Documentation of Nitrogen, Phosphorus and Potassium 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: September 3, 2021

Table of Contents

Project Team

Faculty Research Lead: Bill MacDonald

Research Project Manager: Kimberley Cathline

Horticulture Technologist: Laurie Zuber

Horticulture Technician: Stanley Leggett

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: Nitrogen, Phosphorus or Potassium. 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 fix it.

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, Nitrogen (N), Phosphorus (P) and Potassium (K). 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 nutrient deficiency 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 nitrogen, phosphorus and potassium. Reduction in growth, as observed by height measurements, resulted in a near 50% reduction in height. Most significantly, dry bud weights were reduced by up to 96%.

The photographic documentation of the removal of a single element at a time, in this case, nitrogen, phosphorus and potassium, 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 N (nitrogen), P (phosphorus) and K (potassium). 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 varieties 'Shiskaberry' and 'Cold Creek Kush' were rooted in Rockwool cubes with a complete nutrient solution. After two weeks of rooting, the cannabis plants were transferred to 16 - 15 litre buckets containing a complete nutrient solution. The plants were grown in a complete solution for a further two weeks after which time, two plants of each cultivar were randomly assigned to one of the following treatments, for a total of eight plants:

i) Minus nitrogen (N)

ii) Minus phosphorus (P)

iii) Minus potassium (K)

iv) Control, which was a complete nutrient solution

Nutrient solutions are listed in the Appendix.

Weekly photographs, videos, root and shoot measurements, chlorophyll readings and EC and 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, where A and B, as well as separately coloured bars on the graphs, refer to individual plants.

Nitrogen Deficiency – 3 weeks veg

- Leaf symptoms:
  - Light green coloration
  - Necrotic spots
- Plant symptoms:
  - Light green coloration on the entire plant
  - Main symptoms on bottom half of the plant
- Chlorophyll reading:
  - Top: 37.2
  - Middle: 46.8
  - Bottom: 40.9
- Plant Height:
  - 29 cm

Photo credits: Carson Sinclair

Nitrogen Deficiency – 4 weeks flower

- Leaf symptoms:
  - Yellow coloration
  - Necrosis in the main vein
  - Leaf tip necrosis
- Plant symptoms:
  - Light green coloration on the entire plant
  - Symptoms spreading to entirety of plant
- Chlorophyll reading:
  - Top: 40.7
  - Middle: 25.6
  - Bottom: 17.7
- Plant Height:
  - 30 cm

Photo credits: Carson Sinclair

GrowDoc

Phosphorus Deficiency – 3 weeks veg

- Leaf symptoms:
  - Curling upwards
  - Dark green coloration
  - Lower leaves drying up
  - Necrotic patches
- Plant symptoms:
  - Entire plant
- Chlorophyll readings:
  - Top: 58.5
  - Middle: 63
  - Bottom: 46.2
- Plant Height:
  - 30 cm

Photo credits: Carson Sinclair

Phosphorous Deficiency – 4 weeks flower

- Leaf symptoms:
  - Curling upwards
  - Dark green coloration
  - Complete leaf necrosis
- Plant symptoms:
  - Entire plant
- Chlorophyll readings:
  - Top: 48
  - Middle: 51.1
  - Bottom: 46.0
- Plant Height:
  - 35.5 cm

Photo credits: Carson Sinclair

Potassium Deficiency – 3 weeks veg

- Leaf symptoms:
  - Edges wilting
  - Necrotic edges
  - Spots on the edge of the leaf
  - Claw development
- Plant symptoms:
  - Main symptoms on the lower half of the plant
- Chlorophyll reading:
  - Top: 51.7
  - Middle: 50.6
  - Bottom: 54.9
- Plant Height:
  - 37 cm

Photo credits: Carson Sinclair

Potassium Deficiency – 4 weeks flower

- Leaf symptoms:
  - Edges wilting
  - Necrotic edges
  - Spots on the edge of the leaf
  - Claw development
- Plant symptoms:
  - Symptoms on entire plant
- Chlorophyll reading:
  - Top: 55.2
  - Middle: 52.6
  - Bottom: 47.8
- Plant Height:
  - 52.5 cm

Photo credits: Carson Sinclair

Visual Symptom Overview

Nitrogen

Phosphorus

Potassium

Control

Symptoms of Deficiency

Phosphorous

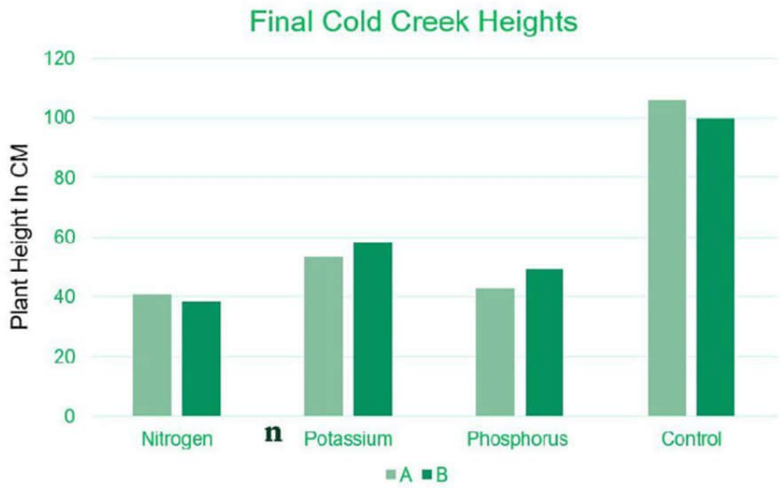
- Plant growth will slow down
- Darkening foliage and slowing growth
- Get brown spot

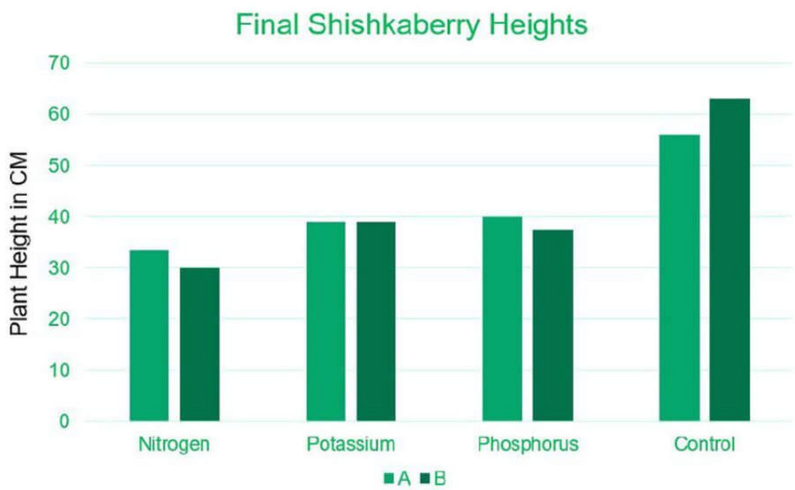
Nitrogen

- Mostly seen in older leaves
- Start between the base and middle of the plant
- yellowing leaves

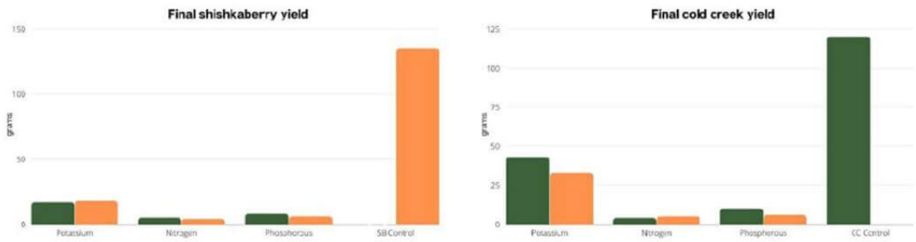
Potassium

- Lower leaves turn brown
- yellow, or burnt edges
- Begin to die
- slow growth


Final Cold Creek Heights
Plant Height In CM
120
100
80
60
40
20
0
Nitrogen
Potassium
Phosphorus
Control
A
B


Final Shishkaberry Heights
Plant Height in CM
70
60
50
40
30
20
10
0
Nitrogen
Potassium
Phosphorus
Control
A
B

Total yields



Discussion

The nutrient deficiency symptoms presented very early in the experiment and progressed rapidly. The nutrients removed in this experiment were all "mobile", meaning that the nutrient can be translocated from one area of the plant to another via the phloem. Thus, when deficiency symptoms occurred, they were first observed on the bottom of the plant.

The removal of one nutrient also caused significant decline in growth, as observed by the height of the plant. 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 one nutrient. For example, the dry bud yield of the 'Shishkaberry' control plant was 135 g, whereas the minus nitrogen plant was only 5.6 g; a reduction of 96%. Similar results were found with the 'Cold Creek Kush' plants, where the dry bud yield of the control plant was 120 g, whereas the minus nitrogen plant was only 4.5 g; a reduction of 96% as well. The same trend was found for the minus phosphorus and potassium plants. Due to the limited space in the CannaBunker, the trial was completed with two replications. As a result, statistics were unable to be performed on the trial, thus the results should be considered as qualitative.

Conclusions

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, such as nitrogen, 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	1.5	203
Calcium Nitrate	$Ca(NO_3)_2$	2.5	540
Ammonium Nitrate	NH_4NO_3	0	0
Potassium Nitrate	KNO_3	2.5	253
Potassium Sulphate	K_2SO_4	0	0
Magnesium Sulphate	$MgSO_4$	1.5	369
Magnesium Nitrate	$Mg(NO_3)_2$	0.5	128
Calcium Chloride	$CaCl_2$	0	0

Micronutrients: Add 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 will be used with this experiment, so 1.0 mM of $NaHCO_3$ (sodium bicarbonate) will be added to all solutions. This is 84 mg per litre.

FERTILIZER		MINUS N	
Name	**Formula**	**mM**	**mg per litre**
Phosphoric Acid	H_3PO_4		
Nitric Acid	HNO_3		

Mono Potassium Phosphate	KH_2PO_4	1.5	203
Calcium Nitrate	$Ca(NO_3)_2$	0	0
Ammonium Nitrate	NH_4NO_3	0	0
Potassium Nitrate	KNO_3	0	0
Potassium Sulphate	K_2SO_4	1.25	218
Magnesium Sulphate	$MgSO_4$	2.0	492
Magnesium Nitrate	$Mg(NO_3)_2$	0	0
Calcium Chloride	$CaCl_2$	2.5	319

FERTILIZER		**MINUS P**	
Name	**Formula**	**mM**	**mg per litre**
Phosphoric Acid	H_3PO_4		
Nitric Acid	HNO_3		
Mono Potassium Phosphate	KH_2PO_4	0	0
Calcium Nitrate	$Ca(NO_3)_2$	2.5	540
Ammonium Nitrate	NH_4NO_3	0	0
Potassium Nitrate	KNO_3	1	101
Potassium Sulphate	K_2SO_4	1.5	261
Magnesium Sulphate	$MgSO_4$	0.5	123
Magnesium Nitrate	$Mg(NO_3)_2$	1.5	384
Calcium Chloride	$CaCl_2$	0	0

FERTILIZER		**MINUS K**	
Name	**Formula**	**mM**	**mg per litre**
Phosphoric Acid (85%)	H_3PO_4	1.5	147 mg (0.1 ml)

Nitric Acid	HNO_3		
Mono Potassium Phosphate	KH_2PO_4	0	0
Calcium Nitrate	$Ca(NO_3)_2$	2.5	540
Ammonium Nitrate	NH_4NO_3	0	40
Potassium Nitrate	KNO_3	0	0
Potassium Sulphate	K_2SO_4	0	0
Magnesium Sulphate	$MgSO_4$	1.5	369
Magnesium Nitrate	$Mg(NO_3)_2$	1.25	320
Calcium Chloride	$CaCl_2$	0	0

Parameter	Cold Creek Control	Cold Creek Nitrogen	Cold Creek Phosphorus	Cold Creek Potassium
Cannabinoid Profile	**Result % (w/w)**	**Result % (w/w)**	**Result % (w/w)**	**Result % (w/w)**
Cannabichromene (CBC)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabichromene Acid (CBCA)	0.34	0.38	0.33	0.39
Cannabidiol (CBD)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabidiolic Acid (CBDA)	<LOQ	0.07	<LOQ	0.06
Cannabidivarinic (CBDV)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabidivarinic Acid (CBDVA)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabigerol (CBG)	0.11	0.13	0.11	0.07
Cannabigerolic Acid (CBGA)	1.76	1.39	1.13	1.24
Cannabicyclol (CBL)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabinol (CBN)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabinol Acid (CBNA)	<LOQ	<LOQ	<LOQ	<LOQ
Delta-8-tetrahydrocannabinol (THC)	<LOQ	<LOQ	<LOQ	<LOQ
Delta-9-tetrahydrocannabinol (THC)	0.49	0.48	0.61	0.47
Delta-9-tetrahydrocannabinol Acid (THCA)	18.48	18.22	12.87	15.35
Tetrahydrocannabivarin (THCV)	<LOQ	<LOQ	<LOQ	<LOQ
Tetrahydrocannabivarin Acid (THCVA)	0.14	0.13	0.10	0.11
Total CBD	<LOQ	0.07	<LOQ	0.05
Total THC	16.70	16.46	11.90	13.93

Terpenes Scan	Result %	Result %	Result %	Result %
Total Terpenes	**2.072**	**1.966**	**1.670**	**1.730**
alpha-Bisabolol	0.028	0.036	0.042	0.033
alpha-Cedrene	<LOQ	<LOQ	<LOQ	<LOQ
alpha-Humulene	0.056	0.046	0.048	0.055
aplha-Phellandrene	<LOQ	<LOQ	<LOQ	<LOQ
aplha-Pinene	0.049	0.051	0.037	0.047
alpha-Terpinene	<LOQ	<LOQ	<LOQ	<LOQ
alpha-Terpineol	0.007	0.01	0.007	0.005
beta-Caryophyllene	0.194	0.154	0.152	0.190
beta-Myrcene	1.158	1.113	0.903	0.931

beta-Ocimene	0.39	0.262	0.286	0.297
beta-Pinene	0.030	0.031	0.025	0.020
Borneol	<LOQ	<LOQ	<LOQ	<LOQ
Camphene	<LOQ	<LOQ	<LOQ	<LOQ
Camphor	<LOQ	<LOQ	<LOQ	<LOQ
Caryophyllene oxide	<LOQ	0.006	<LOQ	<LOQ
Cedrol	<LOQ	<LOQ	<LOQ	<LOQ
cis-Neroloidol	<LOQ	<LOQ	<LOQ	<LOQ
d-Limonene	<LOQ	0.080	<LOQ	<LOQ
delta-3-carene	<LOQ	<LOQ	<LOQ	<LOQ
Eucalyptol	0.01	0.024	0.025	0.018
Fenchol	0.007	0.008	0.006	0.005
Fenchone	<LOQ	<LOQ	<LOQ	<LOQ
gamma-Terpinene	<LOQ	<LOQ	<LOQ	<LOQ
Geraniol	<LOQ	<LOQ	<LOQ	<LOQ
Geranyl acetate	<LOQ	<LOQ	<LOQ	<LOQ
Guaiol	<LOQ	<LOQ	<LOQ	<LOQ
Isoborneol	<LOQ	<LOQ	<LOQ	<LOQ
Isopulegol	<LOQ	<LOQ	<LOQ	<LOQ
Linalool	0.066	0.063	0.045	0.038
Menthol	<LOQ	<LOQ	<LOQ	<LOQ
Nerol	0.007	<LOQ	<LOQ	<LOQ
p-Cymene	<LOQ	<LOQ	<LOQ	<LOQ
Pulegone	<LOQ	<LOQ	<LOQ	<LOQ
Sabinene	<LOQ	<LOQ	<LOQ	<LOQ
Sabinene hydrate	0.005	0.008	0.008	0.006
Terpinolene	<LOQ	<LOQ	<LOQ	<LOQ
trans-Nerolidol	0.041	0.038	0.041	0.039
Valencene	0.037	0.055	0.045	0.046

Legend:
LOQ - Limit of Quantificaiton

GrowDoc

Parameter	Shiskaberry Control	Shiskaberry Nitrogen	Shiskaberry Phosphorus	Shiskaberry Potassium
Cannabinoid Profile	**Result % (w/w)**	**Result % (w/w)**	**Result % (w/w)**	**Result % (w/w)**
Cannabichromene (CBC)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabichromene Acid (CBCA)	<LOQ	0.44	0.57	<LOQ
Cannabidiol (CBD)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabidiolic Acid (CBDA)	<LOQ	0.06	0.05	0.05
Cannabidivarinic (CBDV)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabidivarinic Acid (CBDVA)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabigerol (CBG)	0.16	0.12	0.11	0.14
Cannabigerolic Acid (CBGA)	0.42	0.40	0.40	0.42
Cannabicyclol (CBL)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabinol (CBN)	<LOQ	<LOQ	<LOQ	<LOQ
Cannabinol Acid (CBNA)	<LOQ	<LOQ	<LOQ	<LOQ
Delta-8-tetrahydrocannabinol (THC)	<LOQ	<LOQ	<LOQ	<LOQ
Delta-9-tetrahydrocannabinol (THC)	0.37	0.34	0.52	0.24
Delta-9-tetrahydrocannabinol Acid (THCA)	15.31	13.12	11.94	13.53
Tetrahydrocannabivarin (THCV)	<LOQ	<LOQ	<LOQ	<LOQ
Tetrahydrocannabivarin Acid (THCVA)	0.10	0.10	0.10	0.09
Total CBD	<LOQ	0.06	0.04	0.04
Total THC	13.79	11.85	10.99	12.11

Terpenes Scan	Result %	Result %	Result %	Result %
Total Terpenes	**2.456**	**1.962**	**1.925**	**2.069**
alpha-Bisabolol	0.046	0.056	0.050	0.045
alpha-Cedrene	<LOQ	<LOQ	<LOQ	<LOQ
alpha-Humulene	0.157	0.120	0.091	0.116
aplha-Phellandrene	<LOQ	<LOQ	<LOQ	<LOQ
aplha-Pinene	0.318	0.329	0.376	0.431
alpha-Terpinene	<LOQ	<LOQ	<LOQ	<LOQ
alpha-Terpineol	0.017	0.02	0.014	0.012
beta-Caryophyllene	0.591	0.433	0.317	0.425
beta-Myrcene	0.943	0.661	0.715	0.683

beta-Ocimene	<LOQ	<LOQ	<LOQ	<LOQ
beta-Pinene	0.121	0.119	0.132	0.142
Borneol	<LOQ	<LOQ	<LOQ	<LOQ
Camphene	0.006	0.006	0.007	0.007
Camphor	<LOQ	<LOQ	<LOQ	<LOQ
Caryophyllene oxide	0.007	0.010	0.008	0.006
Cedrol	<LOQ	<LOQ	<LOQ	<LOQ
cis-Neroloidol	<LOQ	<LOQ	<LOQ	<LOQ
d-Limonene	0.110	0.080	0.090	0.080
delta-3-carene	<LOQ	<LOQ	<LOQ	<LOQ
Eucalyptol	<LOQ	0.008	0.010	0.006
Fenchol	0.019	0.015	0.017	0.014
Fenchone	<LOQ	<LOQ	<LOQ	<LOQ
gamma-Terpinene	<LOQ	<LOQ	<LOQ	<LOQ
Geraniol	<LOQ	<LOQ	<LOQ	<LOQ
Geranyl acetate	<LOQ	<LOQ	<LOQ	<LOQ
Guaiol	<LOQ	<LOQ	<LOQ	<LOQ
Isoborneol	<LOQ	<LOQ	<LOQ	<LOQ
Isopulegol	<LOQ	<LOQ	<LOQ	<LOQ
Linalool	0.043	0.037	0.035	0.031
Menthol	<LOQ	<LOQ	<LOQ	<LOQ
Nerol	0.007	0.006	0.008	0.006
p-Cymene	<LOQ	<LOQ	<LOQ	<LOQ
Pulegone	<LOQ	<LOQ	<LOQ	<LOQ
Sabinene	<LOQ	<LOQ	<LOQ	<LOQ
Sabinene hydrate	<LOQ	<LOQ	<LOQ	<LOQ
Terpinolene	<LOQ	<LOQ	<LOQ	<LOQ
trans-Nerolidol	0.034	0.026	0.024	0.031
Valencene	0.041	0.040	0.034	0.038

Legend:

LOQ - Limit of Quantificaiton