Yield and Biofortification of Spinach and Rice using Seed-Core Zinc Technology

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INTRODUCTION

Most staple food, particularly cereal grains, have inherently very low zinc (Zn) concentrations. As a result, the world's poorest people (where plant foods contribute up to 90% of the total dietary consumption) are most vulnerable to Zn malnutrition and deficiency diseases. Zinc malnutrition is a global issue, not just limited to the developing world. Zinc deficiency prevalence in sub-Saharan Africa is estimated to be 13-47% of the population, 18-36% in South Asia, and 27-39% in Southeast Asia (Bouise et al., 2011). The problem is exacerbated in locations where potentially Zn-deficient soils are utilized for cereal crop production.

While modern cereal crop varieties may not exhibit visual Zn deficiency nor yield declines, they tend to have lower Zn content than traditional varieties. Zinc concentrations in rice grain typically range from 10 to 40 mg kg^{-1} with a median of 16 mg kg^{-1} and similarly wheat grain Zn concentrations range from 13 to 68 mg kg^{-1} with a median of 31 mg kg^{-1} (Welch and Graham, 1999). The high concentration range portends that rice and wheat grains have the potential to accumulate Zn to reduce the Zn deficiency problems among humans.Thus, agronomic biofortification of these crops with Zn offers an immediate solution to Zn malnutrition. IFDC is pursuing two major initiatives to mitigate mineral deficiency problems, namely, (i) biofortification of crop plants at source with mineral-rich fertilizers in combination with varieties capable of concentrating minerals when available and (ii) promotion of peri-urban agriculture to diversify diet and improve nutrition.

METHODS

An innovative core technology that used fertilizers such as urea for micronutrient-delivery and enhanced efficiency was used. A greenhouse experiment with a common spinach variety – *Bloomsdale Long-Standing* – was used to test the hypothesis that fertilization with Zn, iron (Fe), and iodine (I) can increase the leaf nutrient concentrations of Zn, Fe, and I in spinach leaves. A follow-up experiment was also conducted with rice variety PSBRc10.

Micronutrient Seed-Core Technology

Fluid-bed granulation – one of the most common manufacturing process for urea – begins with a small "core" of urea. To produce urea granules with Zn, the urea core is replaced by Zn core. The micronutrient seed-core technology requires very little capital investment and process change is also minimal.

Soil applied Zn seed cores with 0.8-3% Zn concentration were evaluated against foliar application of Zn on spinach. The follow-up rice crop grown in the same pots as spinach did not receive any additional application of Zn seed cores, only the foliar Zn treatments received fresh application of Zn. All other nutrients were applied at blanket recommended rates.

RESULTS AND DISCUSSION

As evident from Table 1, all foliar Zn treatments gave significant increase in spinach dry matter. Dry matter production with Zn-core fertilizers was in general higher than the control. Zinc-core fertilizers with other micronutrients (Fe as iron sulfate, B as boric acid, and iodide as potassium iodide) gave lower dry matter yield. Application of Zn as foliar, soil applied Zn-core fertilizer, or combination gave significantly higher Zn tissue concentration than the control. Zinc uptake relative to the control was 1.3 – 35 times higher (data not shown).

Table 1. Effect of foliar and core Zn application on spinach dry matter production and tissue Zn concentration.

Treatment	Method of Application	Total Dry Matter		Zn Concentration[1]	
mg Zn kg^{-1}		(g pot^{-1})	(% increase)	(mg kg^{-1})	(% increase)
0	Control	12.82	0	42.0	0
2.0	Foliar–$ZnSO_4$	16.70	30.3*	121.5	189.4
3.6	Foliar–$ZnSO_4$	15.17	18.3*	195.8	366.2
7.3	Foliar–$ZnSO_4$	15.14	18.1*	403.2	860.1
15.5	Foliar–$ZnSO_4$	15.19	18.5*	730.8	1,640.4
19.6	Foliar–$ZnSO_4$	15.94	24.3*	1,067.3	2,441.9
0.86	Core –$ZnSO_4$ + $FeSO_4$ + KI + B	13.04	1.7	52.7	25.6
3.8	Core –$ZnSO_4$ + $FeSO_4$	12.24	-4.5	110.0	161.8
5.0	Core – ZnEDTA	15.18	18.4*	219.9	423.7
5.2	Core –$ZnSO_4$	13.06	1.9	98.4	134.4
9.1	Core –$ZnSO_4$ + $FeSO_4$ + KI + B	12.16	-5.1	92.3	119.7
10.0	Core –$ZnSO_4$	12.88	0.5	147.8	252.0
10.2	Core –$ZnSO_4$ + $FeSO_4$	10.98	-14.3	117.0	178.5
19.1	Core –$ZnSO_4$	15.24	18.9*	188.9	349.9
26.2	Core + Foliar	13.98	9.0	429.3	922.5
13.7	Core + Foliar	14.47	12.9*	258.4	515.4

*Significance at 5% level. [1] All Zn treatments had significantly higher tissue Zn concentration.

Effect of fresh Zn foliar application on the rice crop grown after spinach was similar with yield increases of -2 to 39% over the control. The effect of residual Zn-core on rice grain yield varied from 13% lower to 25% higher than control yield. At the lower Zn-core fertilizer rate, there was apparently negligible Zn response to previously applied Zn.

CONCLUSIONS

Preliminary studies with spinach and rice have shown that Zn-enriched urea produced by core fertilizer technology is an effective and simpler way to supply Zn. Both foliar and Zn-core fertilizer application resulted in several-fold increases in tissue Zn concentrations and increased uptake of Zn in spinach compared to control (no Zn application). Zinc-core fertilizer with ZnEDTA as the Zn source was more effective than $ZnSO_4$. The results also highlighted that commonly grown varieties are capable of biofortification when applied with mineral fertilizers. The use of the common/popular varieties will enhance the promotion of agronomic biofortification.

Agronomic biofortification trials using Zn-core fertilizers will be conducted on rice, wheat, and vegetables beginning July 2011 in Bangladesh to address productivity increase, and enhance product nutrient status and human nutrition.

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