Purpose of Plant Nutrients and Their Deficiency Symptoms

Micah Whitfield

Abstract

Plants are some of the only organism on earth that strictly use inorganic materials as nutrients instead of consuming other organisms. Much of these nutrients come from either the atmosphere or water. There are a few key nutrients however, that plants absorb from the soil. These essential nutrients play major roles in a plant’s tissue, organs, and metabolic functions. Without these nutrients plants quickly show physical symptoms of metabolic disorders. This experiment is intended to discover the roles different nutrients play in a plant’s growth and development as well as the symptoms that appear from a deficit of these nutrients. To perform this experiment six different nutrient solutions will be created, with each solution missing a different element, except for the complete solution. Tomato plant seedlings will then be transplanted into the solutions for two weeks and have their growth observed and recorded. This data will then be used to determine the most essential nutrient for plant growth and development.

Introduction

Unlike most other organisms on Earth, plants do not consume other organic matter as nutrients for growth. All their nutrients come in the form of inorganic matter and sunlight. It is then odd to think that most of the inorganic matter that plants use to obtain mass comes from either the air or water, with only a small portion of elements being absorbed through the soil where they’re
planted. That is not to say however that that small portion of nutrients is not important to the overall health, growth, and developments of plants. On the contrary, these nutrient minerals play a major role in the development of tissues and organs within plant cells. Without these elements plants will quickly show physical nutrient deficiency symptoms which are the expression of metabolic disorders (Taiz&Zeiger, 1991). The role that the absent nutrient plays in normal metabolic functions will determine the type of disorder that appears. Excluding hydrogen, oxygen, and carbon, which are absorbed through the air and water there are 13 essential nutrients that plants require for normal functions (Chapin, 1980). This experiment will however only focus on four elements; nitrogen (N), phosphorus (P), magnesium (Mg), and iron (Fe). These nutrients are used as components for compounds, the activation of enzymes, and contribute to osmotic potential in cells (Uchida, 2000). The purpose of this experiment is to determine the roles that these 4 elements play in normal plant metabolic functions as well as observe the effects and symptoms that appear when these nutrients are not readily available. Using this data, we will then attempt to determine which nutrients are most essential to the growth and development of plants. To make this determination we will not only look at the symptoms of nutrient deficiencies but also the mobility of the nutrients. If a nutrient is immobile symptoms should first appear on newer growth while if a nutrient is mobile symptoms should first appear in older growth (Taiz&Zeiger, 1991).
Methods

Creating the Nutrient Solutions

Nine different stock solutions were prepared.

A. 1 molar Ca(NO3)2 × 4H2O
B. 1 molar KNO3
C. 1 molar MgSO4 × 7H2O
D. 1 molar KH2PO4
E. 1 molar Na2SO4
F. 1 molar CaCl2
G. 1 molar KCl
H. Iron chelate (ethylenediamine tetra acetic acid) containing 5 mg Fe per ml.
I. Minor elements (contains per liter) 1.81 g MnCl2 × 4 H2O; 2.86 g H3BO3; .22 g ZnSO417H2O; .08 g CUSO4 × 5H2O; .025 g Na2MoO4 × 2 H2O).

Six one liter glass jars were rinsed out then labeled with one of the solutions that they would contain (Complete, -N, -Mg, -P, -Fe, and -Control). The jars were filled about 2/3 full of distilled water then each nutrient solution was created by adding the stock solutions below (-Control doesn’t use any nutrients and is just filled with distilled water).

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<tr>
<td>Complete</td>
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<td>-N</td>
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The jars were then filled within ¼ inch of the top with distilled water. Each jar was then wrapped in aluminum foil and had an aluminum foil cap with three holes punched out made (L113).

*Planting the Seedlings*

Three tomato seedling plants were transplanted into each of the six jars and had absorbent cotton loosely wrapped around the part of the stem that would be above the holes. The plants were then checked on every few days and were refilled with distilled water if needed. Observations of root and stem length, leaf color and shape, and stem and root color were also recorded. Plants were observed for a total of two weeks (L113).

*Results*

By the second day -Mg, -N, and the -Control started showing negative effects and abnormalities. The bottom leaves of -N became yellow while the -Control's shriveled and became yellow. The -Mg leaves only became slightly lighter in color. On day 4 the -N, and -Control plants appeared to be growing at a slower pace than the -Mg plants. The color deficiencies in the -N and -Control plants also continued to progress.

On day 5 the leaves of the -Fe plants began to droop and curl (Figure 1); -N plant’s bottom leaves continued to stay yellow and shrivel while the top leaves
begin to spot and the stems began to purple (Figure 2); -P’s plant leaves drooped and spotted but stayed green (Figure 3); -Control’s bottom leaves stayed yellow and curled, the top leaves began spotting, and the stem began turning purple (Figure 4); no deficiency symptoms appeared in the Complete plants (Figure 5); -Mg plants bottom leaves appeared the same while the top leaves started spotting and the stem began to purple (Figure 6). -Mg and Complete plants experienced a notable amount of both stem and root growth while the -N and -Control plants roots grew a small amount but the stems did not experience notable growth (Figures 1-6). The rest of the plants grew to match the size of the -N and -Control groups.
From day six through nine the only plants that experienced any sort of notable growth were those in the Complete and -Mg groups whose upper stem returned to a normal green color. The growth of the rest of the plants appeared to be stunted while their deficiency symptoms appeared to progress.

On day 10 the -Fe plants top leaves started to lighten in color (Figure 1); the -N plants had not grown, their bottom leaves started falling off, and their top leaves were still spotted and yellow (Figure 2); the -P’s bottom leaves began to curl and yellow (figure 3); the -Control’s leaves started to appear purple and experienced no growth (figure 4); -Mg plants continued to have mostly green leaves and had a significant amount of root growth (figure 6); the Complete plants continued to have healthy leaves, stems, and roots (figure 5). On day 14 only -Mg and Complete plants had grown while the rest of the plants previous symptoms continued to progress (figures 1-6).
Discussion

The first thing to discuss about this experiment is the planting timeline of the different plants. While mixing the nutrient solutions for the plants I ran out of stock solution B and therefore was only able to make solutions for the -N, -Mg, and -Control plant groups. I was not able to transplant and mix the nutrient solutions for the -P, -Fe, and Complete plant groups until three days after the first group of seedlings had been planted. Another important note is that the second group of tomato seedlings started out smaller than the first group of seedlings. This appears to have not been much of a problem though since the second group of plants eventually reached the same size as the first group and that many of the plants’ growth was eventually stunted. An interesting occurrence I noticed in all the plants, but specifically the -N, -P, and -Control groups, was that while the growth of the stems seemed to be stunted the roots continued to grow at a steady pace (Figures 1-6). This is apparently a common occurrence in plants, caused by the allocation of nutrients to root growth rather than stem growth. This ratio of root:stem growth can increase anywhere from 1.5 to 12 fold, though the mechanisms for this ratio increase are still unclear. There is evidence however, that suggests that due to the roots remaining closer to the nutrient supply a disproportionate sharing of the nutrients occurs (Chapin, 1980).

Now to conclude on which nutrient is most essential to plant growth and health we can simply use the -Control (least healthy) and the Complete (healthiest) plant groups as a spectrum of sorts with all the other plants somewhere in between. Right away we can see that the -N plants are the least
healthy shown by their stunted growth, extreme discoloration (chlorosis), and older leaves dying and falling off. These symptoms provide evidence to support the idea that nitrogen is the most essential nutrient for plants. When looking at all the processes that nitrogen is involved in or effects it is made easier to accept this idea. Nitrogen is an important element in the formation of amino acids which then make proteins (Reuter, 1997). And since all plant enzymes are made of proteins, nitrogen plays a big role in all enzymatic processes within plant cells. The amino acids that nitrogen creates are also used in the formation of protoplasm, which is the site for cell division and thus cell growth and development. Nitrogen is also an important component in chlorophyll, the pigment responsible for absorbing light energy for photosynthesis, the process that provides the plant with energy to perform cellular activity (Uchida, 2000).

This means that without nitrogen plants are not only missing components for cell structure but will also be unable to perform necessary chemical reactions and processes thereby slowing down development.

Looking back at the plants again, we see evidence that suggests that phosphorus is the second most essential nutrient to plant growth. When comparing the -N and -P plants together we see that the only real difference between the two is that the -P’s newer leaves have more color than the -N plants’ leaves. This is due to phosphorus being a slightly more mobile nutrient than nitrogen. This simply means that phosphorus can readily move to newer growth, leaving older leaves to purple and eventually fall off. Phosphorus also not only plays a major role in energy storage during photosynthesis as ADP and ATP, but
also aids in root growth along with being part of the structure of DNA and RNA (Uchida, 2000). This translates into large quantities of phosphorus being required in young cells which explains why the nutrient is moved from older leaves to newer ones.

Now looking at the final two plant groups, -Mg and -Fe, we see that the only difference between them is size and the locations of chlorosis. Both these elements play major roles in the structure and or maintenance of chlorophyll, explaining the onset of chlorosis for both groups of plants (Uchida, 2000). The cause of the size difference between the two groups is more likely due to the -Mg plants not only being transplanted before the -Fe group but also starting out bigger, than the effects of the nutrient solutions. The different chlorosis locations can be explained by magnesium being a more mobile element than iron. With a magnesium deficiency, the first leaves to exhibit chlorosis are the older ones as compared to an iron deficiency where the younger leaves are the first to exhibit chlorosis (Uchida, 2000). Overall the -Mg and -Fe plants appeared healthier than either of the -N or -P groups and experienced comparatively steadier growth, leading me to believe that while magnesium and iron may be essential to photosynthesis and the structure of chlorophyll, they are not as essential to the overall growth and development of the plant compared to nitrogen and phosphorus.

References

L113 mineral nutrition protocol

