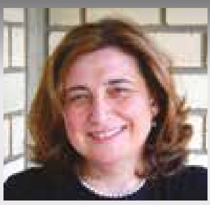
Impact Objectives

- Design new Fe-chelates and evaluate Fe-chelate efficiency in soybean
- Investigate the mechanisms of uptake and root-to-shoot translocation of the Fe-chelates

The future of iron in crops

__Drs Maria da Conceição Rangel__ and __Marta Wilton Vasconcelos__ discuss the importance of efficient iron delivery to crops and the benefits of multidisciplinary collaboration toward this goal through their latest research project __FerPlant__



Dr Maria da Conceição Rangel

Dr Marta Wilton Vasconcelos

Why is iron delivery so crucial for plants?

MR: Iron (Fe) is an essential element to life and ubiquitous on Earth. However, the element is not easily accessible to living organisms since it is mostly present in chemical forms which are very insoluble compounds. This unavailability is especially prevalent in alkaline soils, which account for nearly a third of the world´s agricultural land. For such reason, plants have developed strategies to acquire Fe from the environment with Fe chelation being the most common chemical tool used for metal ion absorption. In the absence of a proper amount of Fe the plants' health is seriously at risk due to Iron Deficiency Chlorosis (IDC). This is a severe condition in which Fe-deficient plants develop yellowing of the younger trifoliate leaves, exhibit reduced leaf areas and shoot and root dry weight. This leads to reduced crop's yield and serious losses for the business.

What different disciplines make up your multidisciplinary team and how do they complement each other?

MV: The disciplines are bioinorganic chemistry and plant nutrition. Dr Maria da Conceição Rangel works in the field of bioinorganic chemistry and her research is focused on the design of molecules that may be of use in novel therapeutic strategies to fight infection, iron overload and diabetes. Her interest in iron biology has recently been extended to plants as a result of collaboration with our group which has been working in the field of plant nutrition for over 15 years. We aim to understand mechanisms of iron uptake, transport and accumulation in different plant species. A strong direct collaboration between the fields of chemistry and plant biology is not so often visible, and this became the perfect time to expand both fields in a different direction, but sharing a common goal, to design and synthesize novel Fe chelates while assessing their efficacy and mode of action.

Why is it important that you reach out for collaborations?

MV: Collaborations are necessary at this stage with academia and industrial partners, since these are crucial to broaden and enrich our research and to develop new products. Collaboration at this stage would be especially beneficial in identifying a partner that could help in the upscaling of the synthesis of the complex, and in providing the necessary fields (especially with alkaline soil) where we could validate our chelate in a real life scenario.

How has your work both on FerPlant ([Fe]rrying plants to prevent chlorosis) and generally benefited from your collaborations?

MR: Research involving multidisciplinary fields of knowledge is very enriching since it implies the exchange of opinions and knowledge transfer between people of different backgrounds. The previous experience of research collaborations with medical and pharmaceutical sciences researchers proved to be essential to the research and myself personally and the present collaboration in the plant sciences field has been extraordinary. It is very stimulating to understand how the common interest in a chemical element can get together so many motivating and friendly people that really inspire themselves.

MV: Until this point my group´s research has mostly focused on the plant sciences and plant nutrition fields. So utilising biochemistry, genetics and plant physiology techniques to answer research questions, as well as working in collaboration with a group so well versed in chemistry techniques and different ways of looking at the same fundamental questions really opened up new horizons of research.

Addressing crop iron deficiency

*The **FerPlant** project is a unique partnership of bioinorganic chemistry and plant technology researchers who are aiming to solve iron deficiency disorders for the world's crops*

Iron (Fe) is the fourth most abundant element in the Earth's crust and is an essential element for plant growth and survival. The problem, however, is that Fe exists in insoluble forms making it extremely difficult for plants to obtain the element. Roughly 30 per cent of the world's arable land lies in alkaline soils where iron exists in these insoluble forms, meaning farmers must rely on supplementing their crops with iron to avoid severe growth deficiencies and disorders such as Iron Deficiency Chlorosis (IDC).

A smart solution plants have developed to obtain iron is the process of chelation, whereby iron is chemically bound to another substance making the whole complex soluble. Finding better, more efficient and environmentally friendly substances to bind iron, known as chelators, is an important field of research that aims to boost crop yields by safely improving upon the iron chelation process. Making a product that can be delivered in a variety of forms, seed coating or leaf spray for example, to a variety of crops takes a team of specialists from different fields combining their expertise. Success in this field will not only improve crop yields but also has an impact on human and livestock health.

FINDING THE PERFECT CHELATOR

The search for better iron delivery compounds has brought together two research groups with different backgrounds under the FerPlant ([Fe]rrying plants to prevent chlorosis) project which is designed to deliver Fe to plants. The two laboratories have different backgrounds, one in plant nutrition and the other in iron biology, but together they have developed and begun testing a promising new class of iron fertilisers.

Dr Marta Wilton Vasconcelos, who specialises in plant nutrition and specifically iron metabolism, has teamed up with Dr Maria da Conceição Rangel, whose laboratory focuses on designing molecules that are able to bind and deliver iron in order to treat several disorders. According to Rangel they have 'found a compound that has potential as a new Fe fertiliser that, even at low doses, is able to avoid IDC symptoms development. This could be economically and environmentally favourable in agricultural contexts'. This exciting new class of Fe fertilisers is synthetically versatile and made in our laboratory. These allow getting the feedback from the experiments with plants and synthesise tailor made compounds designed to provide the appropriate properties to increase their efficiency for IDC correction.

The project was developed to focus on three main branches, explains Rangel. 'Our priorities were to design new Fe-chelates, evaluate Fe-chelate efficiency in soybean and investigate the mechanisms of uptake and root-to-shoot translocation of the Fe-chelates from a physiological, biochemical and molecular standpoint,' she says. In taking this approach they were able to focus on fine-tuning existing families of iron chelators and also study the underlying mechanisms behind activity.

So far, the successful trials of their Fe-chelates on soybean plants grown hydroponically have been published in the journal Plant Physiology and Biochemistry and bringing the results outside of the lab is now possible with the right collaboration says Vasconcelos: 'collaboration at this stage would be especially beneficial in identifying a partner that could help in the upscaling of the synthesis of the complex, and in providing the necessary fields (especially with alkaline soil) where we could validate our chelate in a real life scenario'.

SUCCESSFUL COLLABORATION AND UPSCALING

The project has yielded positive results beyond those published showing the new chelates out-performing the most commonly used compounds in the lab conditions. In the view of Rangel the project is 'also a big success thanks to the sharing of knowledge between two research groups that had not interacted before and that learned a lot from each other'. She also acknowledges the benefit for students saying 'it has been a great success also to see how many young scientists and students became interested in this topic, and wanted to join the research group'.

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The challenge now will be upscaling the compounds' preparation and produce large quantities for testing in fields. Vasconcelos explains: 'both our groups are university-based and do not have the necessary infrastructure to synthesise the complex in very large amounts and within a reasonable timeframe, in order to test this compound and others which we are busy synthesising and testing in the field.' While this is always a hurdle with this type of research it is also a positive one Vasconcelos says, because 'it opens up doors to new collaborations with interested industrial parties.' And there appears to be no shortage of interest either.

The team believes there is a large market for new and more environmentally friendly fertilisers and one major company spontaneously expressed interest early on in the project. Now, after even more successful trials and robust evidence the group is confident that interest exists. To this end, and for the purpose of identifying potential end users of the product, the research teams have also put a focus on making the results open and available to the public. A portfolio containing all the relevant information on results and potential applications is currently being developed for delivery to potential agricultural and commercial partners.

BETTER CROPS, BETTER FOOD

As the team continues to improve methodologies that will increase cost-to-benefit ratios and further investigate the mechanism behind the success of the compound, they are focused on all the potential benefits of their product. In the short term this research has direct implications for soybean producing areas but 'in theory all crop species can benefit from a new, improved iron fertiliser,' comments Vasconcelos. 'Iron deficiency affects many plant species, from strawberries to citrus trees, and the condition may be treated with fertilisers that can be applied as foliar sprays, seed coatings, or soil amendments.' The use of iron fertilisers is also not bound by a specific region or climate. Although external factors such as salinity, soil moisture and temperature will affect how well plants absorb minerals, the mode of delivery of the Fe fertilisers can be considered on a case-by-case basis and the compounds personalised to each region, she says. Beyond increasing crop yields though, producing better quality food is the other important facet of this research.

Cultivation of cereals, vegetables and fruits with better nutritional properties will have an enormous impact on human health. Plants represent a huge part of the human diet and in certain regions plants account for up to 80 per cent of the daily iron intake. This makes healthy plants with the appropriate concentrations of Fe an important health issue because diets deficient in iron are a significant contributor to Iron Deficiency Anaemia, a disorder that affects large numbers of the population in both the developed and developing world. In addition, our livestock rations are also mostly comprised of plant material we produce.

The successful collaboration behind the FerPlant project is delivering worldwide benefits by engaging a new generation of scientists and bridging fields that normally do not communicate to tackle global issues of economic and health importance.

Project Insights

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PARTNERS

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Dr Maria da Conceição Rangel is an Associate Professor at ICBAS-UPORTO. She is Co-Director of the Integrated Master Course of Bioengineering; Member of the Scientific and Technical Board of REQUIMTE; Scientist in charge of NMR and EPR Laboratories of UPORTO and President Inorganic and Bioinorganic Chemistry Division of Portuguese Chemical Society.

Dr Marta Wilton Vasconcelos has been devoted to the field of plant nutrition for the past 15 years. She is a member of the director´s board of CBQF, and heads the PlanTech group (http://plantechesb.weebly.com/). Vasconcelos is Chief Editor of Frontiers in Plant Nutrition, and is one of the young members of the Lisbon Academy of Sciences.

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