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Does the recipe of nutrient solution for alkalinity experiments in hydroponics need modifications?

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Introduction

Iron EDTA is the most used Fe source in hydroponics. However, it is unstable in nutrient solution (NS) above pH 6.5. Therefore, free metallic cations i.e. Cu, Mn and Zn can replace Fe in Fe-EDTA molecules in alkaline NS. This causes Fe precipitation which may lead to its deficiency for plant uptake.

Aim: To reveal; (1) the interaction of Fe-EDTA with EDTA-chelated and non-chelated Zn, Mn and Cu sources for plant growth and nutrients uptake in *Vicia faba* under acidic and alkaline conditions, (2) a suitable Fe source under alkaline conditions.

Hypotheses: (1) Free Cu, Zn and Mn ions in the nutrient solution cause Fe deficiency in plants by replacing Fe from Fe-EDTA. (2) Fe-HBED improves soluble Fe and P in alkaline NS

Methodology

Faba bean (Vicia faba cv FUEGO) plants were grown in standard nutrient solution (2.5 liter) for 4 weeks using Fe-EDTA but Cu, Zn and Mn were either in –EDTA or $–SO_4^{2-}$ form.

Alkalinity levels:

0 (pH 5.2), 5 (pH 7.9) and 15 (pH 8.4) mM $NaHCO_3$

Precipitation of nutrients in the NS was calculated by Chemical Equilibrium Modeling System MINEQL+ 5.0.

Incubation study:

Nutrient solutions prepared using different Fe-chelates with variable levels of $NaHCO_3$ were incubated for 24 hours, 3 and 6 days at room temperature. The filtrate was obtained using 0.02-micron filter paper and analyzed by ICP-MS. The composition and forms of precipitates were determined by using SEM-EDX and XRD.

Results and Discussion

Plant growth and mineral nutrients concentrations

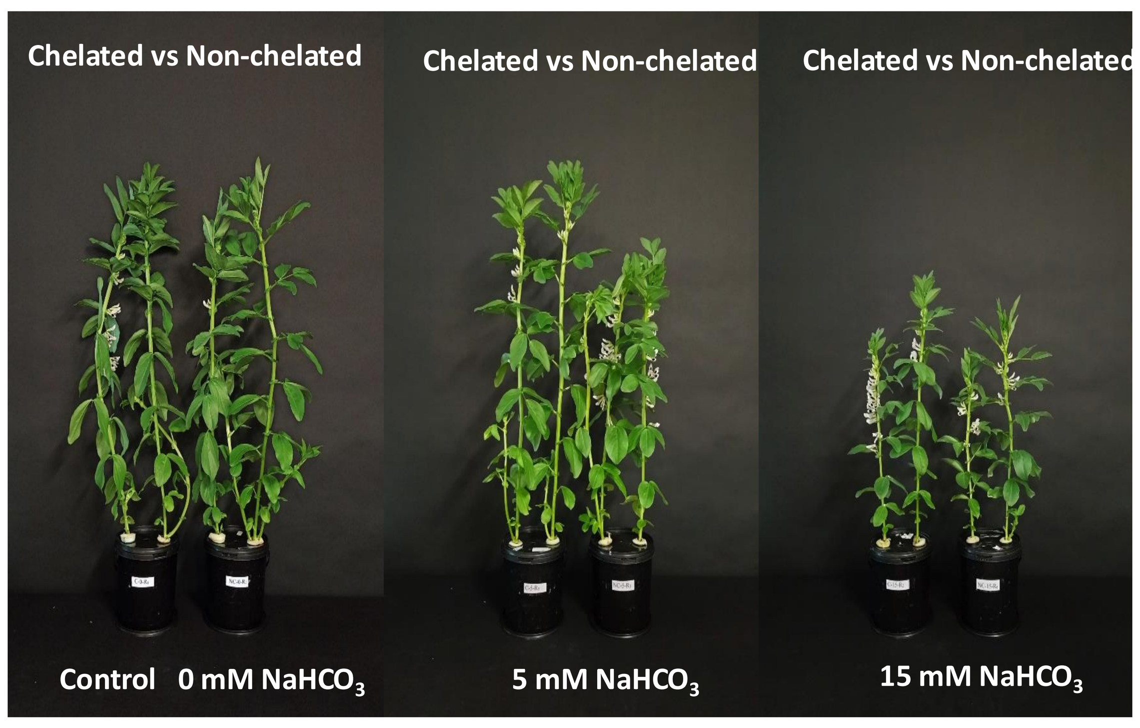


Fig. 1. Growth and *shoot dry biomass (per pot) of 4-week old Faba bean plants grown in nutrient solution with chelated (Fe, Zn, Cu & Mn) and non-chelated (Zn, Cu & Mn) micronutrients under various alkalinity levels.

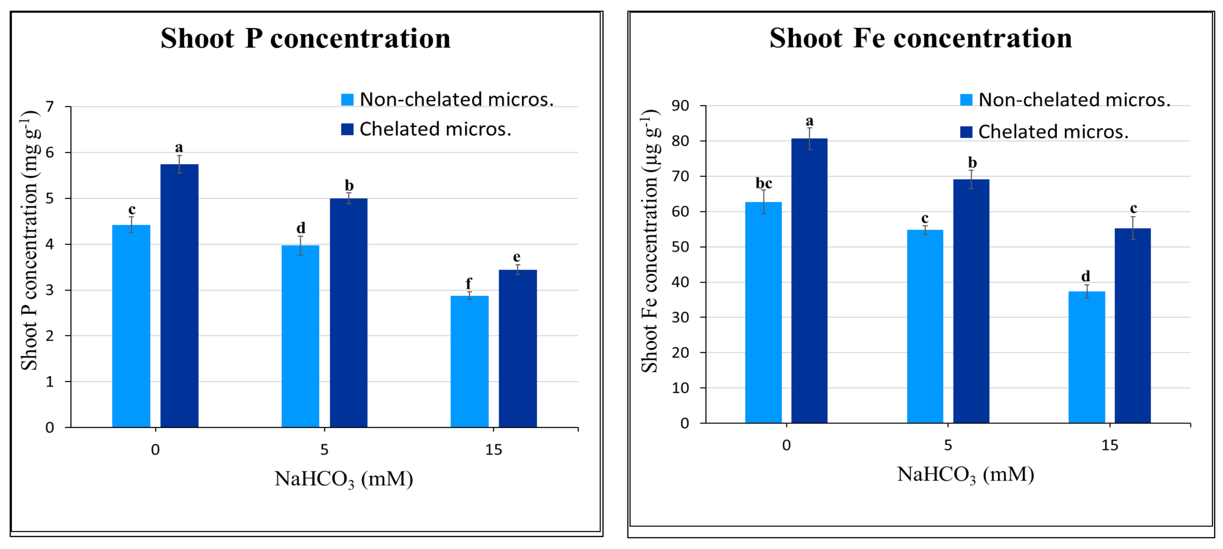
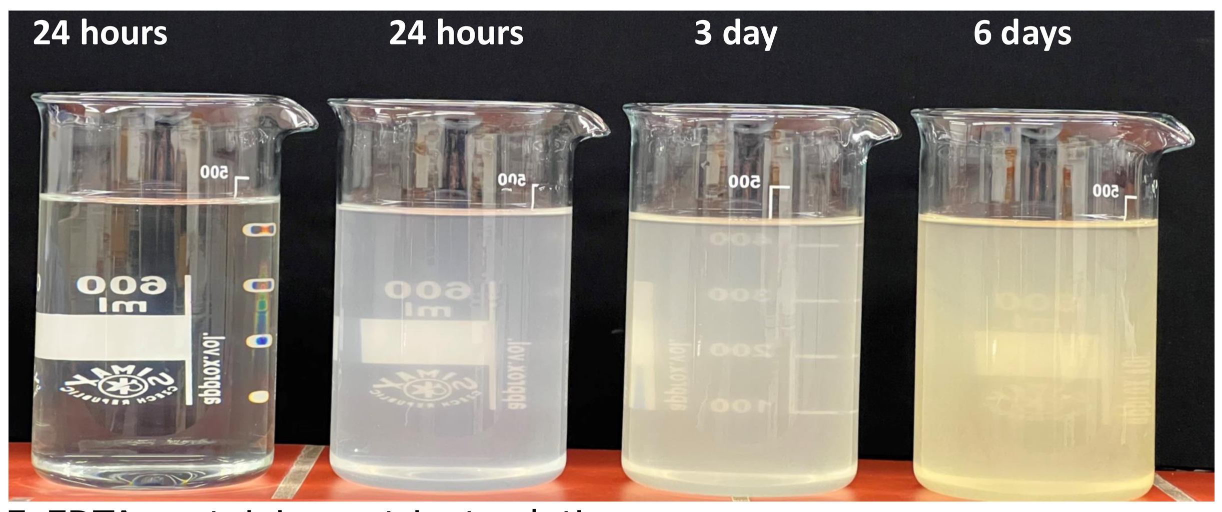
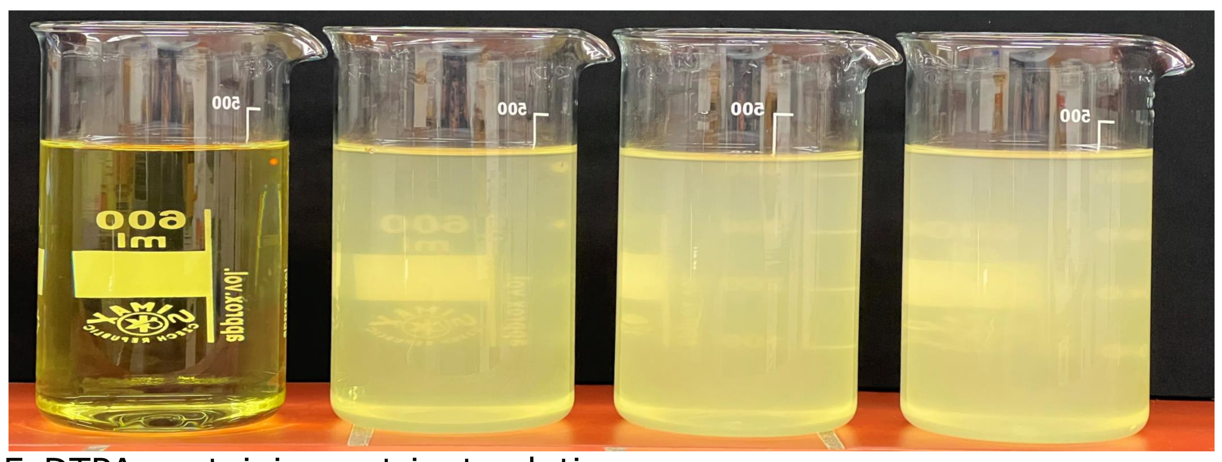


Fig. 2. Concntration of P and Fe in the shoots of Faba bean plant grown in nutrient. Bars indicate means of 4 replicates and S.E.

0 mM 5 mM $NaHCO_3$



FeEDTA containing nutrient solution



FeDTPA containing nutrient solution

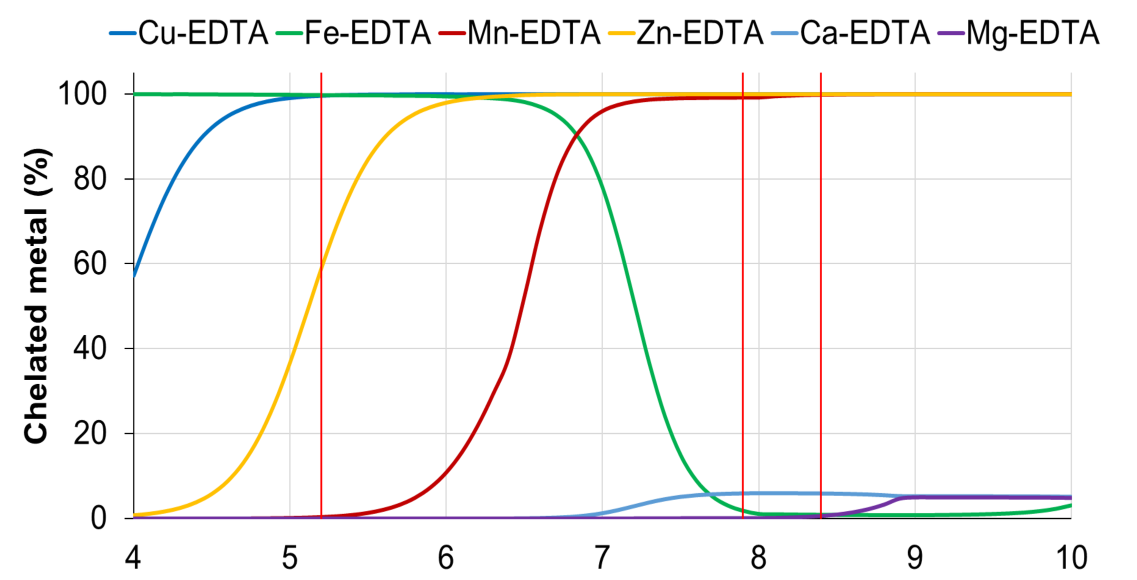
FeHBED containing nutrient solution

Fig. 3. Conditions of nutrient solutions containing different Fe sources at 5mM $NaHCO_3$ concentrations after 1, 3 and 6 days of incubation.

Table 1. Percentage (%) of soluble Fe in alkaline nutrient solutions containing different Fe chelates (filtered through a 0.02 µm filter).

Incubation time		24 hours		3 days		6 days	
Fe Sources	**Alkalinity**	Fe (%)	P (%)	Fe (%)	P (%)	Fe (%)	P (%)
FeEDTA	0 mM $NaHCO_3$	89.7 cd	82.5 a	89.5 cd	90.7 a	90.6 cd	89.0 a
FeDTPA		87.1 d	83.3 a	88.1 cd	88.5 a	92.4 bc	89.8 a
FeHBED		97.0 ab	83.3 a	96.1 ab	85.1 a	96.3 ab	87.2 a
FeEDTA	5 mM $NaHCO_3$	78.7 e	43.6 bc	57.5 g	0.0 e	38.7 j	0.0 e
FeDTPA		62.4 f	35.7 d	55.2 g	0.0 e	50.4 h	0.0 e
FeHBED		96.7 ab	58.1 b	95.4 ab	45.4 bc	96.1 ab	39.9 cd
FeEDTA	15 mM $NaHCO_3$	56.4 g	0.0 e	39.0 j	0.0 e	26.4 k	0.0 e
FeDTPA		41.5 ij	0.0 e	43.1 ij	0.0 e	44.7 i	0.0 e
FeHBED		96.1 ab	0.0 e	96.3 ab	0.0 e	97.9 a	0.0 e

Fate of different nutrients in nutrient solution at various pH levels when Zn, Mn and Cu are applied in $–SO_4$ forms



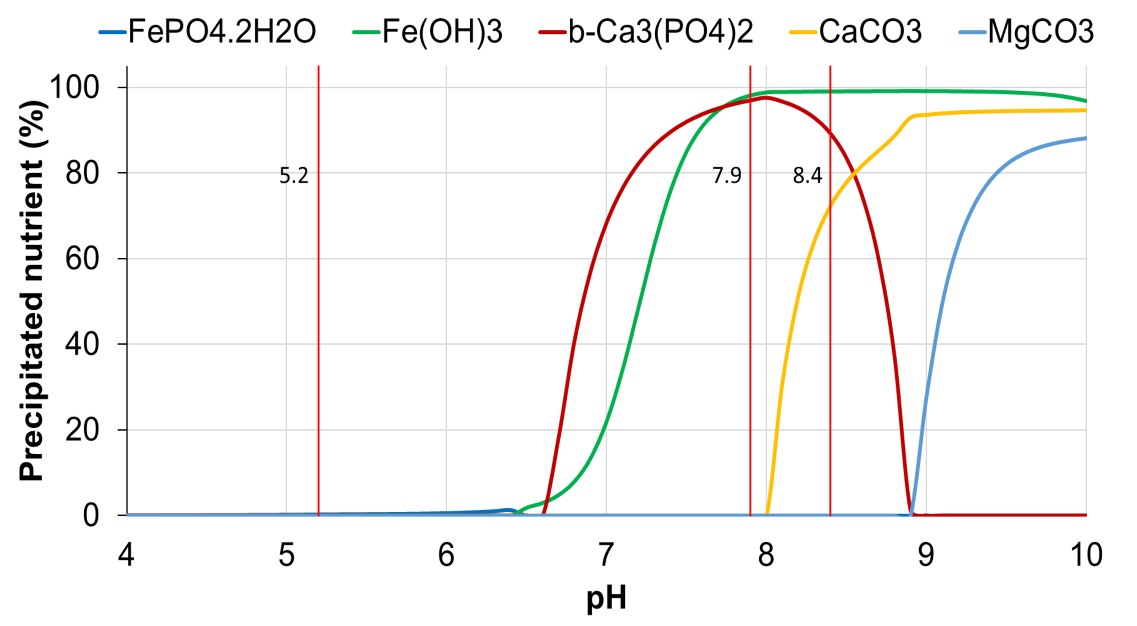


Fig. 4. Proprotion (%) of different micronutrients bound to EDTA (A), precipitated species (B) in nutrient solution at the given pH and various alkalinity levels.

Fig. 5. SEM-EDX composition images of the precipitates collected on the surface of filter papers of 5 mM $NaHCO_3$ containing nutrient solution with different Fe sources. Various colors represents presence of elements at different depths in the sample.

Table 2. Elemental composition of precipitates calculated from SEM-EDX

Fe sources	% C	% O	% Na	% Mg	% P	% S	% K	% Ca	% Fe	% Cu
FeEDTA	19.0	40.2		0.3	10.4			17.8	12.4	
FeDTPA	34.7	38.7		0.2	8.1	0.1	0.1	11.2	6.9	0.1
FeDTPA	46.4	39.6	0.3	0.2	4.8	0.3		8.1	0.2	0.1

Conclusions

Conclusions conclusions conclusions conclusions Based on these results, it is concluded that Fe and P availability to plants can be enhanced by using chelated forms of all the micronutrients, and Fe-HBED is the most suitable Fe source for the nutrient solution with high pH.

Acknowledgements

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Salt-affected soils: threats and potentials