Documentation of Calcium, Magnesium and Sulfur Deficiencies in Cannabis to Aid in Development of the GrowDoc Application

PROJECT REPORT

CONFIDENTIAL

Prepared by: Agriculture & Environmental Technologies Innovation Centre, Niagara College

Prepared for: GrowDoc App Inc.

Date: February 21, 2022

Table of Contents

Project Team

Faculty Research Lead: Bill MacDonald

Research Program Manager: Kimberley Cathline

Horticulture Technologist: Laurie Zuber

Horticulture Technician: Stanley Leggett

Research Assistant: Katayoun Hamidi

Course: Students from CANN9101

Industry Partner Representative: Daniel Lirette – GrowDoc App Inc.

Project Objective

To gather photo and video documentation of cannabis plants as they are subjected to one of the following deficiencies: calcium, magnesium and sulfur. This will be used by GrowDoc App Inc. (GrowDoc) to improve their mobile application, which will help cannabis growers better discern nutrient deficiencies.

Background

GrowDoc is a cannabis recognition mobile application that can determine the cause of unhealthy cannabis plants with the use of Artificial Intelligence (AI). GrowDoc was created to identify the cause of sick cannabis plants. Whether a plant is wilting or showing symptoms on the leaves, GrowDoc will be there to determine the cause and tell the user what needs to be done to correct the problem.

Challenge

In order to develop the GrowDoc mobile application, photo and video documentation of common nutrient deficiencies is required. To produce these images, nutrient deficiency studies are needed and must be conducted in a controlled environment, with procedures that allow these studies to be replicated in the future. Such trials are challenging for GrowDoc to conduct in-house as it requires substantial equipment and processes to ensure the experiment is controlled with very minimal variables.

Solution

As a course-based project, Niagara College carried out growing trials removing only one nutrient at a time from the nutrient solution, and then observed and documented how the cannabis plant reacted. Three nutrient solutions were formulated to remove one common nutrient; specifically, Calcium (Ca), Magnesium (Mg) and Sulfur (S). Visual changes in the plant were documented using photos and video on a weekly basis. The images and videos collected will allow GrowDoc to improve their application AI accuracy and therefore create an improved product.

Executive Summary

Cannabis (*Cannabis sativa*) is a very high value crop that until recently has been illegal to produce in most areas of the world, including Canada. Due to the recent illegality of this crop, very little scientific research has been done on cannabis. In order to maximize yields, and thus profits, nutrients must be supplied in large quantities or deficiencies can occur. Recognizing nutrient deficiencies early, before reduction in yield has occurred, is critical, and visual symptoms are often utilized. Utilization of AI is now being considered as a means to early identification of nutrient deficiencies. GrowDoc has developed a mobile application (GrowDoc App) that can be used for such early detection, and photographic documentation of nutrient deficiencies is needed to further enhance this technology.

The experiment that was conducted at Niagara College removed one nutrient from a complete nutrient solution, thus the effects of the removal of this single nutrient on cannabis plants could be observed and documented. Significant detrimental effects were observed by the removal of calcium (Ca), magnesium (Mg) and sulfur (S). Reduction in plant growth, as observed by height measurements, resulted in a 30% reduction in height for Mg and S deficiencies, and 60% reduction with Ca removal. Most significantly, fresh and dry weights were reduced by up to 96% in all cases.

The photographic documentation of the removal of a single nutrient at a time, in this case, calcium, magnesium and sulfur, will be used to greatly enhance the performance of the GrowDoc App and enable growers to maximize yields.

Introduction

The production of cannabis (*Cannabis sativa*) has long been an illegal and much persecuted activity. Due to its illegal status, growers worked in many clandestine operations. With this sort of environment, scientific research was virtually impossible, or limited to working with a few hemp cultivars.

Cannabis has a high requirement for nutrients, as it is a very vigorously growing plant, thus its nickname of "weed" is actually well earned. Being a vigorously growing plant, nutrient deficiencies are common, although recognition of these can be difficult. Hand drawings of nutrient deficient cannabis plants are common on the internet and many claim to show specific nutrient deficiencies such as Mg (magnesium), S (sulfur) and Ca (calcium). The accuracies of these drawings is questionable, at best.

The need to perform a scientifically controlled experiment that demonstrates the effects of specific nutrient deficiencies is therefore needed. Also, photographic evidence of the progression of nutrient deficiencies is greatly needed. With the advancement of technology, cannabis plants can now be scanned and entered into a mobile application, which can help growers of cannabis recognize nutrient deficiencies early in the growth cycle. The photographic evidence from this experiment will help in the development of this application.

Materials and Methods

Clones of cannabis variety 'Rock Star Tuna' were rooted in Rockwool cubes with a complete nutrient solution. After two weeks of rooting, the cannabis plants were transferred to 12 - 15 litre buckets containing a complete nutrient solution. The plants were grown in a complete solution for a further two weeks after which time, three plants of each cultivar were randomly assigned to one of the following treatments, for a total of twelve plants:

i) Minus calcium (Ca)

ii) Minus magnesium (Mg)

iii) Minus sulfur (S)

iv) Control, which was a complete nutrient solution

After two weeks in the complete solution, the treatments were started. Nutrient solutions are listed in the Appendix.

Weekly photographs, videos, root and shoot measurements, chlorophyll readings, EC (electrical conductivity), pH measurements and adjustments were made. At the conclusion of the experiment, fresh and dry weights were obtained.

Results

All of the pictures and video taken throughout this experiment have been shared with GrowDoc.

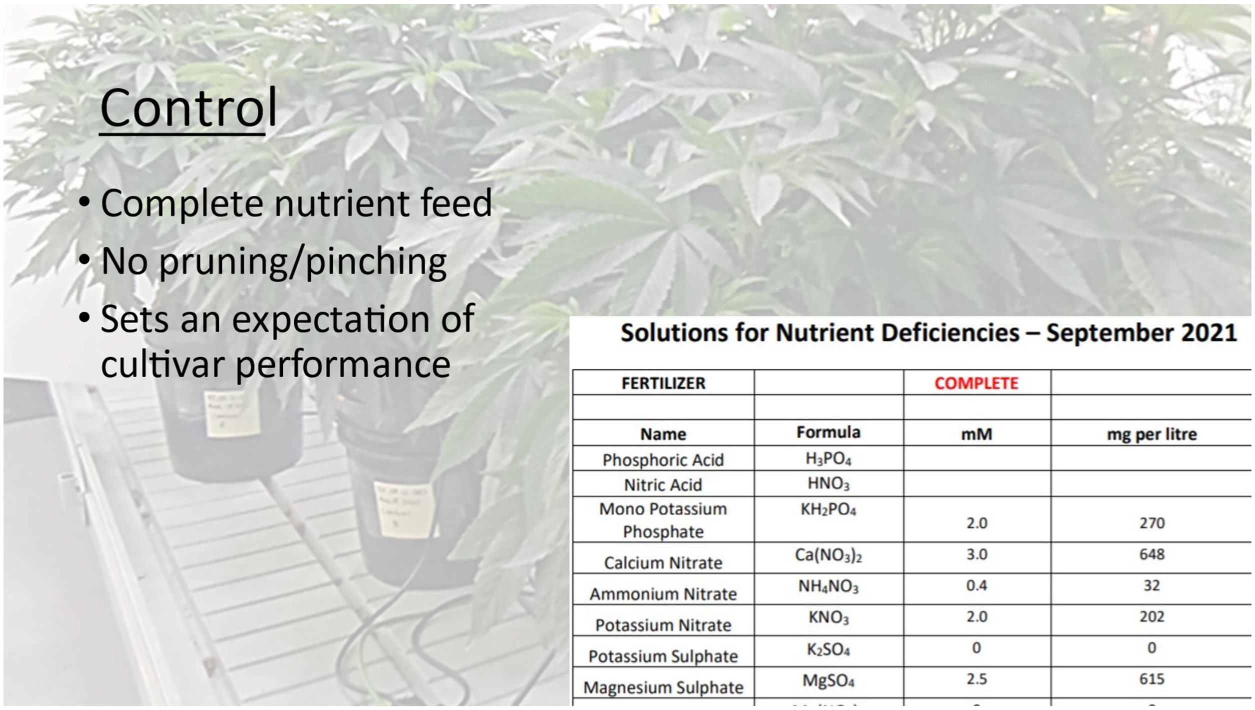
Following are the visual symptoms, chlorophyll readings and height at 3 weeks' vegetative stage and 4 weeks into flowering. Also following are the final plant heights and yield data.

Credit for the following result data goes to Rachel Epworth of the Niagara College, Fall 2021 Cannabis Production Science 1 class.

The numbers associated with particular photos indicate the week number that the picture was taken.

Results were observational in nature and a statistical analysis of the data was not performed.

Control



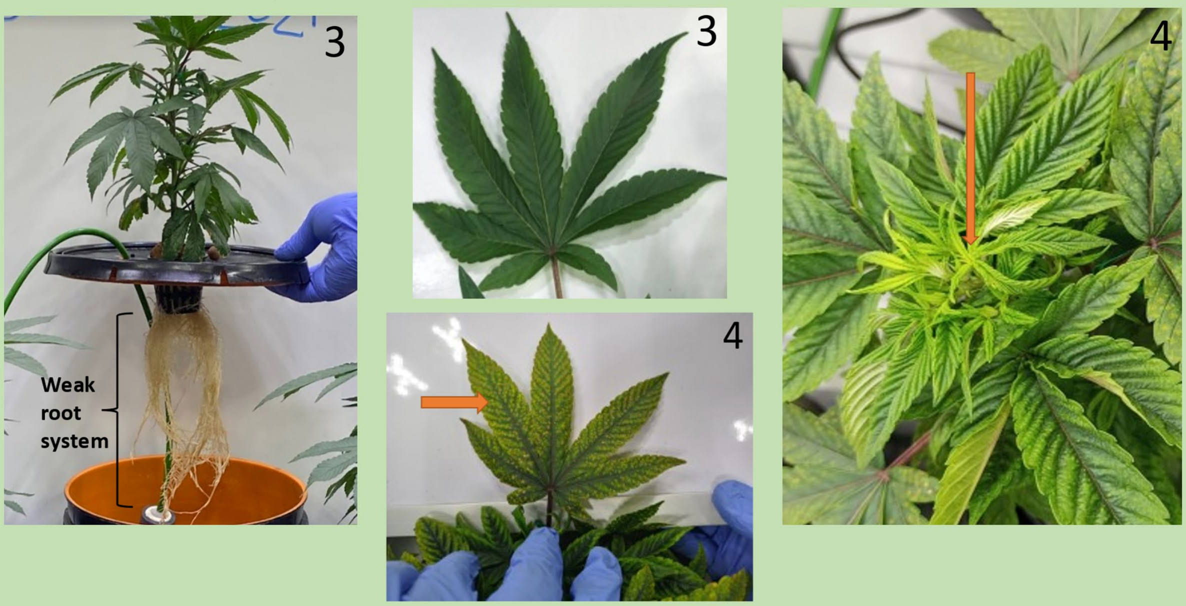
FERTILIZER		COMPLETE	
Name	Formula	mM	mg per litre
Phosphoric Acid	H_3PO_4		
Nitric Acid	HNO_3		
Mono Potassium Phosphate	KH_2PO_4	2.0	270
Calcium Nitrate	$Ca(NO_3)_2$	3.0	648
Ammonium Nitrate	NH_4NO_3	0.4	32
Potassium Nitrate	KNO_3	2.0	202
Potassium Sulphate	K_2SO_4	0	0
Magnesium Sulphate	$MgSO_4$	2.5	615

Calcium

Calcium plays an extremely important role in making plant tissues, it's responsible for holding together the cell walls of plants, its crucial for normal root system development, and its critical in the process of sending signals that coordinate certain activities in the cell.

Calcium is immobile in the plant – deficiencies on newest growth often towards top of plant, new leaves may be distorted, growing tip and root tips may die, increased susceptibility to pests and disease.

Ca Deficiency Initial Results

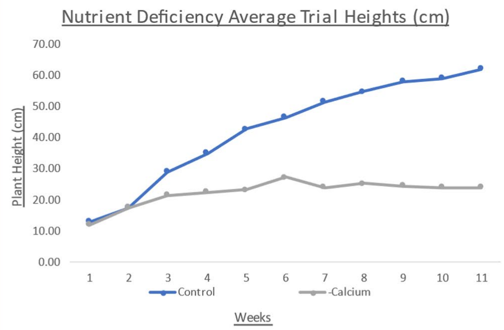


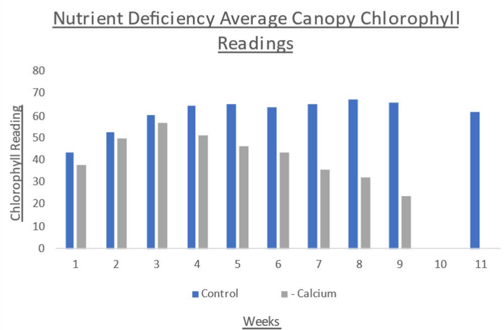
We began to see significant deficiencies presenting themselves by week 4 (some chlorosis and dark veining in the leaves).

The new/youngest leaves looked yellow and sickly, larger fan leaves beginning to spot and curl.

The root system was somewhat small at 5 weeks and brownish in color (calcium is required for early root development). It looked very different from the control plants, where the roots were white and quite large. A sharp increase in necrosis was observed on the leaf edges and tips as shown in the photo above. Branching of the plants and visible stunting and misshaped appearance was also present.

Ca Deficiency Results





Average height for the control plants, indicated by the blue bars in the graph above, was over double the calcium deficiency plants' average height. The calcium deficient average plant growth plateaued by week 3. Calcium deficiency usually results in stunted plant growth and necrosis of leaves, along with eventually the root tips and terminal buds.

The average canopy chlorophyll readings, which were comprised of averaged readings taken from each plant from the top, middle, and bottom of the canopies over the weeks, started consistently dropping weekly by week 4.

Magnesium

Magnesium is a mobile nutrient and is the powerhouse behind photosynthesis. This nutrient is needed by the plant to capture the sun's energy. It performs the following functions:

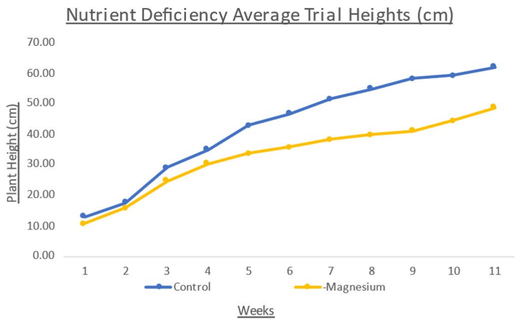
- is a central chlorophyll molecule and gives plants their green colour
- plays an important role in stabilizing cell membranes
- acts as a carrier of phosphorus in plants

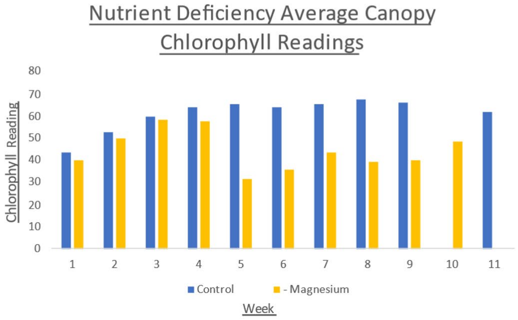
Deficiencies in this nutrient usually appear on lower leaves or older growth first, appearing as discoloration and interveinal chlorosis.

Mg Deficiency Results

Week 4 and week 6 interveinal chlorosis is pictured in the photos above.

Mg Deficiency Results





The Mg deficient plants on average were 12 cm shorter than the control plants. The heights start to diverge at week for, followed by a steep drop from week 4 to 5 in the chlorophyll readings.

Sulfur

Sulfur is semi-mobile within the plant. Some of its key roles include:

- important to photosynthesis
- helps plants exhibit their deep green colour
- essential building block in chlorophyll, amino acids and proteins
- helps increase a plant's stress tolerance and it encourages vigorous growth

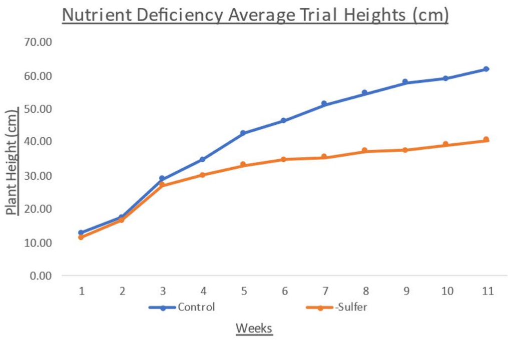
Deficiencies manifest by beginning on the newer and younger growth and progress eventually to the older leaves. Visually this appears as chlorosis, with leaves becoming pale green to yellow, and the plant takes on a spindly appearance with stunted growth.

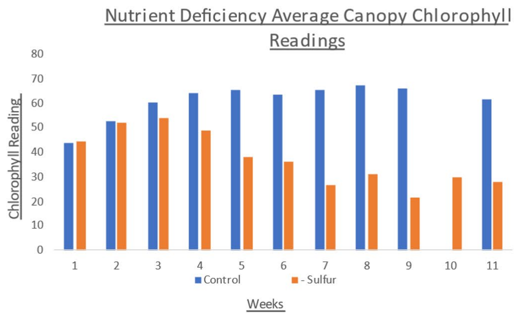
S Deficiency Results

Significant yellowing of the newest growth was observed in the trial around week 4. By week 6, the yellowing had intensified and had progressed to the older fan leaves. The whole plant looked to be shades of yellow and light green, and numerous leaves were experiencing necrotic spots and edges.

The plants at 9 weeks were extremely stressed. Further progression with the necrotic leaves and leaf tips had occurred with yellowing throughout the plants.

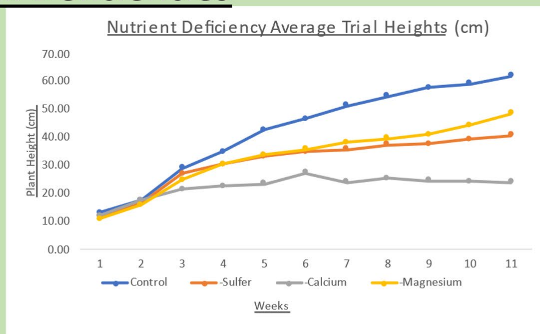
Sulfur Deficiency Results





The graph above shows a sudden drop in the heights of the deficient plants at the week 4 mark. By week 5 it is clear that the plants were struggling.

All Deficiencies



Deficiency Trial	Average Final Wet Weight of Plant (g)
Control	1329
Mg	480
S	102
Ca	84

9

Discussion

The nutrient deficiency symptoms presented very early in the experiment and progressed rapidly. The nutrients removed in this experiment were mobile (Mg), meaning that the nutrient can be translocated from one area of the plant to another via the phloem, semi-mobile (S) and immobile (Ca). Thus, when deficiency symptoms occurred, they were first observed on the bottom of the plant with Mg and S and at the top of the plant with Ca.

The removal of any one nutrient also caused significant decline in growth, as observed by the height of the plants. The heights of the nutrient deficient plants were on average less than half the height of the control plants.

Yield is the most important factor for a cannabis grower, as that is what is sold as a final product. The yields of the cannabis plants in the nutrient deficiency experiments were significantly impacted by the removal of each nutrient. For example, the average fresh weight yield of the 'Rock Star Tuna' control plants was 1,329 g, whereas for the minus calcium plants it was only 52 g; a reduction of 96%. Similar results were found with the minus Mg and S plants, where the average fresh weight was reduced by 64% with the absence of Mg, and 93% with absence of S. Dry weight yields were reduced similarly: 69% (Mg), 91% (S) and 95% (Ca).

Conclusion

Early detection of nutrient deficiencies, and correctly identifying them, is crucial to the production of cannabis. As seen in the above results, the deficiency of one nutrient can have a tremendous impact on yield.

The photographic development of these nutrient deficiencies can used in the development of the mobile GrowDoc App, which in turn will enable growers to recognize nutrient deficiencies and correct these deficiencies, which will maximize yields.

Appendix

Nutrient Solutions for Deficiencies

FERTILIZER		COMPLETE	
Name	**Formula**	**mM**	**mg per litre**
Phosphoric Acid	H_3PO_4		
Nitric Acid	HNO_3		
Mono Potassium Phosphate	KH_2PO_4	2.0	270
Calcium Nitrate	$Ca(NO_3)_2$	3.0	648
Ammonium Nitrate	NH_4NO_3	0.4	32
Potassium Nitrate	KNO_3	2.0	202
Potassium Sulphate	K_2SO_4	0	0
Magnesium Sulphate	$MgSO_4$	2.5	615
Magnesium Nitrate	$Mg(NO_3)_2$	0	0
Calcium Chloride	$CaCl_2$	0	0

Micronutrients: Addition of 30 mg per litre to ALL macronutrient solutions which will result in the following;

Iron (Fe)*	2.1 ppm
Manganese(Mn)*	0.6 ppm
Zinc (Zn)*	0.12 ppm
Copper (Cu)*	0.03 ppm
Boron (B)	0.39 ppm
Molybdenum (Mo)	0.018 ppm

Reverse osmosis water was used with this experiment, so 1.0 mM of $NaHCO_3$ (sodium bicarbonate) was added to all solutions. This is 84 mg per litre.

FERTILIZER		**MINUS Ca**	
Name	Formula	mM	mg per litre
Phosphoric Acid	H_3PO_4		
Nitric Acid	HNO_3		
Mono Potassium Phosphate	KH_2PO_4	2.0	270
Calcium Nitrate	$Ca(NO_3)_2$	0	0
Ammonium Nitrate	NH_4NO_3	2.5	200
Potassium Nitrate	KNO_3	2.0	202
Potassium Sulphate	K_2SO_4	0.5	87
Magnesium Sulphate	$MgSO_4$	1.5	369
Magnesium Nitrate	$Mg(NO_3)_2$	1.25	320
Calcium Chloride	$CaCl_2$	0	0

FERTILIZER		**MINUS Mg**	
Name	**Formula**	**mM**	**mg per litre**
Phosphoric Acid	H_3PO_4		
Nitric Acid	HNO_3		
Mono Potassium Phosphate	KH_2PO_4	2.0	270
Calcium Nitrate	$Ca(NO_3)_2$	3	648
Ammonium Nitrate	NH_4NO_3	1.4	112
Potassium Nitrate	KNO_3	0	0
Potassium Sulphate	K_2SO_4	1.75	305
Magnesium Sulphate	$MgSO_4$	0	0
Magnesium Nitrate	$Mg(NO_3)_2$	0	0
Calcium Chloride	$CaCl_2$	0	0

FERTILIZER		MINUS S	
Name	**Formula**	**mM**	**mg per litre**
Phosphoric Acid (85%)	H_3PO_4	0	0
Nitric Acid	HNO_3	0	0
Mono Potassium Phosphate	KH_2PO_4	2.0	270
Calcium Nitrate	$Ca(NO_3)_2$	1.25	270
Ammonium Nitrate	NH_4NO_3	0	0
Potassium Nitrate	KNO_3	2	202
Potassium Sulphate	K_2SO_4	0	0
Magnesium Sulphate	$MgSO_4$	0	0
Magnesium Nitrate	$Mg(NO_3)_2$	2.5	640
Calcium Chloride	$CaCl_2$	1.75	194