Mineral Interaction in Biofortified Tomatoes (*Lycopersicum esculentum* L.) with Magnesium

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- Magnesium is considered an essential nutrient for humans and the fourth most abundant in the body and thus an adequate supply of Mg is important to maintain health.

- About 60% of Mg is in humans bones and plays an important role in skeletal development

- Mg deficiency can trigger several health pathologies namely, asthma, Alzheimer's disease, hypertension, cardiovascular disease, osteoporosis, and type-2 diabetes mellitus.

- In this context, being tomato (*Lycopersicum esculentum*) one of the most popular and consumed horticultural crop globally and the need to improve mineral content in edible crops, this study aimed to understand the mineral interactions (synergistic and antagonistic relationships) in tomatoes of an industrial variety (H1534) biofortified with Mg.

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Abstract: Magnesium is considered an essential nutrient for humans, where about 60 % of Mg plays an important role in skeletal development. However, its deficiency can trigger several health pathologies (namely, asthma, Alzheimer's disease, hypertension, type-2 diabetes). In plants, Mg is especially important, being involved in protein synthesis and correlated with chlorophyll pigments. Its deficiency can compromise photosynthesis and can also lead to shorter roots and necrotic zones in leaves. Mineral deficiency (namely, Mg) in plants can lead to a global problem considering the increase of human population and the needs to produce more food and that nutritionally meet human needs, being necessary adopt new technology and approaches. In this context, this study aimed to understand the mineral interactions with Mg biofortification in *Lycopersicum esculentum* (H1534 variety). Biofortification was promoted during the life cycle of the culture throughout six leaf applications with four concentrations (4%, 8%, 12%, and 16%) of MgSO4, equivalent to 702, 1404, 2106 and, 2808 g ha^{-1}. At harvest, 4% MgSO4 treatment showed the highest content of Mg and P, and the lowest content of Fe and Zn. Additionally, the highest treatment showed the lowest content of Mg and on the other hand, the highest content of Fe. In conclusion, despite the synergistic and antagonistic relationships between minerals in the different concentrations of Mg applied, there were no significant changes in total soluble solids content in the fruits.

Keywords: Biofortification; H1534 variety; *Lycopersicum esculentum* L.; Mineral Interaction; Natural enrichment with magnesium.

Introduction

In plants, Mg plays important roles, namely in structural and regulatory functions (Ceylan et al., 2016). In fact, Mg has diverse functions and is especially important, being involved in protein synthesis, correlated with chlorophyll pigments (Guo et al., 2016), is a key element in photosynthesis and is deeply involved in the phloem loading of sucrose (Ceylan et al., 2016). Its deficiency can compromise plant growth, photosynthesis, crop productivity, can also lead to shorter roots, and to necrotic zones in leaves (Guo et al., 2016;Ceylan et al., 2016). Additionally, Mg deficiency in fields can be due to is ionic antagonism with competing cations (H^{+}, Al^{3+}, Ca^{2+}, K^{+} and Na^{+}) that strongly inhibit Mg^{2+} root uptake (Ceylan et al., 2016). Magnesium is considered a phloem mobile element and is rapidly translocated within the plant to the growing parts, that's why the first symptoms start to appear on older leaves (Gransee & Führs, 2013). Mineral deficiency in plants begins to be a global problem considering the increase of human population and the urge to meet the future worldwide food and nutrient needs (Clugston & Smith, 2002). Additionally, with the growth and development of food industry and agriculture, the ability to produce safe and nutritious food in the future is largely dependent on new technologies and approaches (Clugston & Smith, 2002). As such, considering that nutrients are mainly obtained through plants in human diet (Díaz-Gómez et al., 2017), agronomic biofortification can be a viable strategy to be implemented with the aim of increasing different mineral content in the edible part of plants, in particular through foliar fertilization/applications (Alshall & El-Ramady, 2017).

Results and Discussion

Mineral content of tomatoes at harvest was assessed in H1534 variety (Table 1). Magnesium, Ca, Zn and Cu did not vary significantly, unlike Fe, P and K which varied significantly. Relatively to control, biofortified tomatoes with 4% and 8% $MgSO_4$ treatments showed an increase in Mg content of 3.5 and 2.6 fold, respectively. In addition, biofortified tomatoes with the 12% $MgSO_4$ treatment showed an increase of Mg content of 2.1%.

Table 1. Mean values ± S.E. (n = 4) of Mg, Ca, Fe and Zn in tomatoes of *Lycopersicum esculentum* (H1534 variety), at harvest. Letters a,b, and c indicate significant differences, between treatments (statistical analysis using the single factor ANOVA test, P ≤0.05). Foliar spray was carried out with four concentrations (4%, 8%, 12%, and 16% of $MgSO_4$). Control was not sprayed at any time.

Treatments	Mg	Ca	Fe	Zn	P	K	Cu
	mg/100g						
Control	53.97a ± 1.08	31.48a ± 0.16	6.36b ± 0.13	1.86a ± 0.47	283abc ± 9	4616a ± 44	1.68a ± 0.24
4% $MgSO_4$	190a ± 91	30.93a ± 6.39	5.13b ± 0.30	0.73a ± 0.16	315a ± 10	3509b ± 89	1.13a ± 0.02
8% $MgSO_4$	143a ± 35	31.20a ± 0.29	6.12b ± 0.86	1.75a ± 0.41	270bc ± 12	3735b ± 67	1.54a ± 0.23
12% $MgSO_4$	55.11a ± 7.43	18.78a ± 0.91	6.41b ± 1.05	1.05a ± 0.41	254c ± 1	3410b ± 116	1.08a ± 0.21
16% $MgSO_4$	49.48a ± 2.50	19.16a ± 2.36	10.25a ± 0.91	1.37a ± 0.20	297ab ± 8	3558b ± 155	1.42a ± 0.04

Tomatoes biofortified with $MgSO_4$ showed higher content of Mg (except in 6% $MgSO_4$ treatment) regarding control, indicating that biofortification occurred and had a better index with the lower concentration applied (4% of $MgSO_4$). Preciously, in another study carried out with the same variety showed also with 4% of $MgSO_4$ treatment the highest Mg content (Coelho et al, 2020). Nevertheless, the higher content of Mg in 4% $MgSO_4$ treatment showed a lower Fe content, presenting a tendency of antagonism in the biofortified tomatoes considering that as the Mg content increased, Fe content decreased. In fact, this antagonistic relationship between Fe and Mg was already verified in growth and metabolism of another horticultural crop (Agarwala et al, 1984).

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Conclusions

At harvest tomato (*Lycopersicum esculentum*) of H1534 variety submitted to a biofortification itinerary with Mg trough foliar spraying, showed a higher content in 4% of $MgSO_4$ treatment. Additionally, was possible to identify an antagonistic effect with Mg and Fe and a tendency of a synergetic relationship with K and Cu. In conclusion, despite the synergistic, antagonistic and no clear tendency of relationships between the minerals analyzed, there were no significant changes in the total soluble solids content in tomatoes, showing in fact, a no significant increase in biofortified tomatoes with $MgSO_4$.

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