Sustaining Crop Production in the Developing World through "The Nutrient Buffer Power Concept" a Case Study with Black Pepper (*Piper nigrum*) Growing at Low pH in Laterite Soils of India

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INTRODUCTION

Black pepper *(Piper nigrum)*, the most important spice crop of the world, which sustains the economy of Kerala State, is ravaged by the dreaded fungus *Phytophthora sp.*, whose onset is caused by Zn deficiency. The pepper plants quickly wilt, and farmers lose the entire crop leading to economic ruin. In many instances, farmers commit suicide, especially if it is a small land holder who cannot withstand the economic devastation. Farmers are advised, on average, to apply in excess 30 kg $ZnSO_4$ as a "blanket dose" based on routine DTPA extraction. This has not led to satisfactory results at all. When a small farmer invests his limited financial resources in Zn fertilizer, which is quite expensive by Indian standards (approximately 5 USD kg^{-1}, which translates to about 150 USD ha^{-1}), based on routine DTPA extractions, and the crop fails, he can be economically ruined. This investigation was initiated to answer the crucial question if Zn fertilizer recommendations based on "The Nutrient Buffer Power Concept" can lead to better results.

METHODS

Basic Concept and Experimental Model

Using Fick's first law,

F = -D (dC/dx),

where F = the flux, dC/dx = concentration gradient across a particular section, and D = the diffusion coefficient, Nye (1979) gave an operational definition of the diffusion coefficient as

D = D10f1 (dC1/dC) + DE,

where D1 = diffusion coefficient of the solute in free solution , 0 = the fraction of the soil volume occupied by solution and gives the cross section for diffusion, f1 = an impedance factor, C1 = concentration of the solute in the soil solution, DE = an excess term which is zero when the ions or molecules on the solid have no surface mobility, but represents their extra contribution to the diffusion coefficient when they are mobile.

The term DE can generally be neglected since only in rare instances will it play any role in diffusion of plant nutrient ions in soil. Based on this, Nair (1984) developed an operational model to define the Zn buffer power, which was quantified by employing electro ultra filtration to quantify soil solution Zn and an adsorption-desorption equilibrium technique developed by Nair (1992) to quantify the total soil Zn pool. The experimental area covered three important pepper-growing regions, namely, Ambalavayal, Peruvannamuzhi and Tamarasseri in the State of Kerala, including several farmers.

RESULTS AND DISCUSSION

Table 1. Correlation coefficients ("r") for the Inter-relationship between routine DTPA soil test vs. Zn concentration, Zn uptake and dry matter production without (A) and with (B) Zn buffer power integration.

Details	A	B
Zn concentration vs. DTPA test	0.884 ***	0.924 ***
Zn uptake vs. DTPA test	0.782	0.862 ***
Dry matter production vs. DTPA test	-0.745	0.777 ***

*** Significant at 99.99 % confidence level.

Note the remarkable improvement in all "r" values with Zn buffer power integration, but, most importantly, the change in the "r" value from negative to positive in the case of dry matter production. Dry matter production in farmers' fields negatively responded to Zn fertilizer application based on DTPA test, but, when the Zn buffer power was integrated into the computations, the picture dramatically changed to a positive response.

Table 2. Pepper yield from farmers fields (kg /vine) weighted against the Zn buffer power.

Region	Pepper vine yield		Percentage deviation
	Targeted	Actual	
Tamaraesseri	0.490	0.487	-0.6
Peruvannamuzhi	0.241	0.401	+66.4

Note that yield targeting was based on the Zn buffer power values. Target weighting was done against the highest vine yield obtained from farmers' fields in the Ambalavayal region, which had the highest Zn buffer power value of 3.0358 compared to Tamarasseri, which had an intermediate Zn buffer power value of 1.5786, while Peruvannamuzhi soils had the lowest value of 0.7824. Note the remarkable similarity between target and actual yields in Tamarasseri soils and the large deviation in Peruvannamuzhi soils, which are unsuited for Black pepper cultivation (atypical pepper soils). Yet, the ministry of agriculture is encouraging farmers to cultivate pepper on these soils, which is wrong practice. These data demonstrate how important it is to plan pepper plantations based on the soil buffer power.

CONCLUSIONS

Results of this extensive investigation in farmers' fields, backed up by controlled laboratory and plant culture experiments, show that an estimation of Zn buffer power is crucial for an optimal management of Zn fertilizer regimes. Results in Table 1 unequivocally indicate that predictability, as statistically quantified by the coefficient of determination, of Zn concentration and Zn uptake remarkably improved when the Zn buffer power data were incorporated into the computations by a margin of 17 and 15 %, respectively. The data also show that the routinely applied DTPA estimation to predict soil Zn availability is not reliable in these soils. Pepper farmers are being appropriately advised now to modify their Zn fertilizer regimes based on the Zn buffer power with remarkable success.

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REFERENCES

Nair, K.P.P. (1984) Towards a better approach to soil testing based on the buffer power concept. Proc. 6th Int. Colloquium for the Optimization of Plant Nutrition, 4: 2-8 September, (Pierre-Martin Prevel Ed.), Montpellier, France, pp.1221-1228.

Nair, K.P.P. (1984) Zinc buffer power as an important criterion for a dependable assessment of plant uptake. Plant Soil 81: 209-215.

Nair, K.P.P. (1992) Measuring P buffer power to improve routine soil testing for phosphate. Eur. J. Agron.1(2): 79-84.

Nair, K.P.P. (1996) The buffering power of plant nutrients and effects on availability. Adv. Agron. 57: 237-287

Nair, K.P.P. (2004) The agronomy and economy of Black pepper (*Piper nigrum* L.) – The "King of Spices". Adv.Agron. 82: 271-389.