Can Andean Potato be Agronomically Biofortified with Iron and Zinc Fertilizers?

Peter Kromann[1], Franklin Valverde[2], Julio Gabriel[3], David Caballero[4], André Devaux[1]

[1]International Potato Center (CIP), P.O. Box 17 19 21, Quito, Ecuador (p.kromann@cgiar.org)
[2]Instituto Nacional de Investigaciones Agropecuarias (INIAP), Quito, Ecuador
[3]Fundación para la Promoción e Investigación de Productos Andinos (PROINPA), Cochabamba, Bolivia (j.gabriel@proinpa.org)
[4]Escuela Superior Politécnica de Chimborazo (ESPOCH), Riobamba, Ecuador (david.caballero@espoch.edu.ec)

INTRODUCTION

Potato (*Solanum* spp.) is the third most important food crop in the world after rice and wheat in terms of total production tonnages used for food (http://faostat3.fao.org/home/E). It was first domesticated in the Andes of South America. The high diversity of potato cultivars, which has been a traditional stable food for centuries, continues to play an important part of life and culture for the Andean people, especially among the rural poor (Devaux et al. 2014).

While economic growth has been steady in the Andean countries of Bolivia, Colombia, Ecuador and Peru, it has not been sufficient to accelerate reduction of hunger and chronic malnutrition. Very high rates of iron (Fe) and zinc (Zn) deficiencies are still found in rural communities; up to 60% of preschool children (http://www.unicef.org/).

The multi-partner R&D project "IssAndes" funded by the EU and coordinated by the International Potato Center (CIP) contributed to strengthen pro-poor agricultural innovation for food security in the Andean region from 2011 to 2014, and worked toward fostering nutrition-sensitive agriculture with diverse intervention approaches. Below we describe an "IssAndes" study that aimed to evaluate the potential role of an Fe and Zn fertilization approach, i.e., agronomic biofortification Cakmak (2008) in increasing the Fe and Zn concentration in Andean potato tubers through a series of coordinated experiments in Bolivia and Ecuador.

METHODS

In 2012 two greenhouse experiments were implemented at the National Agricultural Research Institute of Ecuador (INIAP); i) one with Fe fertilizer and ii) one with Zn fertilizer applied to soil and foliage of potato cultivar INIAP-Natividad (high yielding tetraploid; *Solanum andigena* × (*S. phureja* × *S. pausissectum*)).

In 2012-2013, three field experiments were carried out in Ecuador; at INIAP and CIP, both sites near Quito, and at the Polytechnic University of Chimborazo (ESPOCH). Two factors were studied at the three sites (i) cultivar (INIAP-Natividad, tetraploid; INIAP-Puca Shungo, triploid; Chaucha Amarilla and Chaucha Roja both diploid; and Coneja Negra, tetraploid), and (ii) fertilizer treatment. The three experiments included the following five fertilizer treatments: F1= 40 kg Fe ha^{-1} + 20 kg Zn ha^{-1} applied to soil at planting; F2 = 40 kg Fe ha^{-1} applied to soil at planting; F3 = 20 kg Zn ha^{-1} applied to soil at planting; F4 = 200 mg L^{-1} Zn applied to foliage as foliar sprays 5 times at weekly intervals, F5 = 375 mg L^{-1} Fe applied to foliage as foliar sprays 5 times at weekly intervals.

In 2012-2013, experiments were also carried out in farmer's fields in Bolivia at three sites; one in the Department of Cochabamba and two in the Department of La Paz. The experiments included two cultivars (Waych'a, tetraploid and Pinta Boca, diploid) and 16 soil applied fertilizer treatments (combinations of 0, 10, 20, 40 kg Fe ha^{-1} and 0, 5, 10 y 15 kg Zn ha^{-1} applied to soil before planting).

In 2014, field experiments were carried out with cv. INIAP-Natividad at two locations in farmers' fields in the province of Chimborazo, Ecuador. One experiment with foliar applications included the following five levels of Zn: 0, 1.25, 2.5, 5 and 10 kg ha^{-1} applied in 5 weekly foliar sprays. Another experiment with soil applications included the following five levels of Zn: 0, 10, 20, 30 and 40 kg ha^{-1} applied at planting.

RESULTS AND DISCUSSION

The greenhouse experiments showed a significant effect of Zn applied via foliar applications on Zn concentration in tubers (Fisher's LSD 5%). There was no effect of soil applied Zn fertilizer, which may have been because of the low application rates (<160 mg kg^{-1} in soil). Foliar and soil applied Fe did not affect the Fe concentration in tubers.

In the first field experiments in Ecuador, highly significant differences in Zn and Fe concentrations in tubers were detected among locations and potato cultivars ($P<0.0001$) ranging from 1.9 to 20.8 mg kg^{-1} dry weight average Zn and from 17.2 to 75.5 mg kg^{-1} dry weight average Fe in peeled tubers, and an effect of the fertilizer treatments was detected on the tuber mineral concentrations ($P<0.003$ for Zn; $P<0.048$ for Fe). Treatments with Zn increased Zn concentration in tubers significantly compared to treatments without Zn (Tukey 5%); up to 104% with soil applied Zn and up to 58% with foliar applied Zn.

The results of the experiments in Bolivia were similar to the results from Ecuador; the ANOVAs showed a significant effect of Zn treatments on Zn in tubers, but no effect of fertilizer treatments on Fe in tubers or on tuber yield. The results showed highly significant effects of location and of cultivar, but no significant interaction effects.

In the field experiments in Ecuador with increasing levels of Zn fertilizer in cv. INIAP-Natividad a highly significant effect of Zn fertilizer was found on Zn in tubers ($P<0.01$) and no symptoms were seen of Zn toxicity (Table 1).

Table 1. Concentration of Zn (mg kg^{-1} dry weight) in peeled tubers of potato cv. INIAP-Natividad (tetraploid) at five levels of Zn fertilizer applied to foliage or to soil.[1]

	Field 1.[2]				Field 2.			
Zn levels	Foliar applied		Soil applied		Foliar applied		Soil applied	
Level 4	15.20	a	17.60	a	9.28	a	7.53	a
Level 3	11.40	ab	16.45	ab	7.78	b	6.68	b
Level 2	11.10	ab	15.13	ab	7.27	b	6.10	c
Level 1	9.18	bc	12.90	bc	6.82	b	5.50	d
Control	6.05	c	9.20	c	4.43	c	4.45	e

[1]Treatments followed by different letters in the same column are statistically different (Tukey 5%).
[2]The mean tuber yields in Field 1. and Field 2. were 19.5 and 75.1 t ha^{-1}, respectively.

CONCLUSIONS

This field research shows that application of Zn fertilizers or Zn-enriched NPK fertilizers offers a prompt solution to increasing the Zn concentration in Andean potato tubers, and represents a useful complementary approach to on-going breeding programs. The diploid *Chaucha* cultivars that showed high tuber Zn concentrations in the absence of Zn fertilization also showed correspondingly higher Zn concentration in tubers following foliar and soil applied Zn. High levels of Zn in potato tubers may significantly improve the diets of Zn-deficient populations with high intake of potato and contribute to better nutrition.

REFERENCES

Cakmak, I. (2008) Enrichment of cereal grains with zinc: agronomic or genetic biofortification? *Plant Soil* 302: 1-17.

Devaux, A., Kromann, P. and Ortiz, O. (2014) Potatoes for Sustainable Global Food Security. *Potato Res.* 57: 185-199.