# Effects of KCl Additive on Chlorophyll Concentration and Plant Structure

*Bianca Ravesloot, Elliot Flores, Adriana Hall, Jessica Kasprzak, Yusra Abdelrahman, Patrick Mulcahy, Christopher Repa, Ben Diroll*

**ESRP Team**

**Oak Lawn Community High School, Oak Lawn, IL 60453, U.S.A.**

## Abstract

As one of the largest sources of potassium for plants, necessary for both fighting against abiotic & biotic immune stressors and catalyzing plant metabolism, Potassium chloride (KCl) is the "most widely applied K fertilizer."* This makes further research into the effects of KCl fertilizer both relevant and necessary for further agricultural development. Although the correlation between potassium chloride and plant growth has been well studied—showing a strong positive correlation between added KCl and grain yield*—we hope to make advancements in understanding the compound's effect on various sections of the plant. Our research included analyzing the plant wall structure via electron microscopy, studying the effect on chlorophyll concentration using colorimetric analysis, and observing whether an excess or deficit of KCl powder affects a plant's composition through Raman spectroscopy & quantitative data from electron microscopy imaging. Our aim was that the conclusions of our tests would strengthen the aforementioned positive correlation between KCl and plant growth and yield. We hoped to prove the substance useful in further commercial fertilizer development by finding an optimal potassium concentration for not only growth, but plant health in relation to chlorophyll fluorescence and cell wall thickness.

Following our guidelines mentioned above, the Oak Lawn ESRP team has taken in and monitored the health of bush bean plants in order to best determine the chemical's effects. Each of the six sample groups had different concentrations of KCl powder applied during the planting process (0.0001 mol/L, 0.001 mol/L, 0.01 mol/L, 0.1 mol/L, 0.5 mol/L, and a control group) and were set to be given 1.5 cubic inches of water every 24 hours using an automatic irrigation system. Growth was monitored over 2 months, with planting beginning December 20, 2021 and samples being taken Feb 1, 2022. From extreme differences between the experimental and control group's leaf photoluminescence graphs, we determined that an excess of KCl additive over 0.001mol/L is negatively correlated with chlorophyll concentrate and plant growth. All luminescence data regarding the 0.0001-0.001 mol/L groups yielded positive results, with an overall spike in photoluminescence when compared to our original control group. Raman spectroscopy graphs show no significant effect of KCl additives on plant cell structure, confirmed by virtually identical electron microscope images of leaf and stem samples from each of the six groups.

## Introduction

In the United States of America, an average person eats 1,996 pounds of food per year. It equates to almost one ton of food for every single citizen—at least in the U.S. Common bean plants are utilized across the world in order to supply communities with food and nutrition they may not find in other plants. However, a better understanding of their chemistry is necessary to produce the proper amount for an increasing population. Bean plants such as an everyday bush green bean take around two months to achieve full growth. While they may be ready to produce, many specimens do not necessarily grow enough supply to warrant the prior effort.

In this study, we have evaluated the effects of potassium chloride in varying amounts on a set of common bush bean plants. Potassium chloride (KCl) is often an ingredient found in fertilizer, and noted to enhance a plant's ability to grow. It is believed the chemical could change the structure of the plant's cells, as well as alter its limitations in growth height and overall health. From 0.0001 moL to 0.5, each plant received a designated amount of KCl in order to properly record its potential applications. Analysis of our produced data was performed through the use of electron microscopy and Raman spectroscopy.

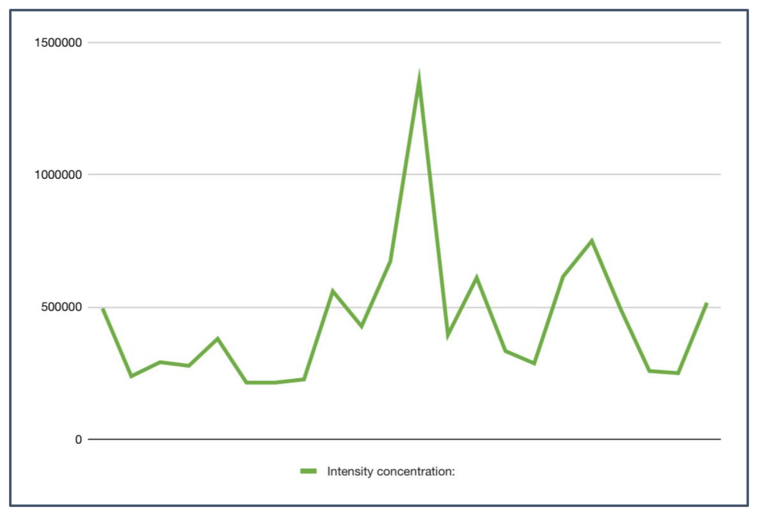
## Methods

60 bush bean seeds in 30 plastic planters (2 seeds per pot) 2 inches into loam soil. 6 concentration groups were established and pots were labeled — a control group, .05 mol group, .1 mol group, .01 mol group, .001 mol group, and .0001 mol group — with 5 pots per group. Using 3 Moistenland Automatic Irrigation Drip Systems and the included plastic tubing, we created timed irrigation systems that watered each plant for 30 seconds every day at 4pm (1.5 cubic inches of water). The pots were placed on shelving with timed overhead growth lights set to turn on 8 hours a day from 7am-4pm. After 2 weeks, they were removed from the unit and placed on a windowsill to promote further growth because shelves were too closely spaced, causing plants to become entangled in the bulbs. After 47 days of growth, a circular hole puncher .25 inches in diameter was used to collect 5 punches from a random leaf on each of the grown plants. The 5 punches were then placed into labeled plastic centrifuge vials with 3 drops of tap water added. To collect stem samples, an inch of the center stem was cut from each plant and placed into labeled vials with 3 drops of tap water. Samples were refrigerated immediately to preserve freshness and sustain cellular life. 4 days later, associate Dr.Diroll picked up the samples to begin testing. Dr. Diroll ran electron microscopy tests, fluorescence microscopy tests, and Raman spectroscopy tests on each of the given samples using Argonne National Lab's equipment. After sending us the data spreadsheets, we created graphs of the Raman and fluorescence data in Google Spreadsheets. Using Microsoft Excel, we then made a cumulative integrated graph of the peaks shown in each fluorescence data set to better visualize differences in each concentration's maximum chlorophyll production.

## Discussion

Graphs representing the leaf photo-luminescence data sets—taken by electron microscopy—are shown in Figures 1-2 (left). Figure 1 regards the total intensity of chlorophyll luminescence for each group of plants, and how it changed as the concentration of potassium chloride (KCl) increased. Figure 2 is quite similar, in which it plots the maximum of every plant's luminescence data to be compared among the others. Although many of the plants containing KCl performed well, those with only minuscule amounts of the substance had almost triple the luminescence intensity present in their chlorophyll. Figure 3 is a display of data taken from Raman spectrography; its bar graph consists of points plotting the pair of "peaks," or maximums, each data set contained. Figure 4-5 are images taken from a plant's inside stem through the use of an electron microscope.

## Results



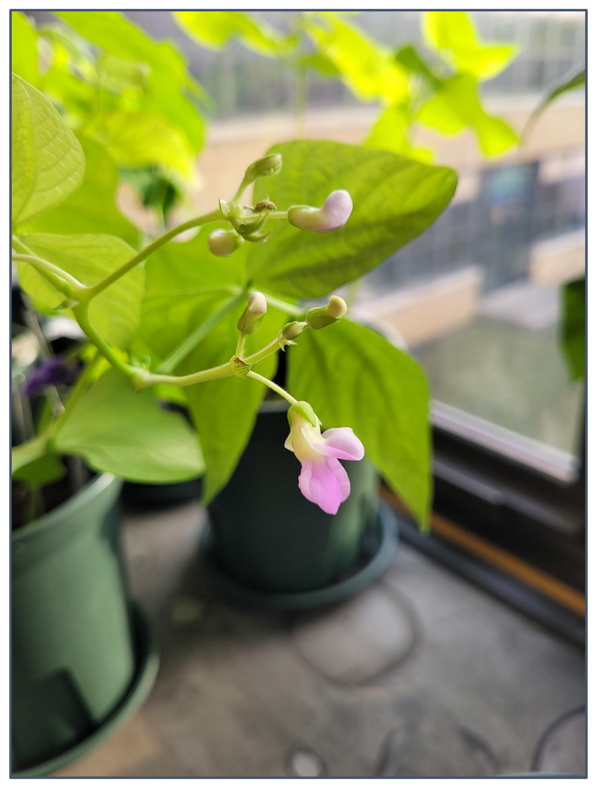



Figure 1: Integration of Average Photoluminescent intensity across all groups (above). The x-axis values are the respective plant numbers. Figure 1a: Flowers produced from the 0.01 moL concentration specimens (right).

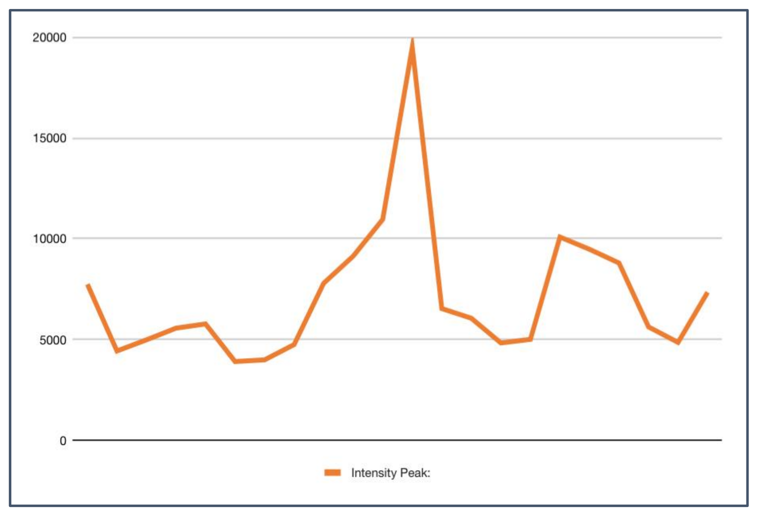



Figure 2: Average maximums of chlorophyll photo-luminescence across all groups (above). The x-axis values are the respective plant numbers. Figures 2a-b: Images taken from the specimen's growing stage (left).

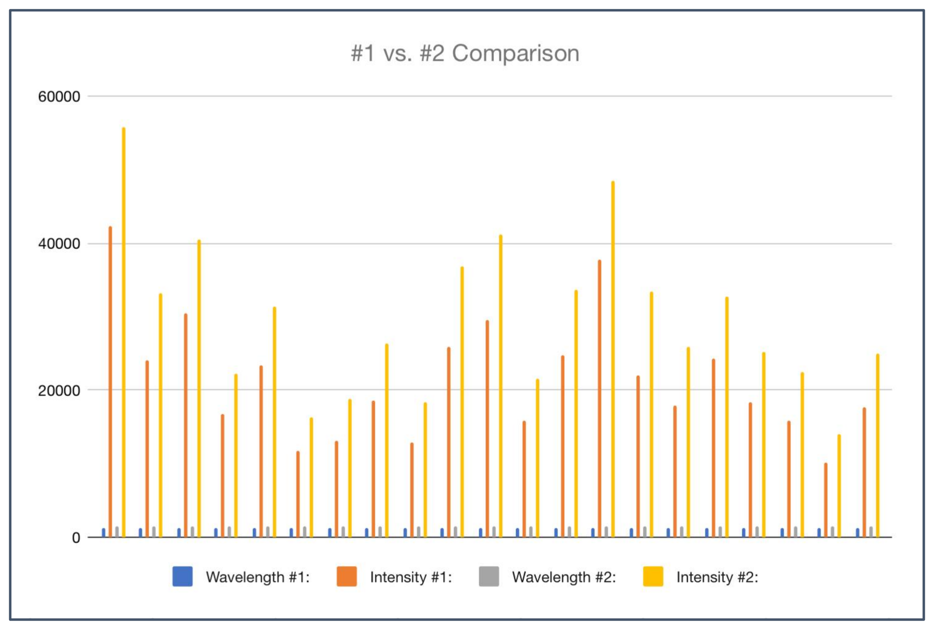



Figure 3: Maximum intensity peaks taken from each set of specimens analyzed through Raman spectrography (above). The x-axis values are the respective plant numbers.

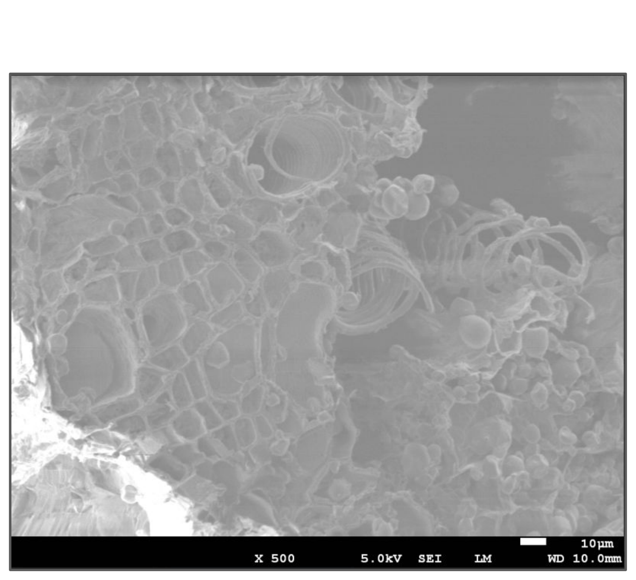



Figure 4: Picture taken of a plant's inside stem cell structure by the means of an electron microscope (left). Figure 5: Image analysis of the area concerning plant cells (below).

| | Label | Area | Mean | Min | Max | Angle | Length |
|---|---|---|---|---|---|---|---|
| 1 | | 1.099 | 156.890 | 149.213 | 165.871 | -115.084 | 13.022 |
| 2 | | 0.882 | 156.727 | 148.033 | 169.000 | -110.179 | 10.427 |
| 3 | | 1.399 | 152.639 | 138.112 | 176.341 | -141.116 | 16.656 |
| 4 | | 0.595 | 159.903 | 151.667 | 173.082 | -64.654 | 7.034 |
| 5 | | 0.392 | 156.257 | 146.872 | 169.848 | -26.095 | 4.564 |
| 6 | Mean | 0.873 | 156.483 | 146.779 | 170.828 | -91.426 | 10.341 |
| 7 | SD | 0.399 | 2.586 | 5.160 | 4.011 | 45.731 | 4.780 |
| 8 | Min | 0.392 | 152.639 | 138.112 | 165.871 | -141.116 | 4.564 |
| 9 | Max | 1.399 | 159.903 | 151.667 | 176.341 | -26.095 | 16.656 |

***This research was made possible through the Exemplary Student Research Program, supported by Argonne National Laboratory's Educational Programs (CEPA), APS User Office, and supported by the Center for Advanced Radiation Sources (CARS) – University of Chicago. Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC .***

## Conclusions

Concentrations of potassium chloride (KCl) present within common bush bean plants correlate with a massive increase in a specimen's chlorophyll photo-luminescence and overall health. As represented through electron microscopy, the 3rd group containing .001 moL of KCl achieved the highest peak at 614813.931 counts of intensity overall. Plants containing minuscule amounts of the chemical base had the strongest positive effects across the board—while larger-portioned specimens ultimately deteriorated in health. We speculate the effects of potassium chloride have a much greater impact on photosynthesis than previously foreseen, as its ability to improve a chlorophyll's fluorescence altered the physical state of the plant on the interior and exterior. However, a balance must be noted in order to properly utilize the chemical considering how quickly it can end a plant's life. The Raman spectrography graphs (Figure 3) produced similar results to the photo-luminescence, with the controlled specimens and those containing 0.001 moL having the greatest structural intensity. This data could be utilized to depict the full-scale impact of KCl additives on plants, as well as improve the balance of said chemical inside fertilizers containing it. Through further testing, agricultural communities can discover the best combination of chemicals in a controlled environment.

## Future Investigations

Future investigation can be conducted to further understand the effects of KCl on plant growth and plant structure. Further experiments include:

1. Investigating the effects KCl fertilizer placement techniques on total KCl uptake
2. Effects of using nano-sized KCl particles in fertilizers
3. The effects of KCl fertilizers on soil Ph and chemical composition
4. The effects of KCl fertilizer on air and runoff water quality

Figure 6-7: Additional pictures of the specimens' growing stages.

## Literature Cited

Mosaic Crop Nutrition. (n.d.). Potassium chloride. Mosaic Crop Nutrition. Retrieved October 21, 2021, from https://www.cropnutrition.com/resource-library/potassium-chloride

Dong, H., Kong, X., Li, W., Tang, W., & Zhang, D. (2010, July 25). Effects of plant density and nitrogen and potassium fertilization on cotton yield and uptake of major nutrients in two fields with varying fertility. Field Crops Research. Retrieved March 16, 2022, from https://www.sciencedirect.com/science/article/abs/pii/S0378429010001668