# Evaluating the Effectiveness of Max Iron® in Improving Iron Levels in Nectarine Trees Effected by Lime Induced Chlorosis

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Iron (Fe) plays a crucial role in the growth and development of plants, specifically in the creation of chlorophyll which is extremely important for photosynthesis, respiration and the creation of energy for the plant (Rout and Sahoo, 2015). When Iron is severely deficient in the soil it is usually accompanied by a soil constraint – which in this case is alkaline soil. Alkaline soil significantly reduces the amount of available Iron causing chlorosis and more specifically, lime induced chlorosis (Hochmutch, 2011). This trial looks at using Max Iron® formulated by Dual Chelate Fertilizer Pty Ltd as a solution to reducing the damaging effects of lime induced chlorosis which effect 20% to 50% of horticultural tree crops. It was found that Max Iron® increased totally available iron in the treated soil by 14.4%, increased the readily available iron soil concentrated by 50% in the treated soil compared to the control soil, decreased the soil pH more in the treated soil and increased the availability of other elements in the soil such as Phosphorus, Silicon and Manganese.

**Key words**: Iron, photosynthesis, lime induced chlorosis, nectarine, soil alkalinity

## Introduction

Iron is an important micronutrient for plant growth as plays a major role in chlorophyll production and photosynthesis (Rout and Sahoo, 2015). When Iron is deficient in plants, it causes chlorosis and affects fruit production. Iron deficiency chlorosis is a big issue for growers as it directly affects production by increasing yield loss by reducing fruit size and making the fruit more bitter. Therefore, iron is a critical nutrient for nectarine production (Bai et al., 2018).

The availability of iron for plants is highly dependent on soil pH where iron is readily available for plants at low pH levels (Mengel, 1994). Lime induced chlorosis happens on strongly alkaline soils which makes iron unavailable for pants and symptoms show yellowing of leaves with dark green colour veins (interveinal chlorosis) (Rhododendron-Lime-induced Chlorosis, 2021). Ways to alleviate this is though applications of iron chelates through synthetic or natural chelates such as amino acids which helps increase the uptake of minerals through plant tissue.

Max Iron® is a triple action liquid fertigation fertilizer produced by Dual Chelate Fertilizer Pty Ltd that contains varied forms of Iron to increase the efficiency and uptake of iron in the soil, especially in soil which experiences soil constraints such as soil alkalinity and iron deficiencies. Max Iron® contains a total iron percentage of 8%. This total iron percentage contains 1% of amino acid chelated iron, 2% of EDDHA chelated iron, 5% of iron complexed with organic acids, 3% of sulphur as sulphate and 0.2% amino acid nitrogen. As Max Iron® provides chelated iron in three ways it is an exceptionally good option for plants that are experiencing lime induced chlorosis.

The aim of this study is to increase plant available iron in the soil by analysing soil tests and looking at tree vigour and growth. Soil testing will be done to evaluate the percentage of readily available iron in the soil before and after application of Max Iron®. Visual assessments against control trees will also be done to give an insight into whole tree health using comparative photos of treated and control nectarine trees. This study hopes to provide a solution to soil that suffers from alkalinity and unavailable iron by using innovative chelation technology such as amino acids and varied iron forms.

## Objectives

1. Assess the effectiveness of Max Iron® in improving soil nutrient levels in nectarines suffering from lime induced chlorosis.
2. Analyse the physical growth and crop vigour of the nectarine trees in the control and treated areas.
3. Compare control and treated soil analyses before and after fertigated application of Max Iron®.

## Materials and Methods

### Site Selection and Trial Design

This trial was conducted on a stone fruit farm in Swan Hill, Victoria. The 2 ha block was selected due to its severe leaf yellowing which had been observed over a number of years. Previous applications of iron had been done but no visual differences were seen by the farmer. It was observed that the block had high variability in soil types, with the iron induced chlorosis being mostly observed in middle and left (west) regions of the paddock (see figure 1).

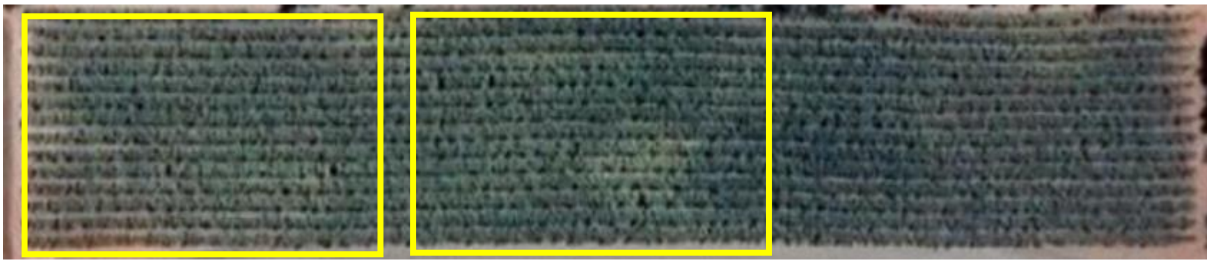

*Figure 1: Aerial image of the block showing symptoms of lime induced chlorosis. Note the yellowing patches.*

One row was isolated as the control row which received no applications of Max Iron® fertilizer but still continued to receive the farmers normal fertilizer application regime. The rest of the block was treated with foliar applications of Max Iron®. See figure 2 for trial layout which also highlights the sampling points were soil tests was analyzed from. There were 3 replicates for both treatments (treated and control).

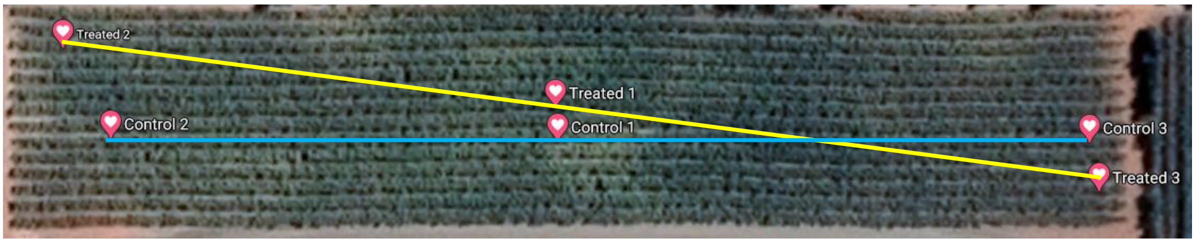


*Figure 2: Soil sampling and monitoring locations*

*Table 1: Application rates and application times for fertigated applied Max Iron®.*

| | Products used | Rate | Growth Stage | Date |
|---|---|---|---|---|
| Application 1 | • Max Iron® | 25 L/ha | End of flowering | 25/08/20 |
| Application 2 | • Max Iron® | 25 L/ha | Schuck fall | 04/09/20 |

Table 1 highlights the fertilizer application details. Max Iron® was applied twice early in the season at end of flowering and at schuck fall. At this time, leaves were small but already showing sever symptoms of iron deficiency. Soil samples were taken just prior to the first application and again 1 week after the last application.

## Observations

### Soil Nutrient Analysis

Before and after the application of Max Iron®, soil samples were taken from the dripper line from nectarien trees in the different sampling locations at the contorl and treated sites (refer to figure 2). These soil samples were then sent to Analytical Laboratories and Technical Services Australia (ALTSA), Victoria for the presence of the listed elements: Nitrogen (N), Posphorus (P), Potassium (K), Sulfur (S), Calcium (Ca), Magnesium (Mg), Sodium (Na), Alminium (Al), Boron (B), Copper (Cu), Iron (Fe), Magnanese (Mn), Zinc (Zn), Silicon (Si) and Molybdenum (Mo).

### Statistical Analysis

A statistical analysis was done using Prism 9 (Graph Pad Software). Significant difference ($P<0.05$) between the treatments was determined by comparing the replicate means. Graphs with error bars were also created using Prism 9.

## Results

*Table 2: Results summary table calculated from the soil tests. Specifically highlighting iron levels in the soil before and after application. Percentages indicate the percentage increase from before application to after application. Other soil parameters are also highlighted such as pH and Ca:Mg ratio.*

| | Before Fert Application | | After Fert Application | |
|---|---|---|---|---|
| | Control | Treated | Control | Treated |
| (TD) Iron | 15,933 mg/kg | 12,150 mg/kg | 14,633 mg/kg (-8.2%) | 13,900 mg/kg (+14.4%) |
| (M3) Iron | 60.5 mg/kg | 95.4 mg/kg | 72.7 mg/kg (+20.2%) | 100.4 mg/kg (+5.2%) |
| (RA) Iron | 8.2 mg/kg | 8.6 mg/kg | 3.4 mg/kg (-58.5%) | 5.1 mg/kg (-40.1%) |
| pH ($H_2O$) | 7.7 | 6.8 | 7.4 (-3.9%) | 6.7 (-1.5%) |
| pH ($CaCl_2$) | 7.0 | 6.1 | 6.8 (-2.9%) | 6.1 (0%) |
| Ca:Mg Ratio | 3.8 | 4.2 | 4.3 (+13.2%) | 4.3 (+2.4%) |

Totally Digestible (TD): Total amount of nutrients in the soil (available and unavailable)

Mehlich 3 (M3): The amount of nutrients available in the soil for plants for the next 3-6 months.

Readily Available (RA): The current available nutrients in the soil for immediate plant uptake. This is what agronomists will make fertiliser recommendations using.

### Visual Soil Comparisons


*Figure 3: Soil collected from the treated 1 and control 1 sampling points*


*Figure 4: Soil collected from the treated 2 and control 2 sampling points*


*Figure 4: Soil collected from the treated 3 and control 3 sampling points*

## Soil Analysis Pre-Fertilizer Application of Nectarines

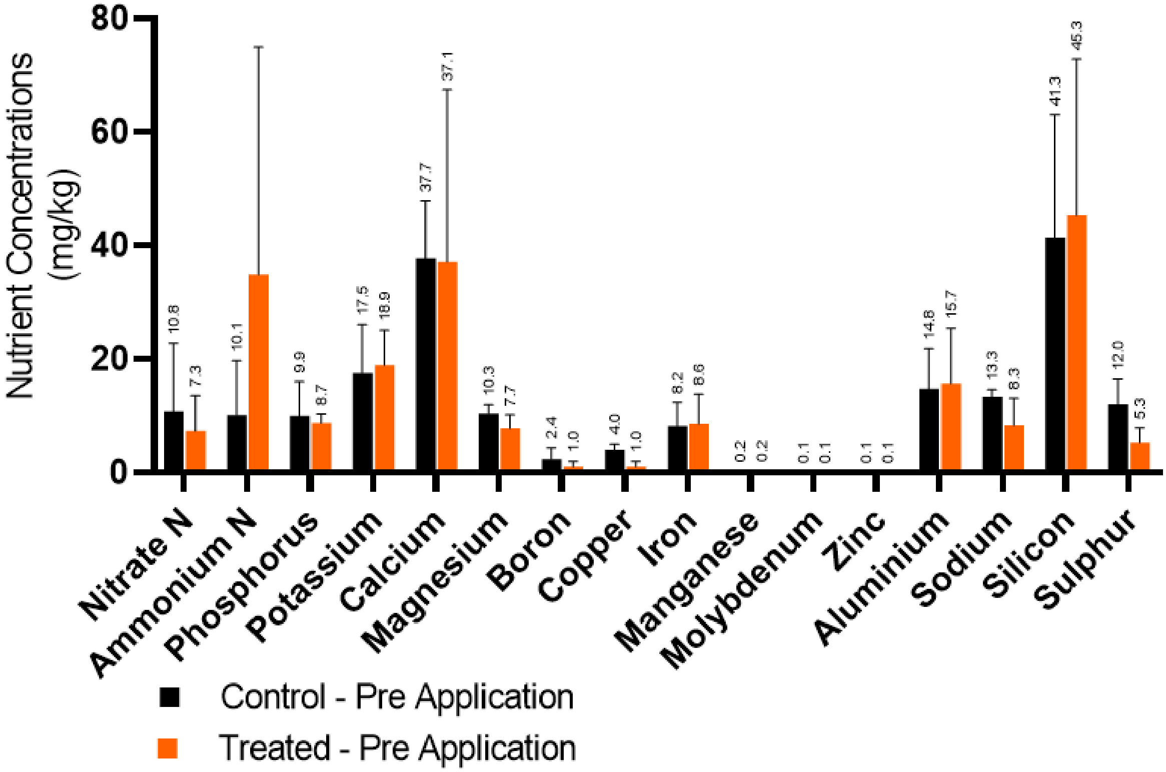


*Figure 5: Soil nutrient concentration (mg/kg)* ***before application*** *of Max Iron®. Averages are highlighted in graphs. No significant difference (P<0.05)*

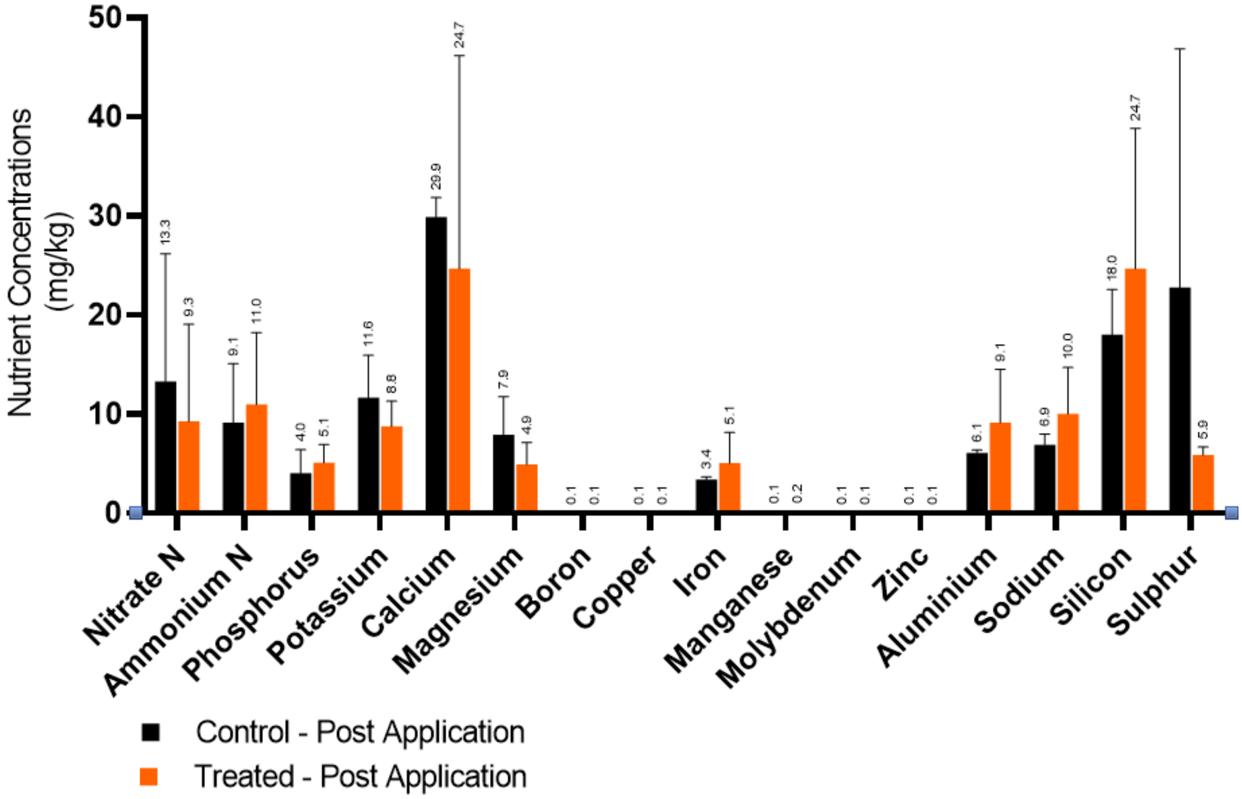


*Figure 6: Soil nutrient concentration (mg/kg)* ***after application*** *of Max Iron®. Averages are highlighted in graphs. No significant difference (P<0.05)*

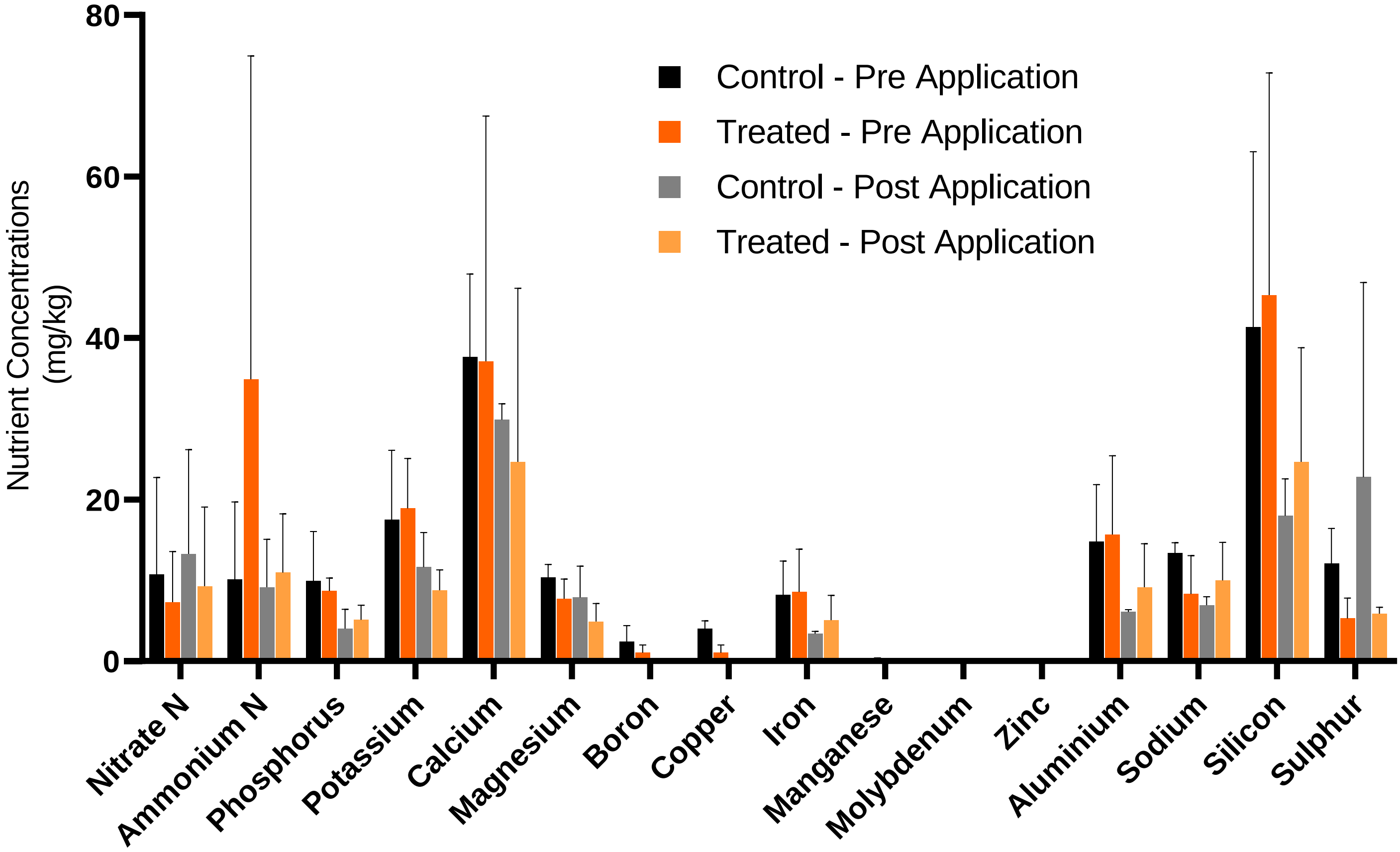


*Figure 7: A combined graph showing the soil nutrient concentrates before and after the application of Max Iron®. Averages are highlighted in graphs. No significant difference between the treated pre-application and treated post-application (P<0.05).*

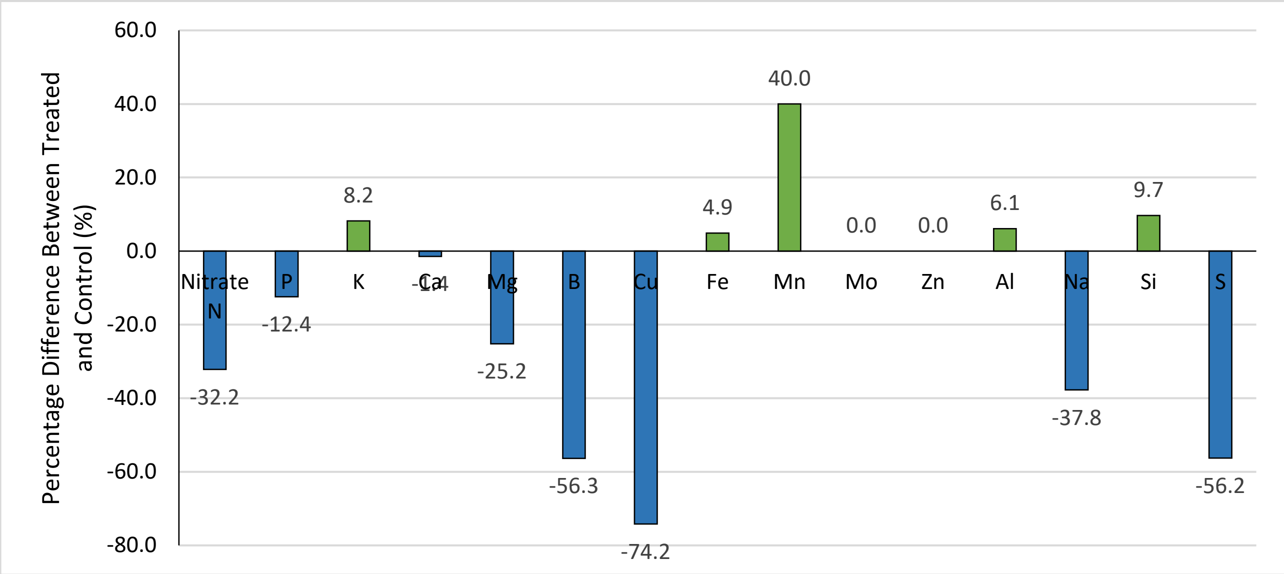


*Figure 8: The percentage change of nutrient concentrations measured in the soil collected from treated and control treated nectarine plants **before application** of Max Iron®. Values with a positive percentage change indicate that nutrient levels were higher in treated soil. Values with a negative percentage change indicate that nutrient levels were higher in control soil.*

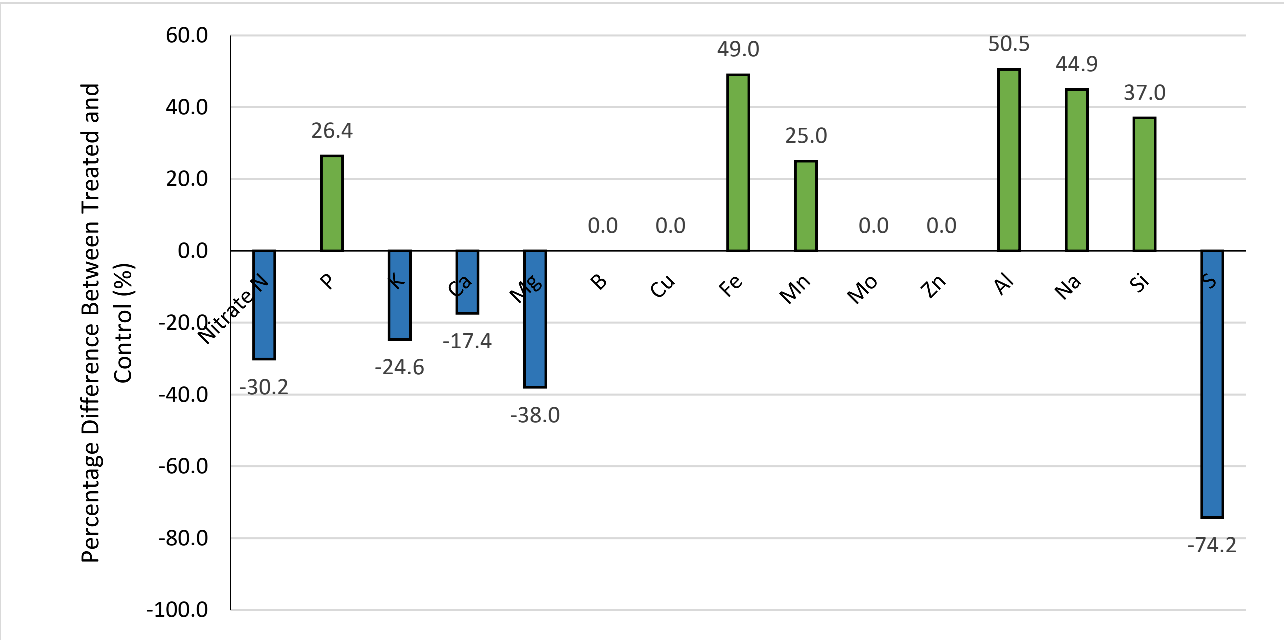


*Figure 9: The percentage change of nutrient concentrations measured in the soil collected from treated and control treated nectarine plants **after application** of Max Iron®. Values with a positive percentage change indicate that nutrient levels were higher in treated soil. Values with a negative percentage change indicate that nutrient levels were higher in control soil.*

## Discussion

When looking at table 2 highlighting the soil summary results, it can be seen that Max Iron® produced a 14.4% increase in total digestible iron in the treated soil whereas the control soil actually had a decrease of 8.2%. This suggests that Max Iron increased the total amount of iron in the soil. This is because Max Iron® is made up of 3 different readily available forms of chelated iron. The decrease in control soil is due to the plant actively growing in its rapid development stage where the nectarines are pushing out many new leaves. The readily available iron already present in the control would have been used up causing this decline. There was no decrease observed in the treated soil as readily available forms of iron were provided and most likely taken up by the plant straight away due to the noticeable iron deficiency.

After the second application of Max Iron, the soil results showed that there was approximately 50% more readily available iron in the treated soil (5.1mg/kg) available for immediate uptake compared to the control (3.4 mg/kg) (refer to table 2). Although there was a decrease in readily available iron in the treated soil from 8.6 mg/kg to 5.1mg/kg, this decrease was not as severe as the control soil which had a decrease of readily available iron from 8.2mg/kg to 3.4mg/kg also highlighted in table 2. This lower decrease observed in the treated soil suggests that the iron supplied by Max iron® was taken up by the plant and used in new leaf development whilst also leaving some iron in the soil for further uptake.

When we consider the pH ($CaCl_2$) levels between the control and treated soil, that was measured that the treated soil had a final pH of 6.1 whereas the control soil had a final pH of 6.8. The lower pH observed in the treated soil is mostly a result from the Max Iron® applications. Max Iron® has iron sulphates contained in its formulation which makes the fertilizer very acidic at a pH of approximately 2.15. Iron sulphate is naturally acidic with a pH of approximately 2. When using Max Iron® through the drippers directly on a highly alkaline soil, the soil will become more acidic for a short amount time making other forms of iron which were previously locked up available again for the plant roots to absorb.

In addition to making the iron more available to the plants, it was also recorded that there were higher concentrations of Phosphorus, Manganese and Silicon (shown in figure 9) in the treated soil compared to the control soil. This may have been a result of the amino acid chelation in the Max Iron® facilitating the movement of other elements in the soil. Another point to add is that since the pH was lower (more acidic) in the treated soil, more nutrients would also become available to the nectarines for uptake. This has a correlation to the acidic nature of Max Iron® facilitating in the acidification of the soil.

## Conclusion

In conclusion, this trial was conducted to evaluate the effectiveness of Max Iron® in improving iron concentration levels in soil with nectarine trees experiencing lime induced chlorosis. Soil results before and after application of Max Iron® were analyzed to assess the levels of available and totally digestible iron in the soil and it was made apparent that the soil contained a large concentration of iron, however only approximately 0.04% of this total iron was readily available in the soil for plant uptake. This is a significant issue which is mainly a result of the alkaline soil instantly turning any applied iron into unavailable forms causing the iron deficiency and lime induced chlorosis.

When studying the figures and tables presented above, it can be found that the nectarine trees treated with Max Iron® had the following improvements:

- Caused the treated soil to have an increase in the totally digestible iron concentrations in the soil by 14.4% where as the control had a decrease of 8.2%.
- Soil treated with Max Iron® had approximately 50% more readily available iron in the soil after Max Iron® applications compared to the control.
- The final treated soil pH after application of Max Iron® application was lower than that of the control soil.
- Other nutrients such as Phosphorus, Silicon and Manganese were in higher soil concentrations in the treated soil in comparison to the control soil. This could be due to the amino acids in Max Iron® chelating other minerals in the soil or because of the acidic nature of Max Iron® increasing the immediate availability of some nutrients.

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