Zn) fertilization options on growth parameters and yields of rice

Treatment	LAI			Chlorophyll index			Tillers/m² at harvest	Root volume (cm³) at harvest	Grain yield (t/ha)	Biological yield (t/ha)
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT				
1% Zn coated urea	1.68abc	5.45ab	5.38abcd	36.2a	39.0ab	36.6a	351.7a	35.9ab	4.81abc	11.05bc
2% Zn coated urea	1.75abc	5.60ab	5.74abc	35.3a	39.1ab	36.8a	360.8a	35.8ab	5.10ab	11.81ab
3% Zn coated urea	1.77ab	5.87a	5.94a	38.0a	40.2a	37.4a	385.0a	40.5a	5.46a	12.54a
Soil application of Zn 2.5 kg/ha	1.66bc	5.63ab	5.32abcd	34.9a	39.3a	35.6ab	355.8a	35.3ab	4.83abc	11.05bc
Soil application of Zn 5.0 kg/ha	1.90a	5.78a	5.83ab	37.6a	40.1a	36.3ab	370.8a	40.4a	5.36a	12.41a
0.1% foliar Zn spray at panicle initiation stage	1.52cde	5.30ab	4.97dc	36.5a	38.2ab	34.8ab	365.8a	36.1ab	4.53bc	10.78bc
0.1% foliar Zn spray at panicle initiation and flowering	1.54bcde	5.22ab	5.07bcd	35.7a	38.6ab	35.8ab	354.2a	36.0ab	4.84abc	11.19bc
0.1% foliar Zn spray at panicle initiation, flowering and grain filling	1.55bcd	4.91ab	5.04bcd	36.3a	37.6ab	35.9ab	362.5a	37.6ab	5.02abc	11.61ab
Prilled urea (Control)	1.42de	4.68b	4.73de	35.6a	36.0b	33.3b	349.2a	34.3b	4.37c	10.13c
Absolute control (No N application)	1.31e	2.78c	4.10e	27.8b	27.8c	29.1c	241.7b	26.7c	3.34d	7.87d
SEm(±)	0.08	0.33	0.27	1.29	1.08	1.02	15.08	2.03	0.24	0.38
CD (P=0.05)	0.23	0.98	0.81	3.83	3.21	3.02	44.80	6.03	0.72	1.13

DAT, Days after transplanting; CD, Critical difference; SEm, Standard error of means.

The chlorophyll index of the rice crop was determined with the help of a SPAD meter. For measurement of biological and grain yield, net plots (10.5 m^2) were harvested and sun-dried and then weighed to record biological yield and grain yield after threshing. The N, P and K concentration in grain and straw was determined following standard procedure. The concentration of sulphur (S) and Zn was determined by using barium sulphate turbidimetry method and Atomic Absorption Spectrophotometer (AAS) from di-acid digested grain and straw sample.

All the data obtained from the experiment were statistically analysed using the F-test as per the standard statistical procedure and least significant difference (LSD) values (P = 0.05) were used to determine the significance of difference between treatment means.

The LAI increased rapidly from 30 to 60 DAT, with marginal increase from 60–90 DAT. The highest LAI was recorded with soil application of Zn at 5 kg/ha at 30 DAT and 3% ZnCU both at 60 and 90 DAT. At 30 DAS, soil Zn application (both 2.5 and 5 kg/ha) and all ZnCU treatments gave significantly higher LAI over prilled urea. However, at 60 and 90 DAT soil application of Zn at 5 kg/ha and 3% ZnCU had recorded significantly higher leaf area over prilled urea. This showed the superiority of soil application of Zn at 5 kg/ha and 3% ZnCU in enhancing LAI (Singh and Shivay 2014). The chlorophyll index was highest at 60 DAT and decreased thereafter (Table 1). At 60 DAT 3% ZnCU and soil application of Zn (both 2.5 and 5 kg/ha) had significantly higher chlorophyll index over prilled urea and at 90 DAT, all three ZnCU treatments had superior chlorophyll index over prilled urea. The chlorophyll index obtained with application of prilled urea was superior to absolute control (no nitrogen application) which signifies the role of N in leaf chlorophyll synthesis.

The highest number of tillers/m^2 was observed with application of 3% ZnCU, which had 35.8 and 143.3 tillers/m^2 higher than prilled urea and absolute control, respectively. Application of prilled urea produced significantly a greater number of tillers/m^2 over no N application. It had been previously reported that application of Zn (Prasad and Shivay 2020) and N play a significant role in enhancing the yield attributes such as tillers/m^2 and panicles/m^2 and yields (Shivay and Prasad 2012). Application of 3% ZnCU and soil application of Zn at 5 kg/ha had significantly higher root volume than prilled urea and increase in root volume in these treatments over prilled urea were 6.2 and 6.1 cm^3, respectively. Soil application of Zn (5 kg/ha) and 3% ZnCU gave significantly higher grain and biological yield than prilled urea. Increase in grain and biological yield due to soil application of 5 kg Zn/ha were 0.99 and 2.28 t/ha and that for 3% ZnCU were 1.09 and 2.41 t/ha, respectively over prilled urea. The biological yield with 2% and 3% ZnCU was significantly higher than 1% ZnCU. Both 2.5 or 5.0 kg Zn/ha to soil gave grain yields on par with each other; while biological yield was significantly higher under application of 5 kg Zn/ha than 2.5 kg Zn/ha.

Table 2 Effect of zinc (Zn) fertilization options on nutrient concentrations in rough rice grain and straw of rice

Treatment	Nutrient concentrations in rough rice grain					Nutrient concentrations in rice straw				
	N (%)	P (%)	K (%)	S (%)	Zn (mg/kg)	N (%)	P (%)	K (%)	S (%)	Zn (mg/kg)
1% Zn coated urea	1.17bcd	0.33abc	0.30bc	0.11a	33.9bcd	0.66ab	0.12	1.99	0.07bc	98.6ab
2% Zn coated urea	1.24ab	0.37ab	0.33ab	0.12a	34.4bcd	0.70ab	0.13	2.07	0.08ab	101.6a
3% Zn coated urea	1.26a	0.38a	0.36a	0.12a	37.8abc	0.73a	0.14	2.09	0.08ab	103.0a
Soil application of Zn 2.5 kg/ha	1.19abc	0.33abc	0.32ab	0.12a	32.2cde	0.64b	0.13	2.00	0.08ab	98.0ab
Soil application of Zn 5.0 kg/ha	1.20abc	0.37ab	0.36a	0.12a	37.0abc	0.65ab	0.13	2.06	0.09a	103.3a
0.1% foliar Zn spray at panicle initiation stage	1.15cd	0.33abc	0.30bc	0.11a	34.6bcd	0.65ab	0.13	2.03	0.07bc	97.2abc
0.1% foliar Zn spray at panicle initiation and flowering	1.22abc	0.32bc	0.31abc	0.11a	39.3ab	0.65ab	0.12	2.05	0.08ab	101.5a
0.1% foliar Zn spray at panicle initiation, flowering and grain filling	1.22abc	0.33abc	0.32ab	0.12a	40.9a	0.65ab	0.13	2.05	0.08ab	104.4a
Prilled urea (Control)	1.16cd	0.31cd	0.29bc	0.11a	30.5d	0.63b	0.12	1.96	0.07bc	88.9b
Absolute control (No N application)	1.11d	0.26d	0.26c	0.09b	26.8e	0.54c	0.13	1.86	0.06c	84.5c
SEm(±)	0.02	0.02	0.02	0.005	1.96	0.03	0.01	0.05	0.003	3.86
CD (P=0.05)	0.07	0.05	0.05	0.01	5.84	0.08	NS	NS	0.010	11.48

* P and K applied uniformly at the rate of 26.2 and 33.3 kg/ha, respectively in all plot; Zn source, zinc sulphate heptahydrate; DAT, Days after transplanting, CD, Critical difference; SEm, Standard error of means.

The enhancement in grain and biological yield under 5 kg Zn were 0.53 and 1.36 t/ha over 2.5 kg Zn/ha, respectively. Application of 2 or 3% ZnCU gave significantly higher grain N concentration over prilled urea and 3% ZnCU gave significantly higher straw N concentration. ZnCU increased grain N concentration by 1–9% over prilled urea and similar increase in grain N concentration due to soil Zn application and foliar application was 3% and 5%, respectively. Application of Zn through 2 or 3% ZnCU or soil application of Zn (5 kg/ha) gave significantly higher grain P concentration than prilled urea; while all treatment with Zn application gave significantly higher grain P concentration over absolute control. In case of K, 3% ZnCU and 5 kg Zn/ha soil application remained statistically superior over prilled urea application. The concentration of S in grain remained unaffected due to different Zn treatments, however all remained significantly superior to absolute control. Straw S concentration with 2 and 3% ZnCU, soil application (both 2.5 and 5 kg/ha) and two and three sprays were significantly higher than prilled urea application.

Application of 3% ZnCU, soil application (5 kg/ha) and two and three foliar spray gave significantly higher Zn concentration in both grain and straw than prilled urea. The increase in grain Zn concentration due to ZnCU, soil application and foliar application over prilled urea was 3.4–7.3, 1.7–6.5 and 4.1–10.4 mg/kg, respectively. The grain and straw Zn concentration under prilled urea application was significantly higher than absolute control which signifies the role of N in enhancing Zn concentration (Jaksomsak *et al*. 2017). The grain yield of rice was positively correlated with Zn application due to Zn coated urea (Fig 1a), soil Zn application (Fig 1b) and foliar spraying of Zn (Fig 1c) which signifies the role of Zn fertilization in improving rice yield.

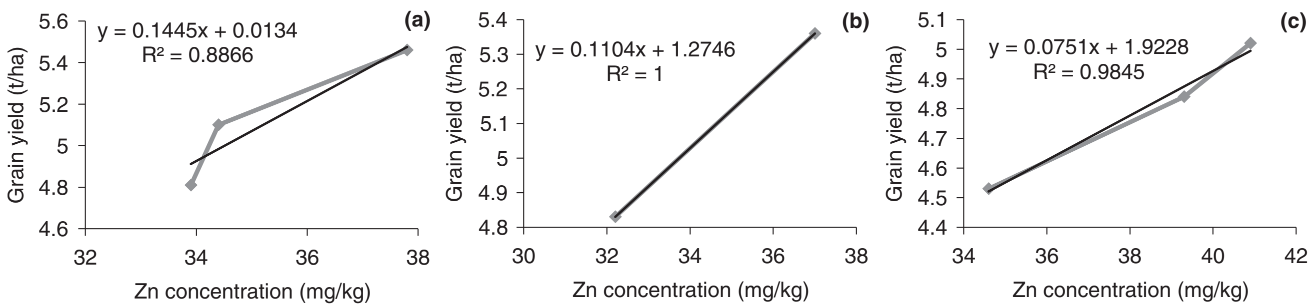

Fig 1 Correlation of Zn concentration with grain yield due to Zn coated urea (a), soil Zn application, (b) and foliar spraying of Zn (c).

SUMMARY

The highest increase in grain Zn concentration was observed with foliar Zn application followed by ZnCU and least with soil Zn application. Among various Zn fertilization options, 3% ZnCU and soil application of Zn (5 kg/ha) was found most promising for improvement in growth attributes, grain and straw yields and Zn, N, P, K and S concentrations in rice grain. Therefore, Zn application through 3% ZnCU to rice is a recommendable option for improving rice productivity and its nutritional status in NEH region of India.

REFERENCES

Alloway B J. 2008. *Zinc in Soils and Crop Production.* 2nd edn. International Zinc Association and International Fertilizer Industry Association Publication, Brussels, Belgium and Paris, France.

Das A, Basavaraj S, Layek J, Ramkrushna G I, Lal R, Krishnappa R, Yadav G S, Babu S, Ghosh P K and Ngachan S V. 2020. Can conservation tillage and residue management enhance energy use efficiency and sustainability of rice-pea system in the Eastern Himalayas? *Archives of Agronomy and Soil Science* **66**(6): 830–46.

Fageria N K, Carvallho G D, Santos A B, Ferreira E P B and Knupp A M. 2011. Chemistry of lowland rice soils and nutrient availability. *Communications in Soil Science and Plant Analysis* **42**(16): 1913–33.

Jaksomsak P, Rerksem B and Prom-u-thai C. 2017. Responses of grain zinc and nitrogen concentration to nitrogen fertilizer application in rice varieties with high-yielding low-grain zinc and low-yielding high grain zinc concentration. *Plant and Soil* **411**: 101–09.

Palmgren M G, Clemens, S, Williams L, Kramer U, Borg S, Schjorring K and Sanders D. 2008. Zinc biofortification of cereal: problems and solutions. *Trends in Plant Science* **13**(9): 464–73.

Prasad R and Shivay Y S. 2020. Agronomic biofortification of plant foods with minerals, vitamins and metabolites with chemical fertilizers and liming. *Journal of Plant Nutrition* **43**(10): 1534–54.

Roy A, Singh N U, Dkhar D S, Mohanty A K, Singh S B and Tripathi A K. 2015. Food security in North-East Region of India —A State-wise analysis. *Agricultural Economics Research Review* **28**: 259–66.

Shivay Y S and Prasad R. 2012. Zinc coated urea improves productivity and quality of basmati rice (*Oryza sativa* L.) under zinc stress condition. *Journal of Plant Nutrition* **35**(6): 928–51.

Singh A and Shivay Y S. 2014. Enhancement of growth parameters and productivity of basmati rice through summer green manuring and zinc fertilization. *International Journal of Bio-resource and Stress Management* **5**(4): 486–94.

Tandon H L S. 2013. *Methods of Analysis of Soils, Plants, Waters, Fertilizers and Organic Manures*. Fertilizer Development and Consultation Organization, New Delhi, India.

Wissuwa M, Ismail A M and Graham R D. 2008. Rice grain zinc concentrations as affected by genotype, native soil-zinc availability and zinc fertilization. *Plant and Soil* **306**: 37–48.