

Analyzing The Effect of Phosphorus and Iron Deficiency on Tomato Plant Growth and Development

By Domenico Comita

INTRODUCTION

Plant development depends on many factors, with one of the most crucial being the availability of essential nutrients (White & Brown, 2010). These nutrients enable plants to produce the organic compounds necessary for growth, development, and reproduction (White & Brown, 2010). To thrive, plants must have access to these essential nutrients (White & Brown, 2010). Without adequate access to these nutrients, plants often show signs of stress, such as yellowing leaves, stunted growth, poor flowering, or weak root systems (White & Brown, 2010).

Essential nutrients come from gasses, minerals, and water (Algiers et al., 2023). Iron and phosphorus are essential plant nutrients (White & Brown, 2010). Iron is classified as a micronutrient because plants only need it in small amounts, whereas phosphorus is a macronutrient, required in larger quantities to support plant health (White & Brown, 2010). Thus, when plants are grown in soil that is low in these nutrients, there will be adverse effects. Plants grown in soils low in iron often show chlorosis and decreased photosynthesis (Zhang et al., 2019). Plants with phosphorus deficiency have decreased nutrient absorption and photosynthetic production (Meng et al., 2021).

Our study examines the importance of phosphorus and iron for the growth and development of tomato plants. Specifically, we aim to determine whether tomato plants can survive without these nutrients and how deficiencies in phosphorus or iron may impair their

growth or development. To do this we will prepare two different hydroponic solutions (one without iron and one without phosphorus), then quantitatively and qualitatively analyze changes in growth over time.

METHODS & MATERIALS

The methods for this experiment are exactly as stated in BIOL3510 Lab Manual, Topic 2. However, our group only focused on making two hypotonic solutions - one hypotonic solution without iron and one hypotonic solution without phosphorus. Another group made a control plant in which all of the essential nutrients were included, which we used later to compare the phenotypes of our nutrient deficient tomato plants.

RESULTS

Control Tomato Plant

The nutrient deficient tomato plants that we grew had clear differences when compared to the control tomato plants that were grown with all the essential nutrients. In the control, the general shape of the leaves were elliptic and the leaves had a rich green coloration. One of the leaves on the control tomato plants had 4 lobes to it (Figure 1). Two out of the 3 tomato plants had 4 leaves while one had 5 leaves (Figure 6). Further, two of the three stems were sturdy and upright with one of the stems being slightly bent to one side at the top. Each of the stems for the control plants had a purplish brown color to them. The height of the control tomato plants all sat around 5cm with the average height being 5.2cm (Figure 5).

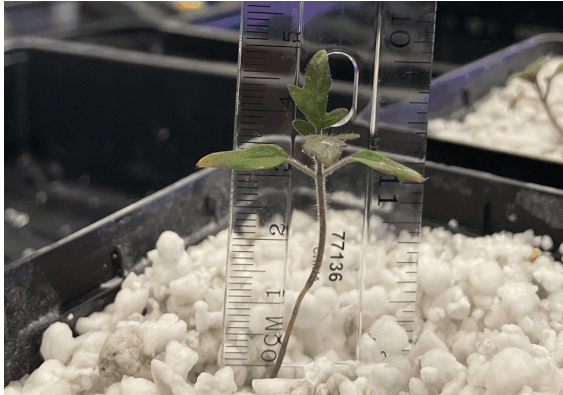


Figure 1. Tomato plant grown in perlite with all essential nutrients (control), containing a leaf with 4 lobes and a height of 5.0cm.

Iron Deficient Tomato Plant

Two out of three of the iron deficient plants had strong chlorosis in which the leaves were a brown with a slight tinge of yellow (Figure 2). As seen in Figure 3, the other iron deficient tomato plant had leaves with a rich green coloration and a purplish brown stem. Each one of the iron deficient plants had 2 leaves of elliptic shape (Figure 6). However, the leaves with strong chlorosis appeared wrinkled and wilted and one of them had a strong bend in their stem (Figure 2).

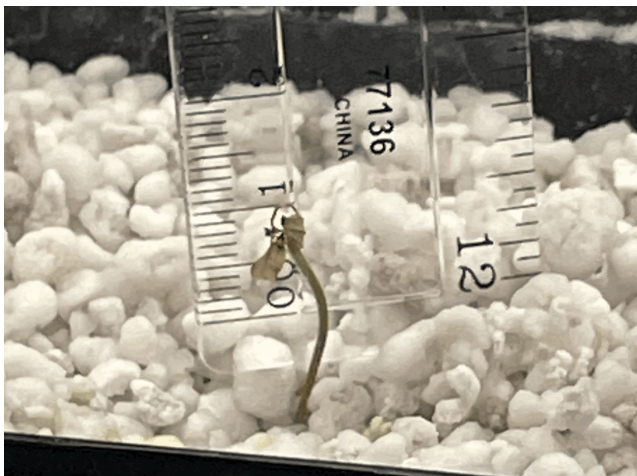


Figure 2. Iron deficient tomato plant grown in perlite with a bent stem and a height of 1.0cm.

The two plants with strong chlorosis had a height of 1.3cm and 1.0cm while the iron deficient plant not showing chlorosis was considerably taller at 5.0cm. The average height of the iron deficient tomato plants was 2.4cm (Figure 5).



Figure 3. Iron deficient tomato plant grown in perlite.

Phosphate Deficient Tomato Plant

The phosphorus deficient tomato plants had leaves with a green coloration. Two out of the three tomato plants had leaves with a rich green coloration while one of the tomato plants had leaves that were a lighter green (Figure 4). The leaf shape in each one of the phosphorus deficient tomato plants was elliptical and the stems all were purplish brown and fairly upright. The average height of the phosphorus deficient tomato plants was 5.1cm, similar to the control plants height (Figure 5).



Figure 4. Phosphorus deficient tomato plant grown in perlite.

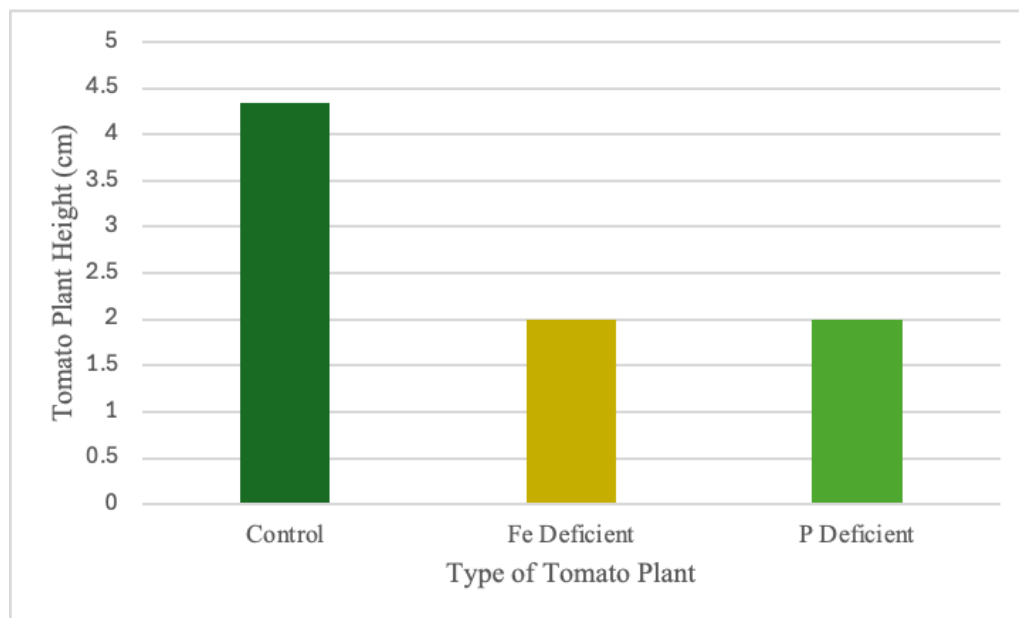


Figure 5. Average height of tomato plants grown in perlite using various hypotonic solutions.

The different colors of the bar represent the average leaf coloration for the tomato plant type.

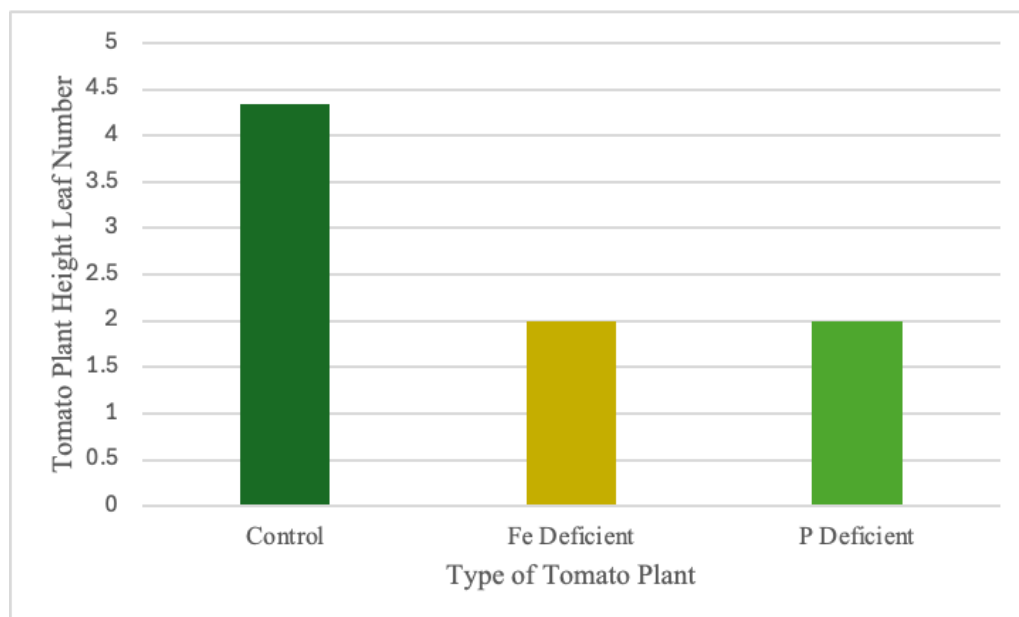


Figure 6. Average number of leaves on tomato plants grown in perlite using various hypotonic

solutions. The different colors of the bar represent the average leaf coloration for the tomato plant type.

DISCUSSION

Key Findings and Interpretation

This study demonstrates the importance phosphorus and iron have on the growth and morphology of tomato plants. In the control group, the tomato plants appeared healthy with sturdy stems, rich green leaves, and an average height of 5.2cm. These observations are expected for plants grown with essential nutrients as they are vital for supporting the plants physiological needs (White & Brown, 2010). Further, the control plants demonstrated typical morphological traits like elliptic leaves and multiple lobes.

In contrast, the iron deficient plants showed significant differences in growth and appearance. Notably, two of the three iron deficient tomato plants displayed strong chlorosis as the leaf color was brownish yellow and there was a stunting in height (1.3cm and 1.0cm). This is consistent with previous research showing that iron is vital for chlorophyll synthesis (Zhang et al., 2019). The one iron deficient plant may have had better genetics that allowed for greater resilience of iron deficiency.

Similarly, phosphorus deficiency had an impact on the tomato plants, although the effects were less dramatic than iron deficiency. The phosphorus deficient plants maintained a green coloration and displayed an average height of 5.1 cm, similar to the control plants. However, the lighter green leaves in one of the plants indicate that phosphorus deficiency can affect chlorophyll content and overall health, as phosphorus is involved in ATP synthesis and root development (Raven et al., 2005). Although there was slight variation in leaf color, the phosphorus deficient plants generally maintained upright stems and healthy morphology, suggesting that it may take longer for phosphorus deficient plants to affect the tomato plants.

Comparison with Previous Studies

Our findings are consistent with the results of previous studies on the effects of iron and phosphorus deficiencies in plants. Similar to our results, other studies have demonstrated that iron deficiency leads to chlorosis, stunted growth, and poor plant health due to its role in electron transport during photosynthesis (Mengel & Kirkby, 2001).

In contrast, the phosphorus deficient plants exhibited less drastic changes, which aligns with research indicating that phosphorus deficiencies typically take longer to show (Meng et al., 2021). While phosphorus is essential for plant growth and energy transfer, plants can sometimes survive under low-phosphorus conditions, although they may exhibit slower growth and reduced productivity (Meng et al., 2021). The slight variation in leaf color in one of the phosphorus deficient plants further supports the concept that phosphorus deficiency can have varied effects depending on the plant's growth stage and environmental conditions (Meng et al., 2021).

Limitations

One limitation of this study is the small sample size, as we only tested three plants per nutrient condition. Because of this small sample size, the reliability of our results may be significantly reduced. For example, in the iron deficient tomato plants, there were 2 short plants at 1.3cm and 1.0cm and one taller plant at 5.0cm, which significantly impacted the average height of the tomato plants. In the future, doing a similar study with larger sample sizes could provide more data and give a more conclusive understanding of how nutrient deficiencies affect tomato plants. Another aspect of the study that could have altered the results is using perlite as a growth medium. In nature, plants do not grow in perlite, so this may not fully reflect what the

plants experience (even with these nutrient deficiencies), as the soil may have bacteria that could support the plant in other ways (Raven et al., 2005).

Broader Relevance

deficiencies impact plant growth, enabling farmers to recognize early signs of deficiencies in their crops and make necessary adjustments to their farming practices. The results of our study suggest that iron deficiencies are particularly detrimental to tomato plants, causing significant chlorosis and stunting growth, which could lead to reduced yields in agricultural settings. Although phosphorus deficiency is less visually apparent, it may still affect plant health over time.

Overall, this study is vital in furthering our understanding of plant nutrient requirements and demonstrates the importance of essential nutrients and their role in optimal plant growth and productivity. Further research could look at the long-term effects of nutrient deficiencies on tomato plant fruit yield or study the potential for nutrient recovery strategies in deficient plants.

References

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