Iron biofortification by foliar spraying in old open-pollinated maize varieties

Alberto Di Stefano, Giuseppe Barion, Manuel Ferrari, Cristian Dal Cortivo, Anna Panozzo, Teofilo Vamerali

DAFNAE, Univ. Padova, IT, alberto.distefano@unipd.it, giuseppe.barion@unipd.it, manuel.ferrari@unipd.it, cristian.dalcortivo@unipd.it, anna.panozzo@unipd.it, teofilo.vamerali@unipd.it

Introduction

Maize-based food is one of the principal human dietary component, but with a low amount of iron in the grains (27.1 mg kg^{-1} kernel; USDA, 2012). A low meal uptake of Fe causes anemia, especially in pregnant women and pre-school children (McLeon et al., 2009); hence the need to increase maize with this mineral. Among the strategies applied to overcome iron malnutrition, agronomic biofortification by foliar fertilization is an economic solution to deal this problem (Cakmak, 2008). Despite of its important role in plants (Eskandari, 2011), previously research focused on correction of iron deficiency (Abadia et al., 2002, Fernàndez and Ebert, 2005), and little studies have dealt with the effect of foliar iron fertilization on yield and its concentration in the grains. Within the PSR project GO-SEEDS on pre-germinated seeds for the food industry, financed by the Veneto Region, this study evaluated if foliar application of iron on maize, with and without the addition of urea, could increase iron content in grains.

Materials and Methods

Two open-pollinated maize varieties, Marano and Corvino, were sown in open field at the experimental farm of the University of Padova at Legnaro (Padova, NE Italy) at density of 7 plants m^{-2}. Foliar fertilization with iron sulphate solution ($FeSO_4$, 18% of iron concentration) together or not with 1% of dissolved urea (46% N) was sprayed to maize after plant silking – beginning of kernel growth following a completely randomized experimental design with three replicates (n=3). The irroration volume was 600 L ha^{-1}. Treatments are listed in Table 1.

Table 2. List of treatments tested in maize (foliar spraying after silking).

Treatment	Commercial $FeSO_4$ (18% Fe)		Urea (46% N)	
	g L^{-1}	kg ha^{-1}	g L^{-1}	kg ha^{-1}
Control	-	-	-	-
Fe1	34	20.4	-	-
Fe2	60	36	-	-
Fe3	90	54	-	-
Urea control	-	-	6	3.6
Fe1+urea	34	20.4	6	3.6
Fe2+urea	60	36	6	3.6
Fe3+urea	90	54	6	3.6

The vegetational index SPAD (Soil Plant Analysis Development) was revealed three times per week after foliar fertilization until physiological maturity on both flag and ear leaves, while iron grain content (ppm, i.e. mg kg^{-1}) was analysed in both crop residues and grains by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectroscopy) at harvest.

Results

In var. Corvino the application of iron sulphate through foliar fertilization increased Fe grain content in Fe2 and Fe3 (+55% and +71% vs. untreated controls respectively, $P \leq 0.05$), and in all treatments with only iron in crop residues (Table 2). Instead, in var. Marano, it was observed an improvement of Fe content in crop residues by all the treatments without urea and in kernels with the addition of urea (maximum +47% in Fe3; $P \leq 0.05$). As regard the vegetational index SPAD, the application of iron caused a general impairment of the leaf chlorophyll content in both varieties (Table 2), but not of yield.

Table 3 Seasonal average of SPAD (adimensional units) and iron content in plant materials at harvest (n=3; ±S.E.) in two maize varieties treated with three doses of iron sulphate together with or without urea. In brackets: % variation vs. untreated controls and urea control. Letters: statistical comparison among treatments within same variety (Student Newman-Keuls test, P≤0.05).

		Iron content (mg kg^{-1})		**SPAD (Units)**	
Variey	**Treatment**	**Crop residues**	**Kernels**	**Flag leaf**	**Ear leaf**
Corvino	Untreted control	308^c (Ref.)	31.6^b (Ref.)	41.6^a (Ref.)	42.9^a (Ref.)
	Fe1	874^b (+184%)	37.4^b (+18%)	28.7^b (-31%)	32.9^a (-23%)
	Fe2	809^b (+163%)	49.2^a (+55%)	40.4^a (-3%)	44.3^a (+3%)
	Fe3	859^b (+471%)	54.1^a (+71%)	29.2^b (-30%)	38.9^a (-9%)
	Control+urea	458^a (Ref.)	33.4^a (Ref.)	36.1^a (Ref.)	40.1^a (Ref.)
	Fe1+urea	782^a (+71%)	35.9^a (+7%)	34.0^a (-6%)	41.0^a (+2%)
	Fe2+urea	496^a (+8%)	42.9^a (+28%)	31.6^a (-12%)	35.2^a (-12%)
	Fe3+urea	817^a (+78%)	46.8^a (+40%)	34.9^a (-3%)	39.1^a (-3%)
Marano	Untreted control	249^b (Ref.)	42.7^a (Ref.)	36.3^a (Ref.)	43.6^a (Ref.)
	Fe1	650^a (+161%)	46.4^a (+9%)	33.2^a (-8%)	35.7^a (-18%)
	Fe2	612^a (+146%)	53.1^a (+24%)	37.8^a (+4%)	40.6^a (-7%)
	Fe3	548^a (+120%)	49.4^a (+16%)	28.3^a (-22%)	34.5^a (-21%)
	Control+urea	310^b (Ref.)	36.2^b (Ref.)	35.0^a (Ref.)	43.3^a (Ref.)
	Fe1+urea	608^{ab} (+96%)	48.4^a (+34%)	34.2^a (2%)	36.6^a (-15%)
	Fe2+urea	440^b (+42%)	48.9^a (+35%)	30.6^a (-12%)	36.6^a (-15%)
	Fe3+urea	879^a (+184%)	53.2^a (+47%)	27.4^a (-22%)	39.3^a (-9%)

Conclusions

Foliar fertilization with iron sulphate can increase iron content in maize kernels, depending on variety choice, with better opportunities in the var. Corvino. This is probably related to improved activity of Fe transport proteins, as hypothesized by Aciksoz et al. (2011). Unfortunately, low iron translocation to the grains, due to its poor mobility, is the main constrain to achieve efficient biofortification (Grusak, 1994). Further research should consider the use of different sources of iron, as suggested by Fernàndez and Ebert (2005), who indicated a better absorption of iron chelates compared to salts.

Literature

Abadia A. et al. 2002. Correction of iron chlorosis by foliar spraying. Acta Hortic, 594: 115-121.

Aciksoz S.B. et al. 2011. Biofortificatin of wheat with iron through soil and foliar application of nitrogen and iron fertilizers. Plant Soil, 347: 215-225

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

Eksandari H. 2011. The importance of iron (Fe) in plant products and mechanism of its uptake by plants. J. Appli. Environ. Biol. Sci, 1: 448-452.

Fernàndez V., Ebert G. 2005. Foliar iron fertilization: a critical review. J Plant Nutr, 28: 2113-2124.

Grusak M.A. 1994. Iron transport to developing ovules from *Pisum sativum*. Seed import characteristics and phloem iron-loading capacity of source regions. Plant Physiol, 104: 649-655.

McLeon E. et al. 2009. Worldwide prevalence of anemia, WH vitamin and mineral nutrition information system. 1993-2005. Public Health Nutr, 12: 444-454.

U.S.D.A Agricultural Research Services. 2012. USDA National Nutrient database for Standard Reference, Release 25. Nutrient Data Laboratory Home Page.