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Introduction

Many nutrients in the soil are vital to a plants proper growth and development. In higher plants these nutrients include calcium, magnesium, potassium and nitrogen, among others. Of these essential nutrients, nitrogen has been proven to have a direct effect on photosynthetic rate in Chris Field's paper titled, *The Photosynthesis-Nitrogen Relationship in Wild Plants*. This relationship is defined as the greater the levels of nitrogen in the soil, the greater the photosynthetic rate of the plant. This is because the plant needs to make RuBiSCO, an enzyme that fixes carbon dioxide in order to produce photosynthetic product. If there is less RuBiSCO for fixing carbon dioxide and a shortage of chlorophyll pigments to absorb light, the energy from the light must be dissipated so that the plant is not damaged by the excessive light. Two known possibilities for this energy dissipation are energy lost as heat and energy reradiated as fluorescence. Mauseth defines fluorescence as "the release of light by a pigment…" (226). The reradiated light is emitted at a longer wavelength, as the color red in the visible light spectrum where energy is lower.

In this study the relationship between nitrogen concentration and fluorescence was tested. The hypothesis stated that since nitrogen is directly proportional to photosynthesis, it will be inversely related to fluorescence. The rationale behind this hypothesis is the increase in nitrogen concentration will increase the amount of light energy the plant can trap and use for photosynthesis, thereby decreasing fluorescence. The plant studied was *Zea mays* because of its rapid growth. A pulse-modulated Fluorometer was used to obtain fluorescence in three experimental groups that contained various nitrogen concentrations.

Materials & Methods

This experiment is going to test the fluorescence of the monocot *Zea mays* with different levels of nitrogen in the soil. We will have eighteen monocots for each concentration of nitrogen. The solutions were based on the nitrogen compounds found in Hoagland's parameters for the nutrient solution that outlines normal concentrations of minerals in a plant. The two compounds responsible for the nitrogen content in Hoagland's solution are ammonium phosphate, $(NH_4)_2PO_4$, and calcium nitrate, $Ca(NO_3)_2{\cdot}4H_2O$. Two stock solutions of 5.754g $(NH_4)_2PO_4$ and 11.808g $Ca(NO_3)_2{\cdot}4H_2O$ in 50 mL of water were made for each compound, respectively. From the stock solutions, a solution with the normal amount of nitrogen was made by adding 4 mL of the stock hydrated Calcium nitrate solution and 2mL of the ammonium phosphate stock solution in a liter of water. For the solution with half the amount of nitrogen, 2 mL of the stock hydrated calcium nitrate solution and 1mL of the stock ammonium phosphate solution was added to a liter of water. For the solution with twice the amount of nitrogen, 8 mL of the hydrated calcium nitrate stock solution and 4mL of the ammonium phosphate stock solution was added to a liter of water. These solutions were added to the plants at the beginning of the experiment. For the remainder of the experiment only water was added to ensure survival of the plant. After 2 weeks of growth, each plant was tested using the pulse-modulated fluorometer to measure fluorescence from a single leaf of the plant. Both dark-adapted and light-adapted fluorescence was measured. The plants were placed under a high intensity lamp after being measured under normal light, so that fluorescence can be measured under light stress.

Abstract

Macronutrients in the soil are essential to the growth and development of a plant. One of the most important nutrients to a plants growth is nitrogen. Nitrogen has been directly correlated to photosynthetic output in various studies and this relationship is the subject of this experiment. Since nitrogen has an effect on photosynthetic rate, there should be a correlation between nitrogen and fluorescence – a form of energy dissipation. This study attempted to show that nitrogen concentration in the soil is inversely proportional to fluorescence of the plant because the more nitrogen in the soil, the more energy should be used for photosynthesis rather than energy dissipation. *Zea mays* was chosen as the species of study because of its rapid growth rate and economical value to society. Hoagland's solution was used as a baseline for the amount of nitrogen utilized by a plant in a naturally occurring setting. Distinct groups were made using the baseline solution as the normal concentration of nitrogen. Then, two other groups were set up – one with half the concentration and another with double the concentration. Using a pulse-modulated Fluorometer, fluorescence was obtained from the plants in each of the groups under normal light, as well as under light stress. In addition, both dark-adapted and light-adapted fluorescence were measured. The results revealed that, under both normal light and light stress, light-adapted fluorescence was significantly different between our three groups. This would suggest that under highly stressful conditions, nitrogen is helpful in utilizing more energy for photosynthesis and energy dissipation is minimized.

Data/Results

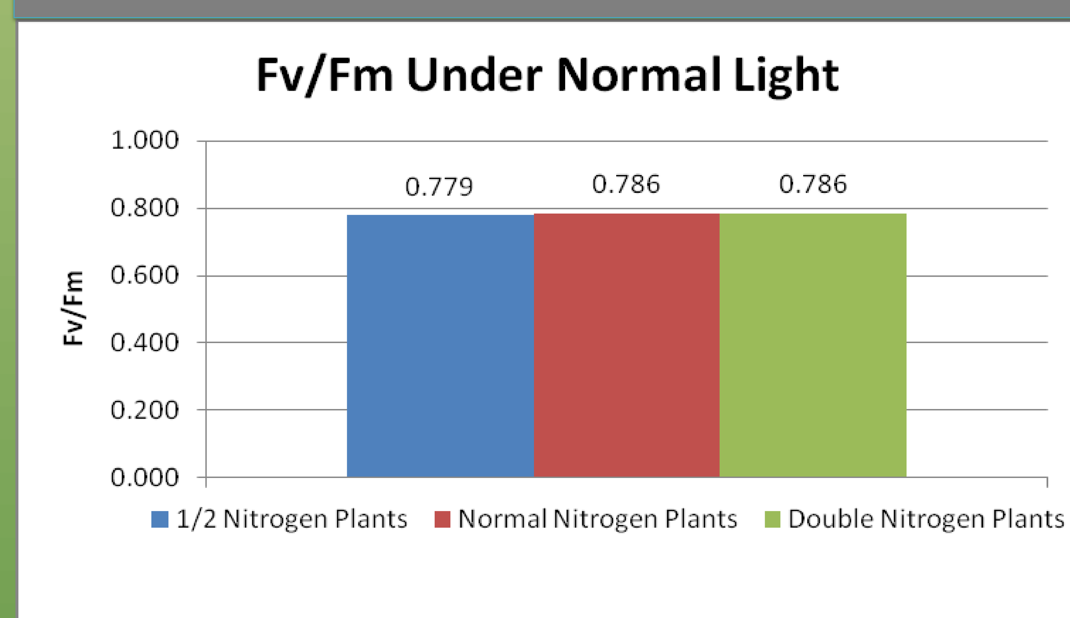

Figure 1. Dark-adapted fluorescence measured under normal light. No significant difference between groups were observed.

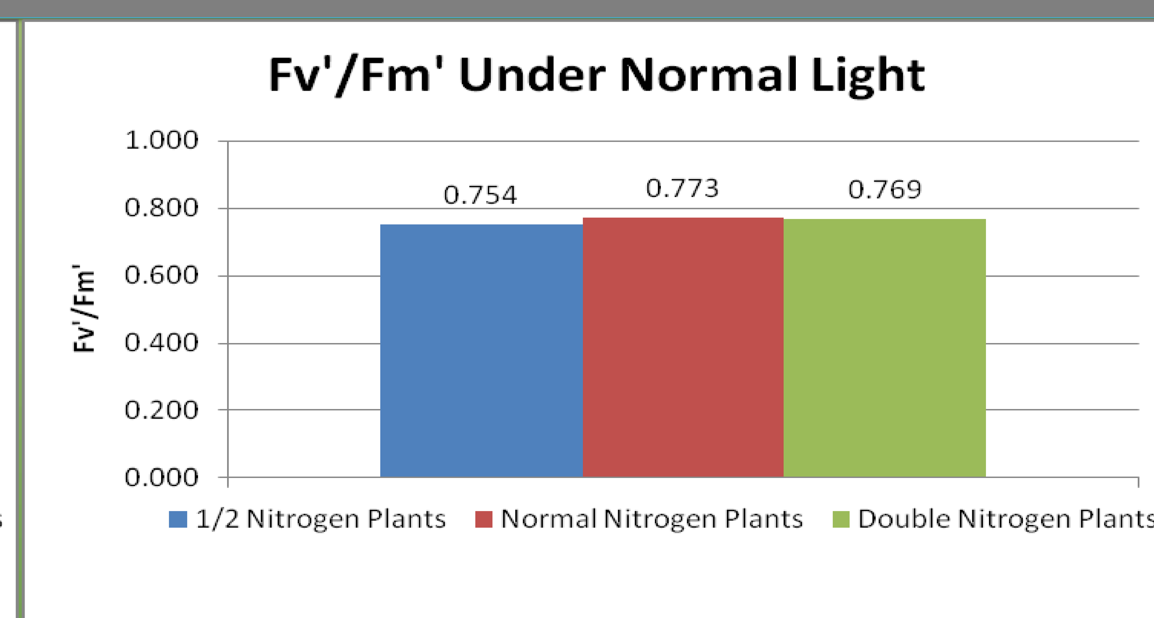

Figure 2. Light-Adapted fluorescence measured under normal light conditions. There was a significant difference observed between the means of the groups.

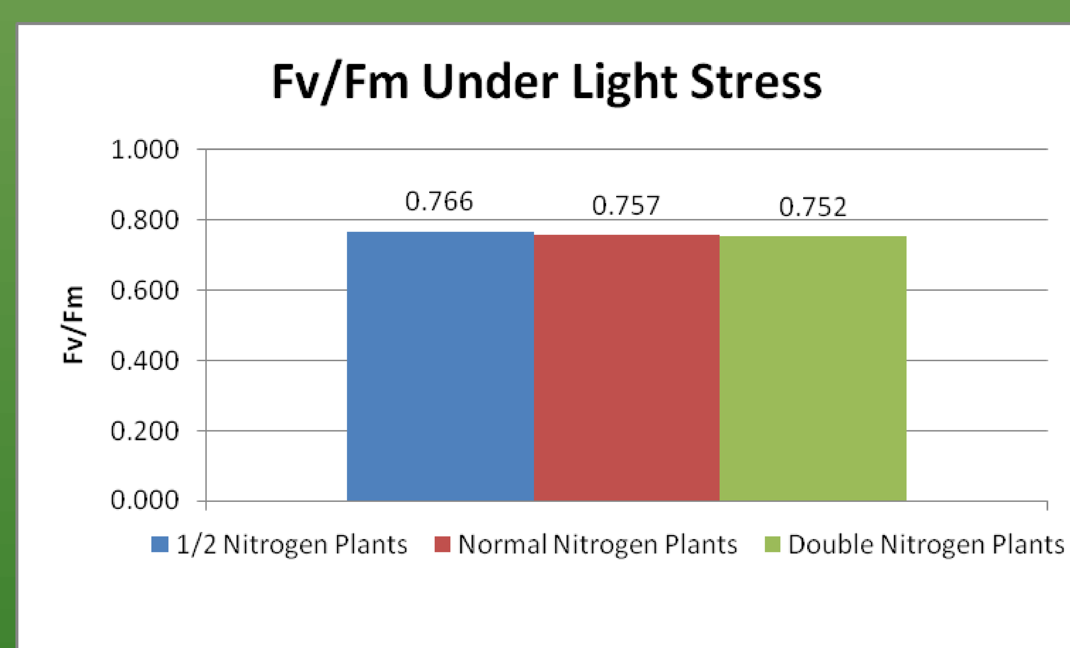

Figure 3. Dark-Adapted fluorescence measured under light stress. No significant difference between groups were observed.

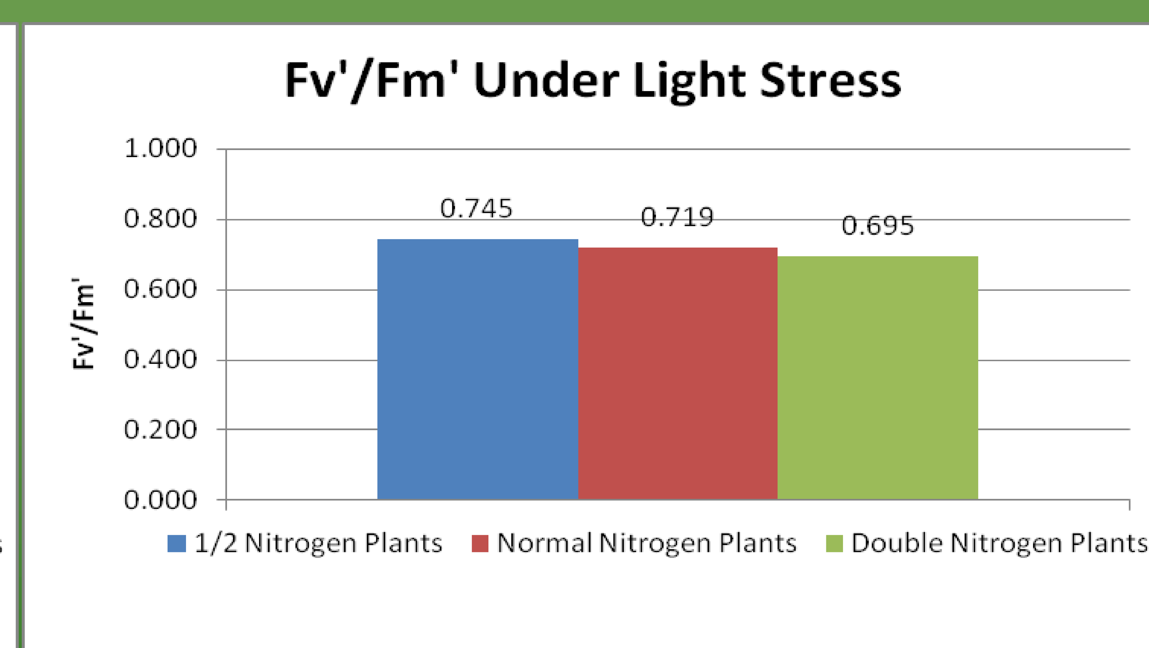

Figure 4. Light-Adapted fluorescence measured under light stress. There was a significant difference in the means between the groups.

Measurements of fluorescence were taken to observe how nitrogen concentration in the soil affected the light reradiated from a leaf. Measurements taken when Photosystem II was rested (dark-adapted, Fv/Fm) had no significant differences in the three experimental groups as per a one-way ANOVA test ($P=0.227$, $P=0.354$). The means of the different groups reveal no significant differences as shown by Figures 1 and 3. However, the analysis of light-adapted fluorescence (Fv'/Fm') with a one-way ANOVA test reveals there is a significant difference between the nitrogen concentrations ($P=0.012$, $P=0.043$). Figures 2 and 4 show the differences in the three means for each group.

Discussion

The purpose of this experiment was to identify the relationship between nitrogen concentration and fluorescence. After meticulous interpretation of the results, it was found that light adapted fluorescence showed significant difference between the groups. The intense light conditions showed significant difference between the half nitrogen experimental group the double nitrogen group. These results support the experimental hypothesis that nitrogen is inversely related to photosynthesis. As a result of the nitrogen concentration increase, there is more nitrogen available to create enzymes such as RuBiSCO and pigments such as chlorophyll. Nitrogen concentration is found to affect the chlorophyll content in a leaf, which is the main pigment in chloroplasts responsible for intercepting light to drive photosynthesis (Mauseth, 2009). The more RuBiSCO and chlorophyll, the more light energy can be absorbed, the more carbon dioxide can be fixed thereby increasing photosynthetic rate and decreasing energy dissipation such as fluorescence. In dark-adapted fluorescence, there was no difference in fluorescence values, thereby showing similar photosynthetic rates. This phenomenon shows the effect of nitrogen is very minimal in the dark reaction by not affecting the activity of RuBiSCO. However, light adapted fluorescence revealed a significant difference in the experimental groups. This could possibly be attributed to the necessity of nitrogen in the synthesis of chlorophyll molecules. This suggests that since chlorophyll is a vital pigment in harvesting light for photosynthesis, the excess of nitrogen builds up more chlorophyll molecules that enable plants to utilize more light energy for photosynthesis. The results showed that fluorescence decreased as nitrogen increased in the light-adapted state, showing a potential correlation between nitrogen concentration and chlorophyll synthesis.

Conclusion

In this study, nitrogen was found to potentially contribute to the synthesis of chlorophyll molecules. The reason light-adapted fluorescence was lower than dark-adapted fluorescence is due to influx of nitrogen causing chlorophyll anabolism. This chlorophyll build up increases photosynthetic rate which in turn decreases fluorescence as a form of energy dissipation, as stated in the hypothesis. Possible further study would be to find the direct correlation between nitrogen and chlorophyll in relation to other forms of energy dissipation.

Acknowledgements

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