Agronomic Biofortification of Cassava with Zinc and Other Micronutrients to Improve Human Health

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INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is an important staple crop, especially for resource-poor populations in sub-Saharan Africa. Many soil types on which cassava is grown are deficient in Zn, Se and I, and these deficiencies are also prevalent, often concurrently, in the human populations in these areas (Vanderpas et al. 1990, Oldfield 1999).

Recent genotype-environment interaction studies suggest that variation in Zn concentration in cassava roots is due mostly to soil available Zn level and soil pH (CIAT 2006). Although genotypic variation for Zn has been reported (Chavez et al. 2005), results were not conclusive. Therefore, breeding for higher Zn in cassava may not be feasible. However, it has been shown that Zn fertilisation can be highly effective in overcoming Zn deficiency in cassava, to which cassava is susceptible (Asher et al. 1980).

Genotypic variation of Se and I density in edible parts of cereals also appears to be low (Lyons et al. 2005, Lyons et al. unpublished), hence (as for Zn), fertilisation of cassava may be preferable than trying to breed for higher density of these micronutrients. If cassava could be efficiently and inexpensively biofortified agronomically, it could become a valuable source of dietary Zn, Se (in storage roots) and I (in leaves, which are consumed widely in Africa), in addition to its important role as a provider of dietary energy.

PILOT TRIAL

A pilot agronomic biofortification trial with cassava was conducted in a growth chamber at The University of Adelaide. Conditions: 12-hour photoperiod; day temperature 25-28°C; night temperature 12-18°C; light intensity 545 µmol/m^2/sec; mean relative humidity 60%. Stems of a high-yielding, sub-tropical, low-cyanogen cultivar, *M Aus 10*, bred at The University of Queensland were planted in University of California (Waite Campus version) growth medium, which is based on sand, “coco peat” and contains all essential nutrients and micronutrients [pH (H_2O) 6.0]. After 6 weeks plants were transplanted to large plastic pots (51cm diameter, 70kg total weight). At 5.5 months after planting, treatment plants were biofortified by application of Zn, Se, Cu and I to the growth medium (as zinc sulphate, sodium selenate, copper sulphate and potassium iodate, respectively) (Table 1).

Storage roots and youngest mature leaves were harvested at 7 months after planting and analysed by Inductively Coupled Plasma (ICP)-Optical Emission Spectrometry (OES) (Zn, Cu and other inorganic nutrients) and ICP-Mass Spectrometry (MS) (Se, I). There were four control replications and six treatment replications. Data analyses were performed by t-test, and significance of treatment means was declared at $P < 0.05$.

Agronomic biofortification resulted in increases in concentration of Zn and Se in roots and leaves, along with increased I in leaves (roots not tested for I) and increased Cu in roots (Table 1). The largest effect was an 82-fold increase in Se concentration in leaves. The mean

Se concentration in roots and leaves of 5 and 25 mg/kg, respectively (along with the I level in leaves of 192 mg/kg) would be considered too high for consumption, but would be diluted as the plants continue to grow, with roots normally consumed after 11-16 months of growth.

Table 1. Concentrations of agronomically biofortified micronutrients in storage roots and leaves of cassava [mg/kg DM: mean (SD)]

		Roots		Shoots		
Micronutrient	Conc.[1]	Control	Treated	Control	Treated	Significance
Zinc	10	20 (4)	61 (23)	30 (3)	78 (14)	$P<0.05$ (both)
Selenium	2	0.2 (0.1)	5.0 (0.4)	0.31 (0.2)	25 (7)	$P<0.001$ (both)
Copper	2	0.9 (0.1)	2.3 (0.9)	1.2 (0.4)	1.5 (0.2)	$P<0.05$ (roots)
Iodine	4	Not tested	Not tested	10 (3)	192 (89)	$P<0.01$ (leaves)

[1] Concentration in UC mix growth medium (mg/kg)

There was no difference in yield between control and biofortified plants, and no toxicity was observed, despite the relatively high Se and I concentrations in biofortified plants. Interestingly, transfer of both Se and I from biofortified to control plants via volatile forms was apparent, as plants grown on this medium usually have much lower levels of Se and I. Furthermore, the range of Se in control roots (64-290 µg/kg) suggests translocation of Se from the leaves. No effect of biofortification was evident in concentrations in roots and leaves of other nutrients, including Fe, Mn, B, Ni, Ca, Mg, Na, K, P and S. In a small concurrent trial, soil application of micronutrients was more effective than foliar application.

FIELD TRIALS

Field trials to investigate agronomic biofortification of cassava with Zn, Se, I and Cu are being conducted by CIAT in Colombia, at several sites which vary in soil pH and in other soil and climatic characteristics. Included are sites low in available Zn, at which a yield response to Zn biofortification could be expected.

CONCLUSIONS

The trials in Colombia will show whether the promising findings from agronomic biofortification of cassava with Zn and other micronutrients in a growth chamber trial can be translated to the field. Further benefits of this multiple-micronutrient approach could include exploitation of synergies, for example Se/I and Se/Zn (Lyons et al, 2004). Moreover, higher Zn levels may improve conversion of beta-carotene to vitamin A, when high-carotenoid cassava cultivars bred at CIAT are consumed.

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