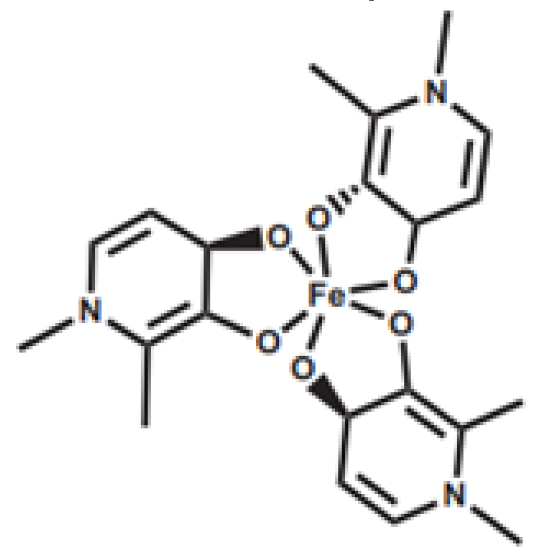
Advanced Nanofertilizers for Iron Uptake in Calcareous Alkaline Soils

<u>Simão Pinho</u>*[1,2], Carla Santos[1], Maria Rangel[3], Marta Vasconcelos[1], Salette Reis[2] and Tânia Moniz[2,3,4]

[1]CBQF, Centro de Biotecnologia e Química Fina, Universidade Católica Portuguesa, Edifício de Biotecnologia, Rua de Diogo Botelho, 1327, 4169-005 Porto, Portugal;
[2] LAQV, REQUIMTE, Departamento de Ciências Químicas, Faculdade de Farmácia, Universidade do Porto, Rua de Jorge Viterbo Ferreira, 228, 4050-313 Porto, Portugal;
[3]LAQV, REQUIMTE, Instituto de Ciências Biomédicas de Abel Salazar, Universidade do Porto, Rua de Jorge Viterbo Ferreira, 228, 4050-313 Porto, Portugal;
[4]LAQV, REQUIMTE, Departamento de Química e Bioquímica, Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre, s/n 40169-007 Porto, Portugal;
* s-sppinho@ucp.pt

Introduction

In the current agronomic context, approximately 30% of the world's cultivatable land is composed by calcareous alkaline soils, which can induce iron deficiency chlorosis in certain crops (Figure 2), potentially diminishing their yields. The present study focuses on the development of nanofertilizers, consisting of polymeric nanoparticles carrying iron (III) chelates belonging to the 3-hydroxy-4-pyridinones (3,4HPO) class (Figure 1). Previous research [1,2] has highlighted these chelates' efficacy in counteracting chlorosis in *Glycine max* (soybean) (Figure 3). The primary advantage of these nanofertilizers is their ability to provide a consistent and sustainable supply of iron to affected plants.



[Fe(dmpp)$_3$]

Figure 1- Iron (III) chelate of the 3-hydroxy-4-pyridinones (3,4HPO) class used in the produced nanoparticles.

Figure 2- Chlorotic soybean leaves.

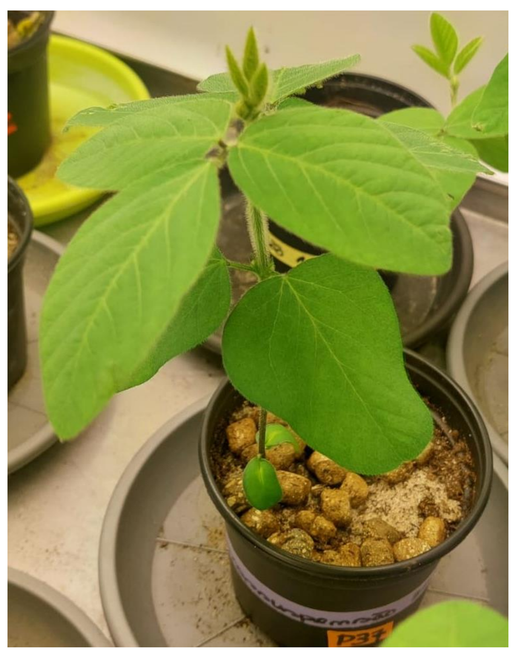


Figure 3- Healthy soybean leaves.

Methods

In our recent investigation, *G. max* seeds were subjected to three distinct treatments:

a) Nanosuspensions with the newly produced nanoparticles containing FeDM, the iron chelate of the 3,4HPO class in the concentrations of 10 µM and 20 µM;
b) Iron chelate solutions in water, containing the same compound in the concentrations of 10 µM and 20 µM ;
c) A control group treated with water.

The seeds were subsequently planted in soil, and the following parameters were examined over time:

- SPAD values (chlorophyll levels);
- Time taken for each plant to reach different developmental stages up to V3;

Upon reaching the V3 stage, all plants were harvested, and their root and shoot fresh weights were also measured.

Results

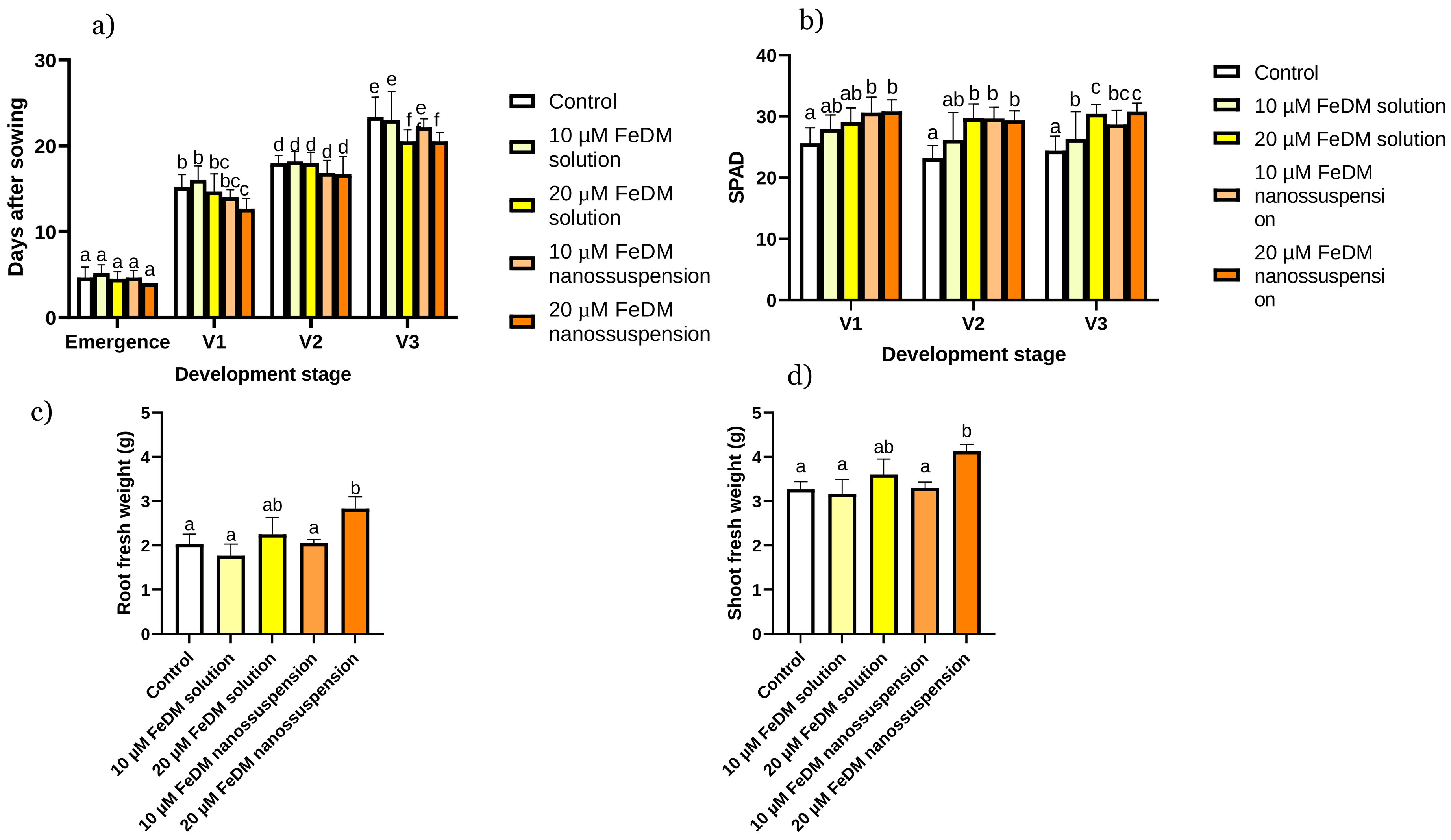


Figure 4- Morphological parameters on plants grown after application of the treatments:
a) Number of days it took to reach each development stage;
b) SPAD (chlorophyll levels) in different development stages;
c) The fresh weight of the roots, in grams;
d) The fresh weight of the shoots (stem and leaves), in grams;
Different letters indicate significant differences ($p<0.05$).

Conclusion and future perspectives

- Plants that had their seeds treated with 20 µM nanosuspensions reached the V3 vegetative stage earlier than those treated with water, 10 µM solutions, or 10 µM nanosuspensions.
- In terms of chlorophyll levels, plants that had their seeds treated with 20 µM nanosuspensions exhibited higher SPAD values than the control during the V1 and V2 stages. They also surpassed those treated with 10 µM solutions at the V3 stage.
- These plants also demonstrated greater fresh weight in both roots and shoots compared to those treated with water, 10 µM solutions, or nanosuspensions.

In summary, plants that had their seeds exposed to 20 µM nanosuspensions appeared to grow more rapidly and healthily compared to plants under other experimental conditions (Figure 4).

The forthcoming phase will encompass an in-depth genetic, mineral, and FTIR analysis of both plants' tissues. In the end, we expect to get insight on efficacy of these nanoparticles in enhancing iron uptake through this type of application.

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References:

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[2] C. S. Santos, A. Leite, S. Vinhas, S. Ferreira, T. Moniz, M. W. Vasconcelos, M. Rangel, Plant Direct, 4 (2020) e00256