THE EFFECTS OF REFLECTIVE PLASTICS ON FLOWER AND CANNABINOID YIELDS IN DAY-NEUTRAL *CANNABIS SATIVA* L. IN A GREENHOUSE ENVIRONMENT UNDER SUPPLEMENTAL LIGHT

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Master of Professional Studies in Controlled Environment Agriculture

by

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ABSTRACT

Many cannabis cultivators have been keen on the use of white or silver reflective plastic mulches for indoor cultivation. Many cultivators claim that it improves yields because of the increased amount of light caused by the reflectivity of the plastic. There has been a fair amount of research on other crops with reflective mulches but there is a lack of scientific research for cannabis. The objective of this study was to determine the effect of three types of plastic (black, white, and silver) on yield and cannabinoid concentration of day-neutral cannabis. The experiment was conducted in a glass greenhouse at Cornell University with supplemental high pressure sodium lights. There were three replicate blocks, each consisting of three plastic treatments and within each containing at least 3 replicate plants of the cultivar Dr. Chunk, 3 replicate plants of the cultivar Maverick, and at least 1 replicate plant of the cultivar Purple Star. The silver plastic treatment had the highest percentage of reflected supplemental light in the treatment sections. The black treatment sections had the highest average PAR in the treatment sections. There was no significant difference across any of the treatment sections for cannabinoid content percentages. The higher PAR average in the treatment sections may have contributed to the cultivars in those treatment sections being taller on average and having higher dry flower yields in the Maverick and Purple Star cultivars.

BIOGRAPHICAL SKETCH

Howard Rice is a student pursuing his Master of Professional Studies in Controlled Environment Agriculture at Cornell University. Howard grew up in Vernon Center New York. He attended SUNY Morrisville for his bachelor's degree in Horticulture & Business Management and graduated in 2016. He has spent ten years in the Horticulture industry gaining experience in many areas including organic fruit and vegetable production, aquaponics, hydroponics, floriculture, cut flower production, landscape maintenance, cannabis cultivation, and more. Howard is part owner of Vernon Farm & Market LLC. Vernon Farm & Market runs a community supported agriculture program and has a seasonal farm stand.

DEDICATION

This project is dedicated to everyone who has had an influence and has been a mentor in my horticulture career including Neil Mattson, Nicholas Kaczmar, Mike Kintgen, Michael Guidi, David Soucy, Kelly Hennigan, Eduardo Lozano and Mark Doherty.

ACKNOWLEDGMENTS

I would like to extend special thanks to Neil Mattson and Nicholas Kaczmar for helping guide and assist me by providing the information and resources necessary to complete my project.

I would also like to thank Jeffrey Persky for helping assist me in the greenhouses when I needed supplies or help with any tasks.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

PAR…………………………………………….………….Photosynthetically Active Radiation

HPS……………………………………………......................................High Pressure Sodium

EC………………………………………………………………............Electrical Conductivity

PH…………………………………………………………………………..Potential Hydrogen

HPLC…………………………………………………...High Pressure Liquid Chromatography

CBD………………………………………………………………………………Cannabidiol

THC…………………………………………………………………Tetrahydrocannabinol

APPFD……………………………………………...Average Photosynthetic Photon Flux Density

DLI…………………………………………………………………………….Daily Light Integral

INTRODUCTION

Cannabis (*Cannabis sativa* L.) cultivators have implemented many interesting techniques to grow cannabis for the duration of prohibition. One technique that has been commonplace amongst cannabis growers in recent years is the use of reflective plastic mulches in their growing spaces. Growers use these reflective plastic mulches in spaces like a closet, grow tent, grow room or other growing space. There are a few brands of white reflective mulch available to growers. A couple that are commonly used are "Extenday" and "Panda Film". Extenday is a reflective plastic that is typically used in the pomology and viticulture industries for improving fruit coloration in orchards and vineyards. Panda Film is more commonly used in the cannabis industry by growers who claim it reflects light back into the canopy leading to less lost light and increased yields. Panda film, also known as panda plastic, gets its unique name because it is white on one side and black on the other side. Depending on which side faces out, Panda film can be used for light reflection as well as light exclusion.

But is there a benefit to using reflective plastics? It seems there is a lot of anecdotal evidence surrounding panda film when it comes to yield increases. On Polysprout.com they claim that “High reflection rate (approx. 90%) to maximize growth and plant yield”. This is a website that sells Panda film as well as other reflective mulches. One vendor selling Panda film on amazon.com claims it is “designed to give you greater growth and increased *yield*”. Even on Wal-Mart.com they insinuate yield is increased by the reflective plastics they are selling. “Use plastic sheeting in hydroponics, the lighter your plants get, the more they yield. Hydro Film is double-sided with a black side for facing to the outside to block out all light, and a white side to face towards the plants to maximize the reflections.” With other crops reflective mulches have shown benefits, but there is no existing scientific data on cannabis and reflective plastic mulches to our knowledge.

Cannabis is a crop that has very high light needs, so any method that can be used to increase the amount of light getting to the canopy besides adding more lights could be extremely beneficial. In a recent publication, researchers at the University of Guelph looked at different daily light integrals and light intensities for growing cannabis Their research showed cannabis can thrive at high light levels. "The range of APPFD's (average photosynthetic photon flux density) that plants grew under in this trial was 135–1430 $\mu mol \cdot m^{-2} \cdot s^{-1}$. With a 12 hr photoperiod this corresponding to DLIs ranging from 7.8 to 82.4 $mol \cdot m^{-2} \cdot d^{-1}$. Notably, there were no signs of transplant shock or light stress, even in plants placed under the highest DLIs which were exposed to up to 7 times higher LI (light intensity) than in the propagation stage." (Moher et. al 2022). Even at the highest light intensities evaluated there were still linear increases in flower yield.

Greenhouse growers *could* line their greenhouse bench tops with reflective plastics. This may reflect more light back up to the cannabis canopy and could increase the rate of photosynthesis, growth, and yield since it will provide higher light levels. It could also mean that the efficiency of the supplemental lights used in the greenhouse would increase.

There has been much previous research on growing fruit and vegetable crops with plastic mulches. Growers have used many different colors of plastic mulch to achieve various desired results depending on the crop they are growing. In vineyards and orchards, the typical use for reflective mulch is to improve coloration of the fruit. There are many vineyards that use white reflective mulches. "Reflective mulches applications are also used for improving sunlight distribution of inner side of grapevine canopy, leading to an enhanced grape skin color" (Kok, 2022). White reflective mulches are also used in apple orchards to improve fruit color on apples.

Extenday is the typical reflective mulch that is used. Reflective mulches increased light that was reflected back into the canopy by as much as 5 times compared to bare ground (Petridis, 2021). Extenday reflective mulch was used in a kiwifruit orchard with beneficial effects on yield and average fruit weight (Grappadelli, 2003). In a study on using plastic mulches to grow pumpkins, reflective mulches increased overall yields especially in second and third plantings vs. black or no-mulch (Brust, 2000). The technique was reported to be a "cost-effective way of delaying virus problems and increasing pumpkin yields in midwestern United States." (Brust, 2000)

The objective of this experiment was to evaluate the use of reflective mulches for high cannabinoid production of low-THC hemp in a greenhouse. If reflective mulches significantly increase yield, then it could provide a way for greenhouse growers to produce their cannabis more efficiently. With rising energy costs and uncertainty surrounding prices in the cannabis industry this could be an economically viable solution to help maximize flower production.

MATERIALS & METHODS

This experiment was conducted on the Cornell campus in Ithaca, NY in the Guterman Greenhouse complex in greenhouse 165e. Three benches that were four foot wide and twenty-eight foot in length were used for the experiment. Centered above each bench were six 600-watt high pressure sodium lights that were 6 feet above the bench. Two reflective plastics were chosen for the experiment: chrome embossed vinyl manufactured by Ameri-Cal Corporation (having a silver color) and Panda film manufactured by Vivosun. A third treatment consisted of black plastic. Treatment one was chrome embossed reflective vinyl facing upwards on the bench top. Treatment 2 was the white side of the panda film facing upwards on the bench top. Treatment 3 was the black side of the panda film facing upwards on the bench top. Treatment sections were randomized so that each bench represented a block and had one section of chrome embossed vinyl, one section of black panda film and one section of white reflective panda film for a total of 9 sections. Each treatment section was 4 foot wide and 8 feet long. A gap of 18 inches was between each treatment on the bench tops. Seed was sourced from Phylos Bioscience. The three day-neutral CBD cannabis cultivars used for the experiment were ‘Dr. Chunk’, ‘Maverick’, and ‘Purple Star’. 35 seeds of each cultivar were started in 72 cell trays on January 20th, 2023 (day 1) and placed on a bench in Guterman Greenhouse 165e (e.g., **Figure 1-2**). Humidity domes were used to aid with germination (e.g., **Figure 3-4**). Ten days after sowing seed germination percentages were recorded, and the humidity domes were removed. ‘Maverick’ had a germination percentage of 94%, ‘Dr. Chunk’ had a germination percentage of 100%, and ‘Purple Star’ had a germination percentage of 37% (e.g., **Figure 5**). The two trays of seedlings were raised up on the bench so that the seedling canopy was three feet from the high-pressure sodium light and an oscillating fan was added to help prevent etiolation and improve stem rigidity (e.g., **Figure 6)**. On day 19 locations for the two-gallon pots were marked for each treatment section where the center of the two-gallon pots would be placed on the reflective plastics. This was conducted using a two-gallon pot, a measuring tape, and small pieces of duct tape to mark the position for all 81 pots on each treatment section (e.g., **Figure 7-8**). This ensured spacing would be the same for the 9 plants in each of the 9 sections. At each plant location an Apogee Quantum Sensor was used to determine Photosynthetically Active Radiation (PAR) during the night to determine supplemental light intensity. Readings were taken 20 inches above the bench top (e.g., **Figure 9**). On day 20, two-gallon pots were filled with Cornell soilless media mix and 35 ‘Dr. Chunk’, 34 ‘Maverick’, and 12 ‘Purple Star’ seedlings were transplanted into the two-gallon pots for a total of 81 plants (e.g., **Figure 10-12**). Plants were then placed out randomly onto the treatment sections on the benches so that each section received at least 3 Dr. Chunk plants, 3 'Maverick' plants, and 1 Purple Star plant (e.g., **Figure 13**). The number associated with each plant cultivar, the bench it's on, and the treatment each plant received can be found in table 1. All the plants received the same nutrient regimen for the duration of the experiment of Jacks 15-5-15 at a delivered using a 1:200 ratio injector and supplying 150 ppm of Nitrogen with a complete fertilizer (e.g., **Figure 14-15**). Plants were watered by hand for the duration of the experiment as needed. Holes were poked underneath each pot in in the plastics to allow for drainage in each of the sections. The high-pressure sodium (HPS) fixtures were on from 6am to 11:59pm daily (18 hr photoperiod).

Periodic measurements were taken to record light intensity reaching plant canopy that reflected from the plastic using the Apogee Quantum sensor. Readings were always taken at night when HPS fixtures were on at 20 inches above the benchtop on each side of the middle 3 plants in each treatment (e.g., **Figure 16-19**). The readings were taken facing upwards and downwards so that light reaching the canopy as well as light reflecting off the plastic back to the canopy could be recorded. The percentage of reflected light was calculated. Height was recorded throughout the duration of the experiment using a Milwaukee 25' tape measure (e.g., **Figure 20**). Height was recorded by measuring from the base of the stem (at the substrate line) to the tip of the apical meristem/inflorescence. Soil readings were taken throughout the experiment with a Bluelab soil probe that recorded soil moisture percentage, electrical conductivity (EC), and soil temperature (e.g., **Figure 21-22**). On day 54 and day 70 a Pour through test was conducted on select plants in the experiment to determine pH and electrical conductivity using a Bluelab pH and EC meter. On day 73 it was decided that plants were ready to be harvested. Flower samples were taken from the apical meristem of one representative plant from each cultivar for each of the 9 treatment sections. The 27 samples were weighed and placed in paper bags to dry until ready to be sent for HPLC analysis (e.g., **Figure 23**). On day 73 plants were harvested by cutting one centimeter above the base of the stem and total wet biomass was recorded for each plant using a Mettler PM 30,000-K scale (e.g., **Figure 24**). Plants were then hung on wires above the benches in greenhouse 165e to dry (e.g., **Figure 25**) for 10 days. On day 83 dry sample weights for HPLC analysis were recorded with the Mettler PM 30,000-K scale. Then samples were ground using a coffee grinder (e.g., **Figure 26**). Samples for HPLC analysis were prepared using the ground flower and a Mettler Toledo precision weight scale (e.g., **Figure 27**). Samples ranging from 0.05-0.058 grams were placed in tubes and sent to the lab for analysis (e.g., **Figure 28**). On day 83 the plants hanging in greenhouse 165e were determined to be dry after performing the “snap” test on the stems of the plants. Stems were able to be bent and easily snapped, indicating that it was time to collect the dry floral biomass weight. Floral biomass was stripped or sometimes referred to as “bucked” off the plants by hand into a tray on the Mettler PM 30,000-K scale to get the total dry flower weights (e.g., **Figure 29**). At the end of the experiment final PAR readings were recorded at each plant location (e.g., **Figure 33**). Then a final PAR map was made by using the PAR average from the initial PAR readings and final PAR readings.

EXPERIMENTAL LAYOUT

The numbers in Figure 31 represent plants and their locations in the treatments on the benches. Each bench represented one block and had each of the three treatments, each with 9 plants. Plant spacing remained uniform across all treatments and is laid out in figure 31. The “X’s” in figure 31 represent the CBD cannabis plants. There were 9 plants in each section for a total of 81 plants.

Table 1 lists what number was associated with each plant cultivar, the treatment it received, and the bench number it was on.

SCHEDULE & TIMELINE

Day: 1 (1/20/23) Seeds were sown.	Day 10 Germination percentage recorded. Plants moved closer to lights and fan added.	Day 12 Moved seedlings closer to light.	Day 19 Initial light readings collected at each plant location.
Day 20 Seedlings transplanted into 2-gallon pots and placed randomly into treatment sections.	Day 21 Initial height measurements collected.	Day 28 2^{nd} height measurement collected.	Day 33 Initial PAR readings done on plants in the middle of the treatment sections. Initial soil readings collected.
Day 35	Day 39	Day 42	Day 44

3rd height measurement was collected	2nd set of soil readings was collected.	4th height measurements were collected.	2nd set of PAR readings was taken on plants in middle of treatment sections.
Day 47 3rd set of PAR readings were collected.	Day 49: 3rd set of soil readings. 5th set of height measurements were taken.	Day 54: 1st pour through test was taken.	Day 56: Final height measurements were taken.
Day 57: 4th set of PAR readings were taken.	Day 61: 5th set of PAR readings were collected. 4th set of soil readings were taken.	Day 69: 6th and final set of PAR readings collected on the plants in middle of the treatment sections.	Day 70: 2nd pour through test was taken. 5th and final set of soil readings were taken.
Day 73: Flower samples were weighed and taken for later HPLC analysis. Plants were harvested and wet	Day 83: Samples for HPLC analysis were weighed, ground, prepared, and sent to lab for analysis. Dry plants were stripped	Day: 89 Final PAR was recorded for each plant location.	Day: 90 Greenhouse cleaned out.

total biomass was recorded.	of floral biomass and dry floral biomass weight was recorded.		

RESULTS

The experiment yielded a few interesting data sets that can be observed. PAR maps that were made from the initial light readings and final readings can be found in figure 32. Black plastic treatments had the highest average PAR levels at 194.7 µmol m^{-2} s^{-1} (figure 32). The silver treatment had the second highest PAR average at 183.9 µmol m^{-2} s^{-1} and the white had the lowest average PAR at 180.2 µmol m^{-2} s^{-1}. From the PAR readings that were taken during the experiment between plants with the light sensor facing upwards a light map can be found in figure 33. PAR averages were very similar with the black PAR average coming in at the highest with a PAR average of 136.5 µmol m^{-2} s^{-1} (figure 33) The silver treatment PAR average was second at 136.4 µmol m^{-2} s^{-1} and the white treatment had the lowest PAR average at 135.7 µmol m^{-2} s^{-1}. The light readings that were taken facing downwards during the experiment to those PAR readings can be found in figure 34. The silver treatment had the highest reflected PAR average at 27.4 µmol m^{-2} s^{-1} followed by the white treatment at an average of 23.1 µmol m^{-2} s^{-1} and then lastly the black treatment with a reflected PAR average of 8 µmol m^{-2} s^{-1}. The percent of light that was reflected was calculated using the averages from figure 33 and figure 34. This showed that the silver treatment had the highest average reflected light at a percentage of 21%. The white treatment had the second highest reflection rate at 17% and the black treatment had the least amount of reflected light at 6%.

For the average wet biomass weights for the different treatments black had the highest average wet biomass weight at 411 grams, silver was second at 314 grams and white was third at 308 grams (e.g., **Figure 36d**). For the average dry flower yields the black treatment was the highest at 81 grams, silver was second at 64 grams and white was third at 63 grams (e.g., **Figure 36**).

Soil temperatures were similar during the experiment with the silver treatment having the highest average soil temperature at 26.5 °C, black was second at 26.3 °C and the white average soil temperature being the lowest at 26 °C (e.g., **Figure 36h**). There was no significant difference in soil temperature across the different treatments. Average EC across the experiment was similar with silver having the highest average EC at 2.03 followed by the white treatment at 2.02 and then lastly the black treatment had the lowest average EC at 1.84 (e.g., **Figure 36g**). There was no significant difference across the treatments for EC.

Figure 35 shows the results from the HPLC analysis of the samples. Sample HR-26 was excluded from the data analysis because it is believed that it was an inaccurate reading. There was no significant difference across treatments in any of the cannabinoids or cannabinoid ratios. Numerically, total potential cannabinoid percentages showed that the highest average CBD percent was achieved in the silver treatment at 7.19% followed by the black treatment at 6.95% CBD, and the white had the lowest average CBD levels at 6.32%. Total THC%, CBC %, CBG%, and CBDV % averages across the treatments were all very similar (e.g., **Figure 36f**).

For height, there was a significant difference for 'Maverick' between black and silver treatments with black being the tallest at harvest (**Figure 36c**). For whole plant fresh weight at harvest there was a significant difference for the black treatment compared to the white and silver treatments in the ‘Maverick’ cultivar being that black whole plant fresh weights were much higher than white and silver for the ‘Maverick’ cultivar (e.g., **Figure 36d**). For floral dry weight there was a significant difference in the black treatment for the Maverick cultivar compared to the white and silver treatments (e.g., **Figure 36**).

There was a significant difference across each treatment for the percent of light that is reflected (e.g., **Figure 36a**). For percentage of light reflected on bench 1 there was not a significant difference between the white and silver treatments but there was a significant difference from white and silver over the black treatment where white and silver both reflected a much higher percentage of light than black. For bench 2 in the silver treatment there was a significant difference over the white and black treatment for percent of light reflected. Interestingly there was no significant difference between black and white percentage of light reflected on bench 2. On bench 3 there was a significant difference of white and silver over the black treatment. There was no significant difference for percent light reflected between the white and silver treatments on bench 3 (e.g., **Figure 36b**).

DISCUSSION

Both the white and silver plastic treatments had much higher percentages of reflected light (e.g., **Figure 36a**). Although treatment section was randomized for each block, PAR in the black treatment sections was higher than white or silver which may be why the black treatment sections had higher yields (e.g., **Figure 32**). The correlation with light intensity and yield seemed to be positive, which confirms the findings from researchers at the University of Guelph (Moher, 2022). The white plastic did not seem to have yield benefits over the black or silver plastic. This was contrary to what I found for a few studies where white reflective plastic had positive benefits on kiwi fruit yield (Grappadelli, 2003) and pumpkin yields (Brust, 2000).

There could be many different factors influencing results of this experiment. During the experiment it was observed that several of the 'Maverick' cultivars didn't appear to be true to type. They exhibited different characteristics than most of the other 'Maverick' cultivars such as taller and with smaller flower buds. The 'Dr. Chunk' and 'Purple Star' cultivars were observed as being very uniform in their growth habit and I would deem them as being "true to type". The 'Purple Star' cultivar had a poor germination percentage which led to the 'Purple Star' cultivar having less replicates for the treatment sections. The Black treatments happened to have the highest PAR levels from the HPS lights during the experiment. This could have influenced the higher yields and heights of the cultivars in those treatment sections. Although the PAR average in the black treatments was only 10 µmol m^{-2} s^{-1} higher than the white treatment sections which had the lowest PAR average. Another factor to be considered is if there would be different effects from the plastic treatments during different times of the year. Since this experiment was started in late Winter and run until early Spring in a greenhouse the varying light levels and temperature fluctuations in the greenhouse throughout the seasons could help exhibit different effects in the treatment sections.

CONCLUSION

Based on this experiment there may be positive effects from using plastic mulches on greenhouse bench tops for growing cannabis under artificial light. While the white and silver reflective plastics led to a greater percentage of reflected light back to the canopy than the black plastic, they did not result in significant benefits for growth, flower yield, or cannabinoid concentration. The black plastic treatment had the highest flower yield, but this might also be due to the treatment locations happening to be located in areas with greater supplemental light intensity. Reflective plastics did not influence cannabinoid concentration. More research should be done in this area to further determine the impact of reflective plastics in cannabis.

TABLE: 1

1	Dr. Chunk	silver	28	Maverick	white	55	Maverick	black
2	Maverick	silver	29	Dr. Chunk	white	56	Purple Star	black
3	Purple Star	silver	30	Maverick	white	57	Maverick	black
4	Dr. Chunk	silver	31	Maverick	white	58	Maverick	black
5	Maverick	silver	32	Dr. Chunk	white	59	Dr. Chunk	black
6	Dr. Chunk	silver	33	Purple Star	white	60	Purple Star	black
7	Dr. Chunk	silver	34	Dr. Chunk	white	61	Dr. Chunk	black
8	Purple Star	silver	35	Maverick	white	62	Dr. Chunk	black
9	Maverick	Silver	36	Dr. Chunk	white	63	Maverick	black
10	Maverick	white	37	Purple Star	black	64	Maverick	silver
11	Dr. Chunk	white	38	Dr. Chunk	black	65	Dr. Chunk	silver
12	Dr. Chunk	white	39	Maverick	black	66	Maverick	silver
13	Dr. Chunk	white	40	Dr. Chunk	black	67	Dr. Chunk	silver
14	Purple Star	white	41	Purple Star	black	68	Maverick	silver
15	Maverick	white	42	Dr. Chunk	black	69	Maverick	silver
16	Dr. Chunk	white	43	Maverick	black	70	Purple Star	silver
17	Maverick	white	44	Maverick	black	71	Dr. Chunk	silver
18	Maverick	white	45	Dr. Chunk	black	72	Dr. Chunk	silver
19	Purple Star	black	46	Maverick	silver	73	Dr. Chunk	white
20	Maverick	black	47	Dr. Chunk	silver	74	Dr. Chunk	white
21	Dr. Chunk	black	48	Dr. Chunk	silver	75	Maverick	white
22	Maverick	black	49	Purple Star	silver	76	Maverick	white
23	Maverick	black	50	Dr. Chunk	silver	77	Maverick	white
24	Maverick	black	51	Dr. Chunk	silver	78	Dr. Chunk	white
25	Dr. Chunk	black	52	Maverick	silver	79	Purple Star	white
26	Dr. Chunk	black	53	Maverick	Silver	80	Maverick	white
27	Dr. Chunk	black	54	Maverick	silver	81	Dr. Chunk	white

Bench: 1 **Bench: 2** **Bench: 3**

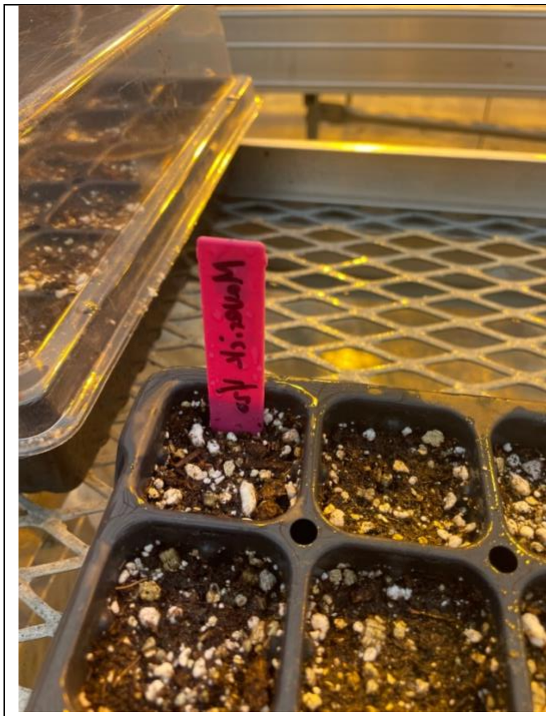


Figure: 1 Maverick seed tray.

Figure: 2 Purple Star seed tray.

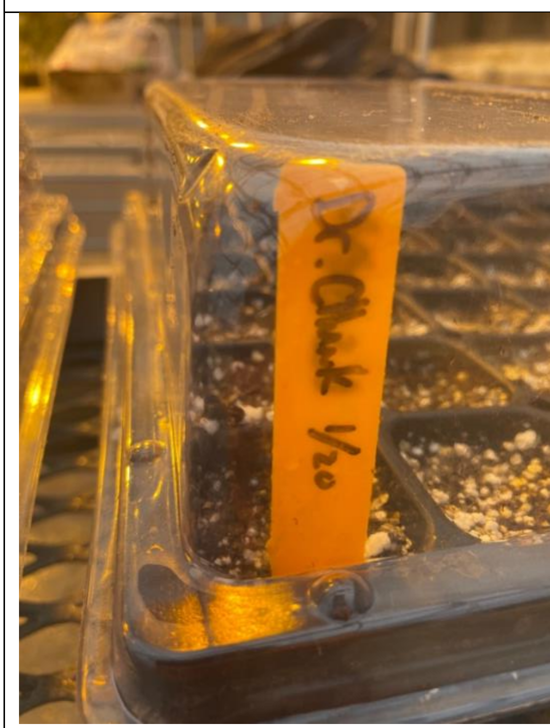


Figure: 3 Dr. Chunk seed tray with humidity dome.

Figure: 4 Humidity domes to help with germination.

 Figure: 5 Maverick seedlings germinating.	 Figure: 6 Seedlings raised up to be closer to HPS light source.

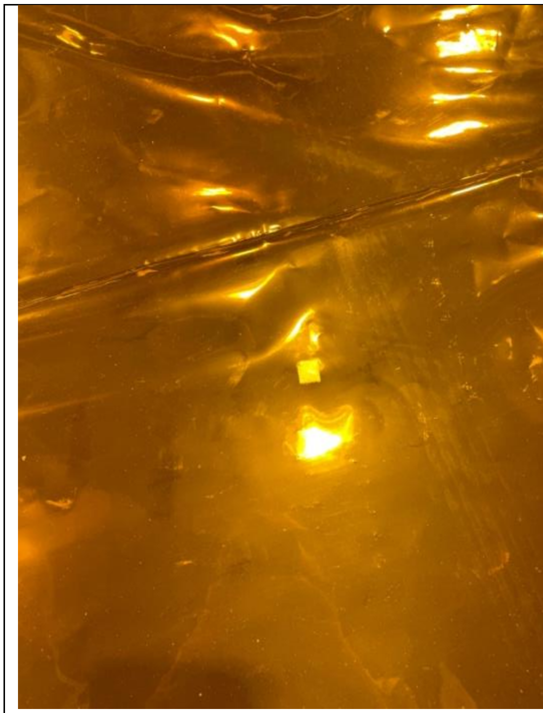


Figure: 7 Silver embossed vinyl with tape marking plant locations.

Figure: 8 White side of Panda Film with tape marking plant locations.

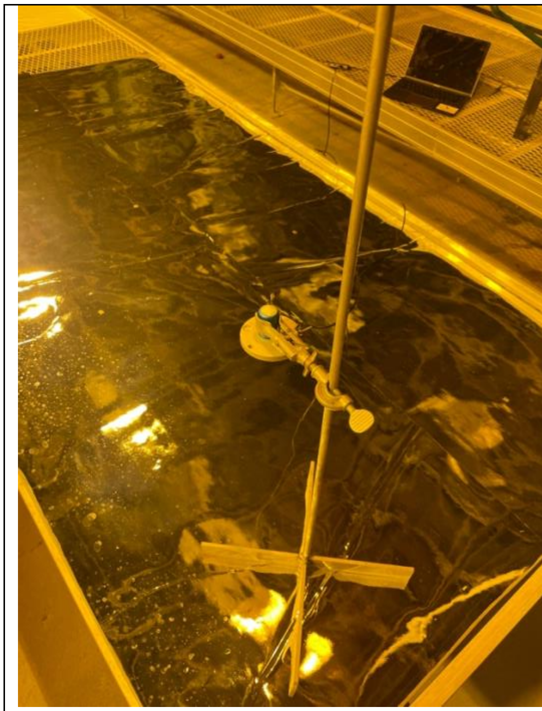


Figure: 9 PAR meter getting light readings from where plants will be placed

Figure: 10 Seedlings just before transplanting into 2 gallon pots.

Figure: 11 Transplanting seedlings.

Figure: 12 Transplanted seedlings.

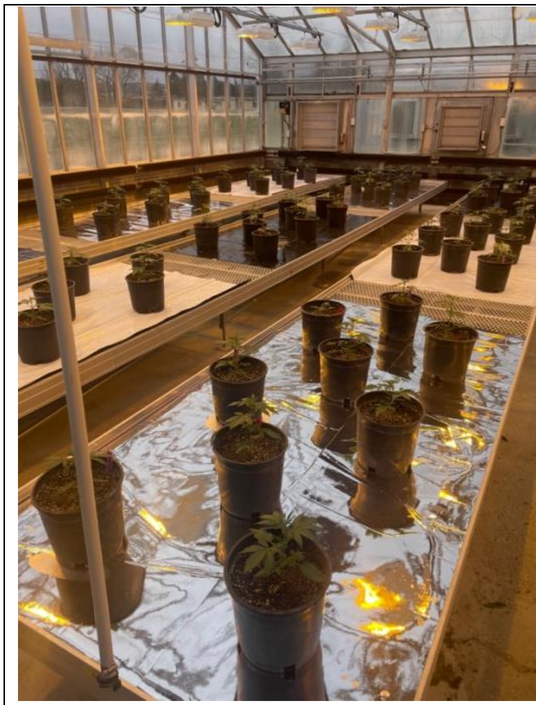


Figure: 13 Plants placed randomly into treatment sections.

Figure: 14 Dosatron injection ratio.

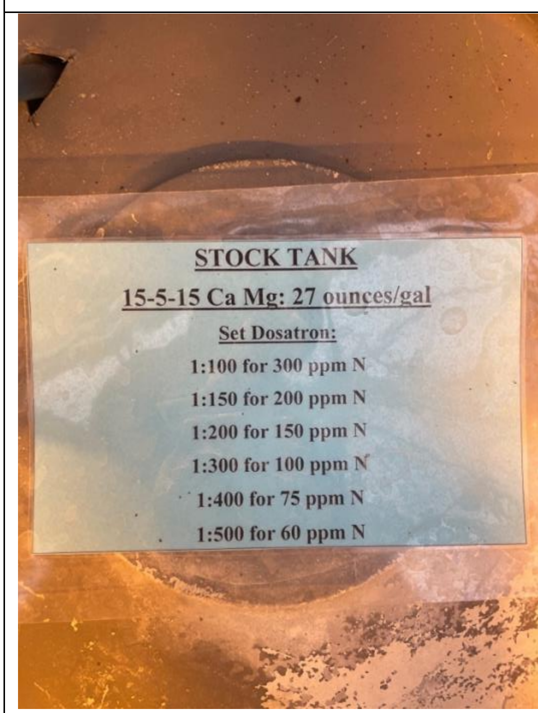


Figure: 15 Fertilizer solution used.

Figure: 16 Getting reflective light readings.

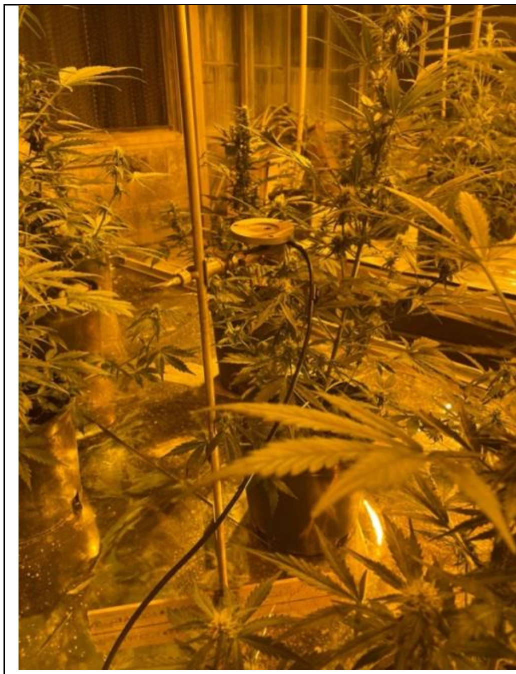
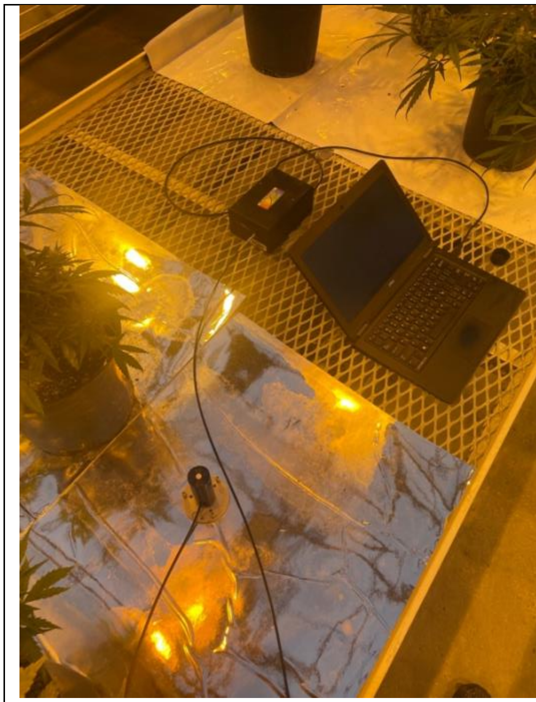


Figure: 17 Getting reflective light readings.

Figure: 18 Getting reflective light readings.

 Figure: 19 Getting spectroradiometer readings.	 Figure: 20 Tape measure used to record plant height during the experiment.

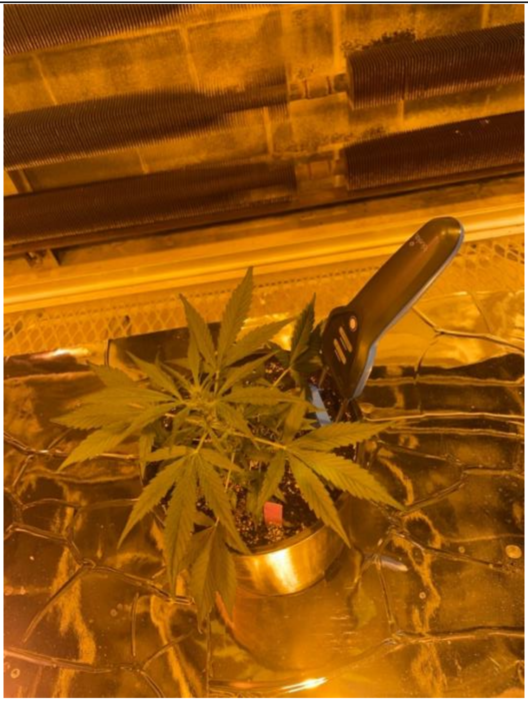


Figure: 21 Getting EC, soil moisture and soil temperature readings.

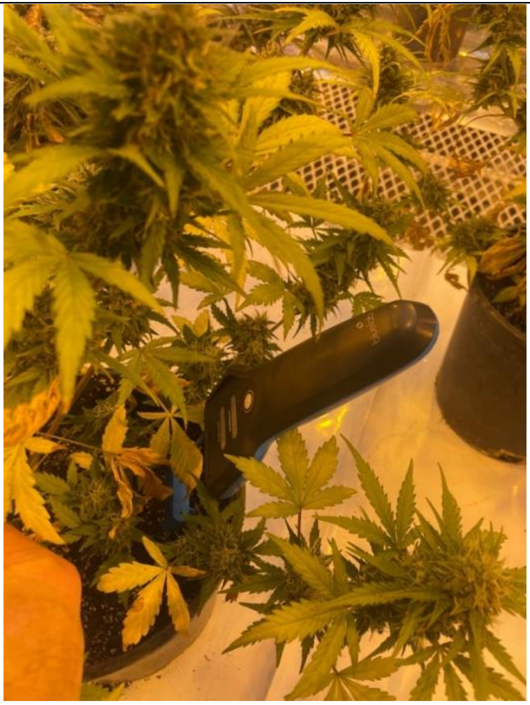


Figure: 22 Getting EC, soil moisture and soil temperature readings.

Figure: 23 Weighing wet samples for HPLC analysis.

Figure: 24 Weighing total wet biomass.

Figure: 25 Hanging plants to dry in greenhouse

Figure: 26 Coffee grinder used for dry HPLC samples.

Figure 27 Scale used for HPLC samples.

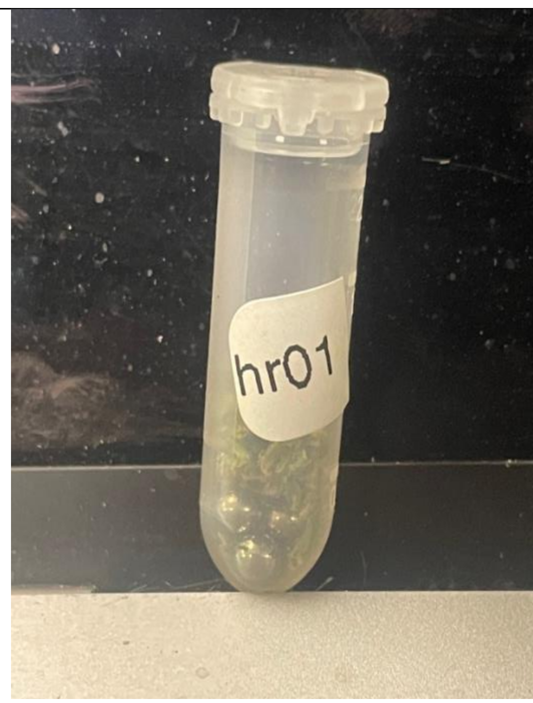
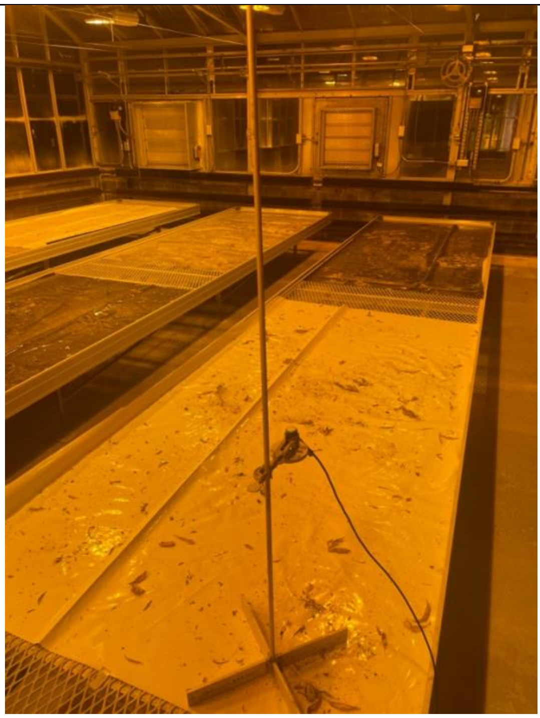


Figure: 28 Vial for HPLC samples.

 Figure: 29 Bucking dry flowers off stems to get dry floral biomass weights.	 Figure: 30 Getting PAR readings at the end of the experiment from each plant location.

Door ← Aisle **Figure: 31** Aisle Wall →

1 2 3 4. 5 6 7 8 9	28 29 30 31. 32. 33 34 35 36	55 56 57 58 59 60 61 62 63
10 11 12 13 14 15 16 17 18	37 38 39 40. 41 42 43 44 45	64 65 66 67 68 69 70 71 72
19 20 21 22 23 24 25. 26 27	46 47 48 49 50 51 52 53 54	73 74 75 76 77 78 79 80 81
Bench:1	**Bench: 2**	**Bench: 3**

Figure 32: PAR map made from each plant location.

P.A.R. Map	Made From	Intial and	Final P.A.R.	Readings						
	Bench 1				Bench 2				Bench 3	
	Silver				White				Black	
122	157.5	146.5		168.5	197	168		142	150	119
170	173.5	170		213	220.5	212		180.5	171.5	150.5
187.5	184.5	186.5		232	234	233		201.5	186	167
	White				Black				Silver	
178.5	190.5	213.5		252	245	247		211.5	194.5	177.5
182.5	196.5	210.5		251.5	225.5	243		210.5	192	176.5
182	184.5	211.5		250	231	241		211.5	180.5	178.5
	Black				Silver				White	
185.5	192	215		226	201.5	211.5		178.5	154.5	146.5
173.5	182.5	199.5		211	182.5	196.5		156	132	130
147.5	133.5	174		183.5	149	173		131	102.5	109

Figure 33: PAR map made from regular readings facing upwards during experiment.

P.A.R. Map	made from	P.A.R. readings	facing up L & R				
Bench 1			Bench 2			Bench 3	
Silver			White			Black	
113	102		122	143		80	108
124	119		203	208		171	172
190	185		171	151		177	74
White			Black			Silver	
116	150		145	139		173	196
90	105		194	190		110	76
160	149		182	136		112	164
Black			Silver			White	
147	140		125	115		98	149
110	98		142	98		129	139
95	99		156	155		80	80

Figure 34: PAR map made from reflected light readings during experiment.

P.A.R. Map	made from	P.A.R. readings	facing down	L & R	(reflected light)		
Bench 1			Bench 2			Bench 3	
Silver			White			Black	
11	16		19	23		5	5
25	26		24	29		7	6
32	48		31	32		11	7
White			Black			Silver	
24	30		10	11		38	26
16	18		11	10		28	24
25	21		13	12		36	27
Black			Silver			White	
8	8		29	29		23	22
5	5		27	20		24	26
5	6		31	21		13	16

Figure 35: HPLC analysis results

05/05/2023 analysis - Samples HR1 – HR28					Cannabinoids in % (w/w)															Total potential in % (w/w)						
Sample Number	Cultivar	Treatment	Plot #	Bench	THCA	CBDA	CBCA	CBGA	THCVA	CBDVA	CBGVA	THCd9	THCd8	CBD	CBC	CBG	THCV	CBDV	CBN	THC	CBD	CBC	CBG	THCV	CBDV	CBGV
HR-1	Maverick	silver	53	2	0.48	11.84	1.03	0.27	0.00	0.06	0.00	0.04	0.00	0.30	0.03	0.09	0.00	0.00	0.00	0.46	10.69	0.93	0.33	0.00	0.05	0.00
HR-2	Purple Star	black	37	2	0.22	5.36	0.22	0.09	0.00	0.03	0.00	0.02	0.00	0.17	0.01	0.02	0.00	0.00	0.00	0.21	4.87	0.21	0.10	0.00	0.03	0.00
HR-3	Dr. Chunk	silver	65	3	0.41	9.60	0.42	0.50	0.00	0.04	0.00	0.02	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.38	8.60	0.37	0.44	0.00	0.04	0.00
HR-4	Maverick	black	44	2	0.43	10.51	0.59	0.44	0.00	0.09	0.00	0.05	0.00	0.37	0.04	0.11	0.00	0.00	0.00	0.43	9.58	0.56	0.49	0.00	0.08	0.00
HR-5	Dr. Chunk	silver	47	2	0.39	8.03	0.40	0.53	0.00	0.04	0.00	0.02	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.36	7.22	0.35	0.47	0.00	0.03	0.00
HR-6	Dr. Chunk	black	38	2	0.29	6.30	0.36	0.40	0.00	0.03	0.00	0.02	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.27	5.67	0.31	0.35	0.00	0.03	0.00
HR-7	Purple Star	silver	49	2	0.28	5.28	0.24	0.16	0.00	0.03	0.00	0.03	0.00	0.22	0.02	0.04	0.00	0.00	0.00	0.27	4.85	0.23	0.18	0.00	0.03	0.00
HR-8	Maverick	white	28	2	0.30	7.52	0.66	0.48	0.00	0.05	0.00	0.02	0.01	0.12	0.01	0.00	0.00	0.00	0.00	0.28	6.72	0.59	0.42	0.00	0.04	0.00
HR-9	Maverick	silver	68	3	0.31	7.26	0.43	0.83	0.00	0.04	0.00	0.02	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.29	6.55	0.38	0.73	0.00	0.04	0.00
HR-10	Purple Star	black	56	3	0.34	7.08	0.35	0.31	0.00	0.04	0.00	0.02	0.00	0.20	0.00	0.05	0.00	0.00	0.00	0.32	6.41	0.31	0.32	0.00	0.04	0.00
HR-11	Maverick	black	55	3	0.29	7.13	0.79	0.75	0.00	0.03	0.00	0.04	0.00	0.26	0.06	0.00	0.00	0.00	0.00	0.29	6.52	0.76	0.66	0.00	0.03	0.00
HR-12	Dr. Chunk	white	74	3	0.38	8.18	0.51	0.90	0.00	0.06	0.00	0.02	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.35	7.39	0.45	0.79	0.00	0.06	0.00
HR-13	Maverick	silver	2	1	0.32	7.43	0.33	0.63	0.00	0.02	0.00	0.03	0.00	0.34	0.03	0.00	0.00	0.00	0.00	0.31	6.86	0.32	0.55	0.00	0.02	0.00
HR-14	Dr. Chunk	silver	1	1	0.35	7.58	0.53	0.70	0.00	0.05	0.00	0.01	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.32	6.77	0.46	0.61	0.00	0.04	0.00
HR-15	Maverick	white	75	3	0.27	6.78	0.31	0.25	0.00	0.03	0.00	0.04	0.00	0.33	0.03	0.10	0.00	0.01	0.00	0.28	6.28	0.30	0.32	0.00	0.03	0.00
HR-16	Maverick	silver	64	3	0.28	6.60	0.33	0.30	0.00	0.03	0.00	0.02	0.00	0.23	0.02	0.05	0.00	0.01	0.00	0.27	6.02	0.30	0.31	0.00	0.03	0.00
HR-17	Maverick	white	10	1	0.36	8.45	0.95	1.00	0.00	0.04	0.00	0.03	0.00	0.29	0.04	0.00	0.00	0.01	0.00	0.35	7.70	0.88	0.88	0.00	0.04	0.00
HR-18	Dr. Chunk	black	26	1	0.46	9.76	0.46	0.74	0.00	0.04	0.00	0.03	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.43	8.78	0.41	0.65	0.00	0.04	0.00
HR-19	Dr. Chunk	white	11	1	0.43	9.53	0.56	0.73	0.00	0.06	0.00	0.02	0.00	0.19	0.01	0.00	0.00	0.00	0.00	0.39	8.55	0.51	0.64	0.00	0.05	0.00
HR-20	Maverick	black	20	1	0.32	7.47	0.50	0.85	0.00	0.03	0.00	0.02	0.00	0.15	0.02	0.00	0.00	0.00	0.00	0.30	6.70	0.45	0.74	0.00	0.03	0.00
HR-21	Maverick	white	30	2	0.28	6.91	0.32	0.15	0.00	0.01	0.00	0.02	0.01	0.21	0.00	0.04	0.00	0.00	0.00	0.27	6.27	0.28	0.17	0.00	0.01	0.00
HR-22	Dr. Chunk	white	29	2	0.33	6.95	0.36	0.57	0.00	0.03	0.00	0.02	0.00	0.27	0.02	0.00	0.00	0.00	0.00	0.32	6.37	0.33	0.50	0.00	0.03	0.00
HR-23	Purple Star	white	79	3	0.27	5.47	0.24	0.21	0.00	0.02	0.00	0.04	0.00	0.37	0.02	0.06	0.00	0.00	0.00	0.27	5.17	0.23	0.25	0.00	0.02	0.00
HR-24	Purple Star	white	14	1	0.21	4.94	0.20	0.13	0.00	0.03	0.00	0.01	0.00	0.15	0.01	0.03	0.00	0.00	0.00	0.20	4.49	0.19	0.15	0.00	0.02	0.00
HR-25	Purple Star	black	19	1	0.32	7.02	0.29	0.39	0.00	0.04	0.00	0.04	0.00	0.24	0.02	0.00	0.00	0.00	0.00	0.32	6.40	0.28	0.34	0.00	0.03	0.00
HR-26	Purple Star	silver	8	1	0.03	0.54	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.01	0.00	0.00	0.00	0.03	0.50	0.04	0.01	0.00	0.00	0.00
HR-27	Dr. Chunk	black	62	3	0.40	8.45	0.41	0.61	0.00	0.09	0.00	0.02	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.37	7.59	0.36	0.54	0.00	0.08	0.00
HR-28	Purple Star	white	33	2	0.20	4.67	0.20	0.00	0.00	0.02	0.00	0.01	0.00	0.19	0.01	0.00	0.00	0.00	0.00	0.19	4.29	0.19	0.00	0.00	0.02	0.00

Figure 36: Dry floral weights for each cultivar in the different treatment sections.

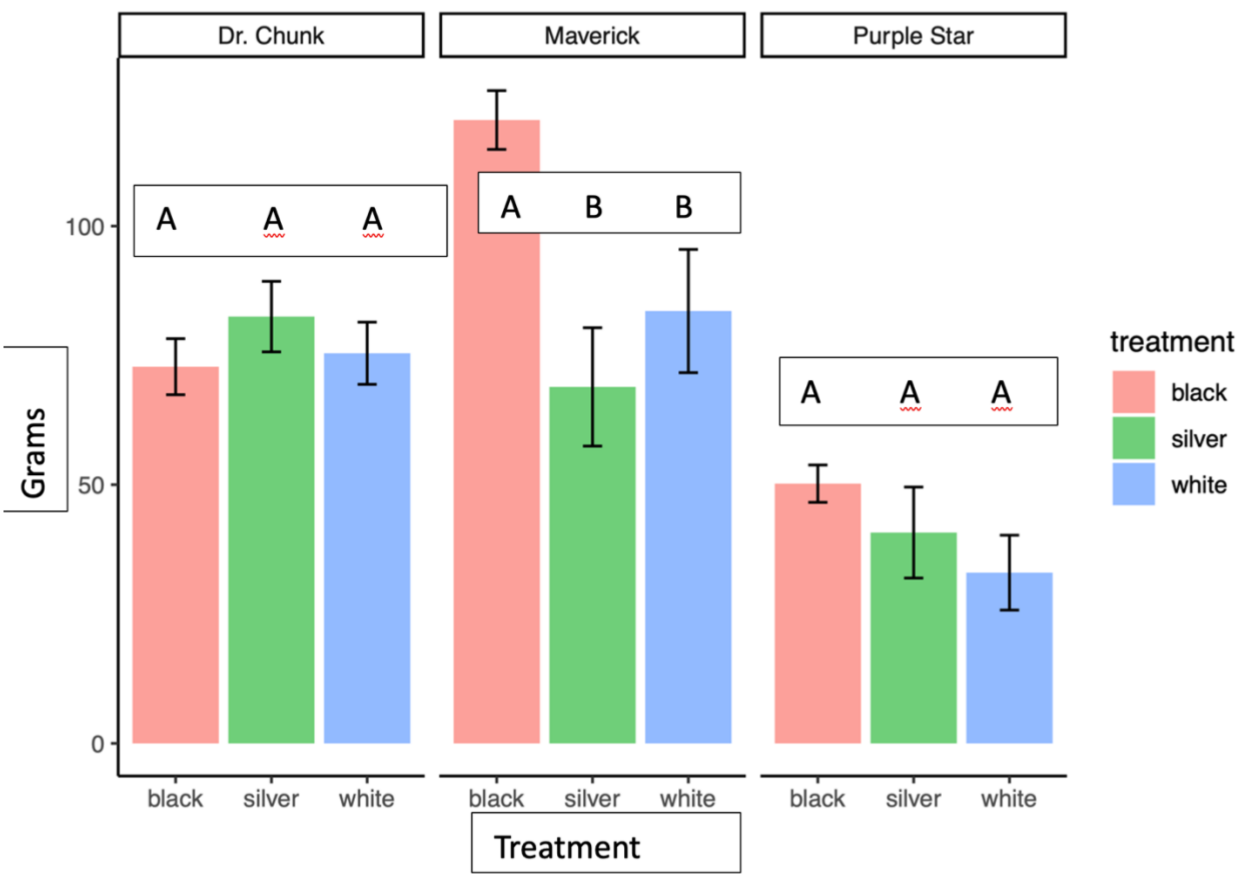


Figure 36a: Percent light reflectance for each treatment section.

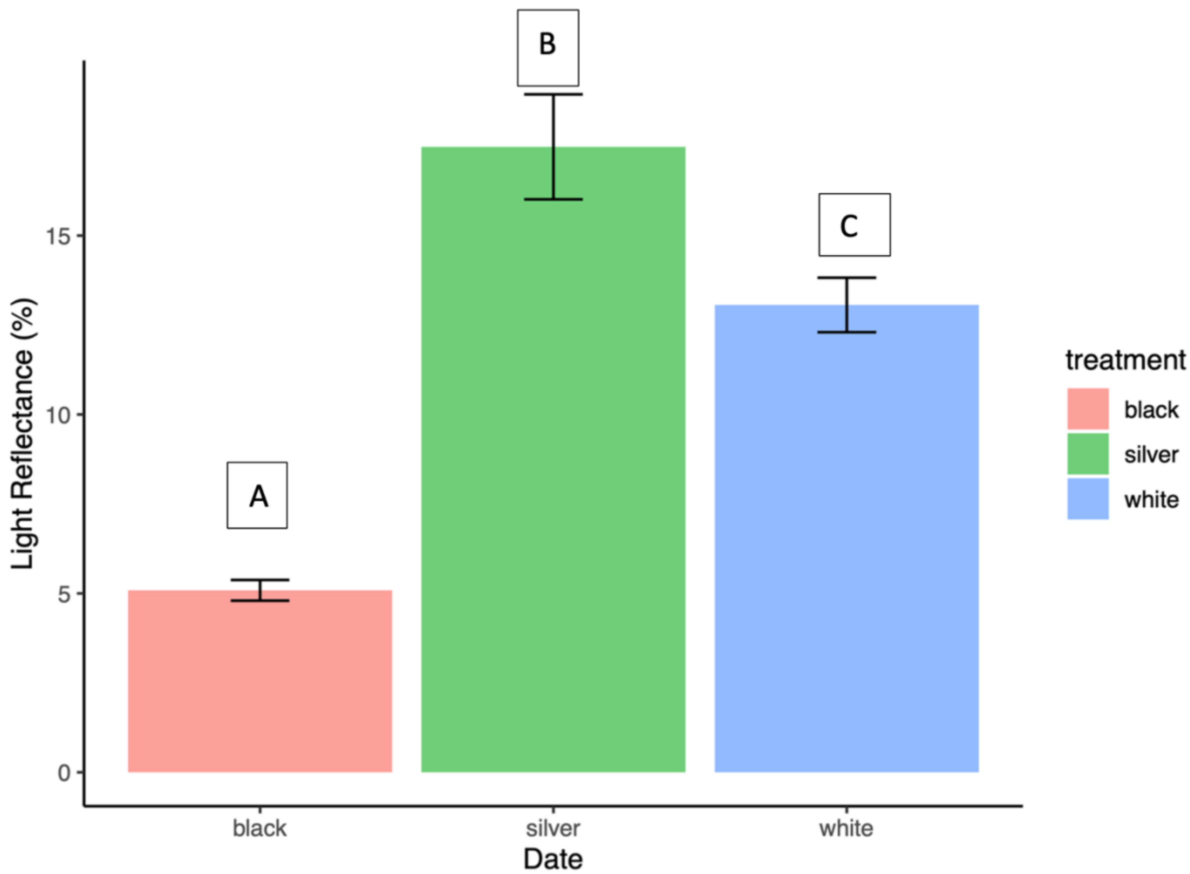


Figure 36b: % light reflected in each treatment section on each bench.

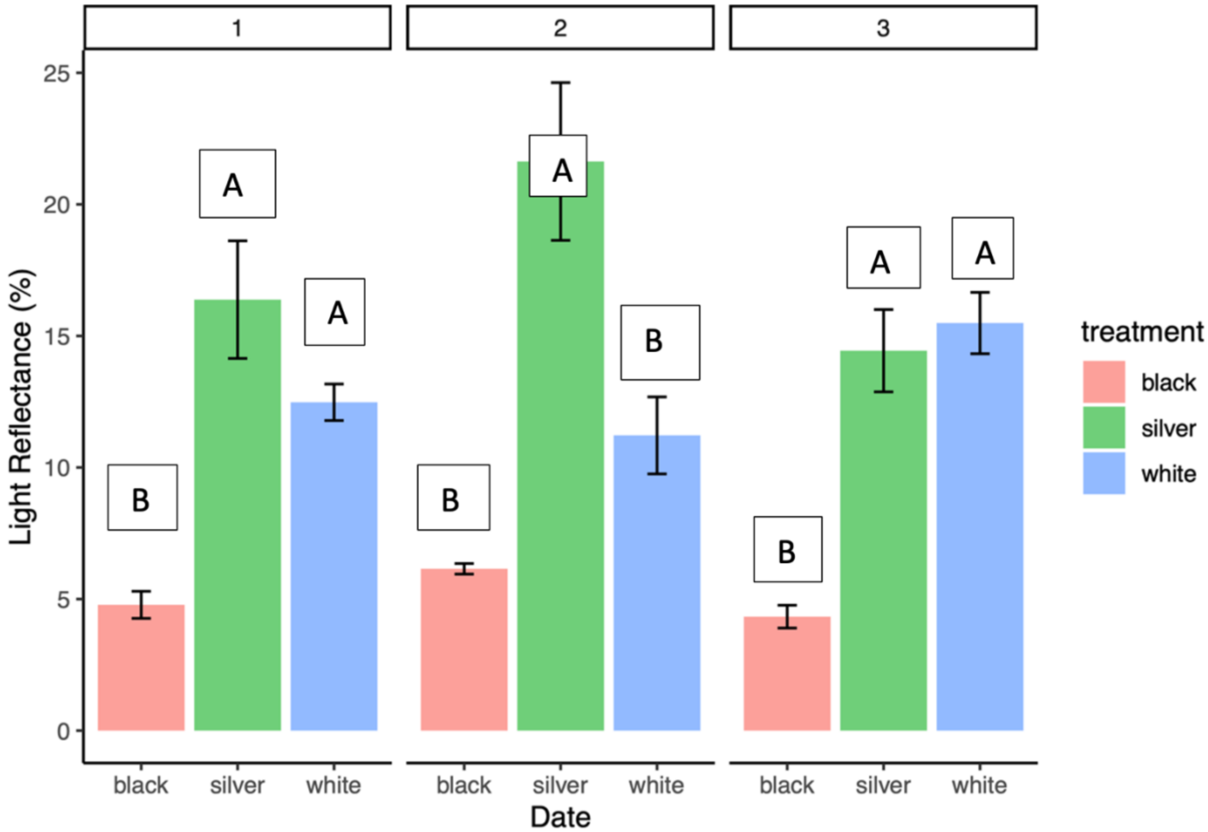


Figure 36c: average cultivar height at harvest by treatment.

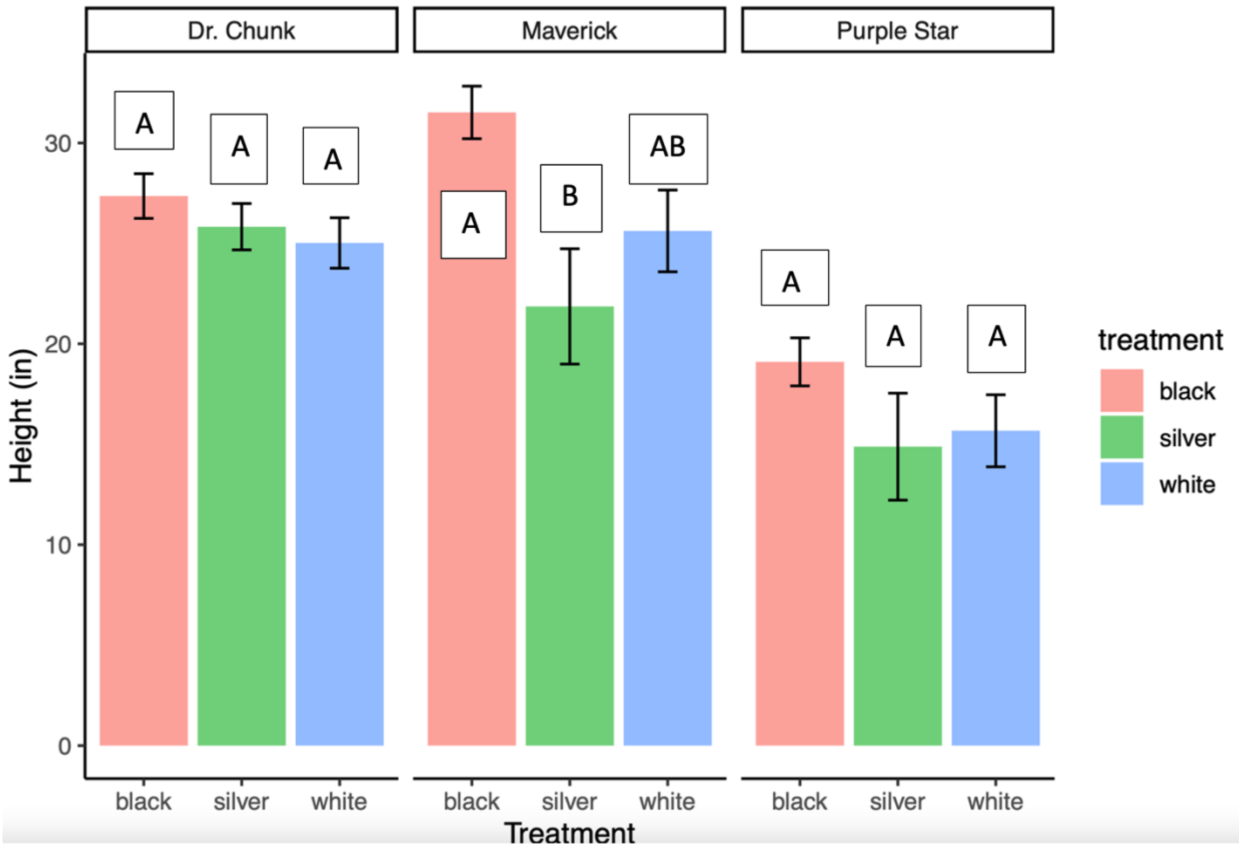


Figure 36d: Wet total plant biomass at harvest for cultivar and treatment sections.

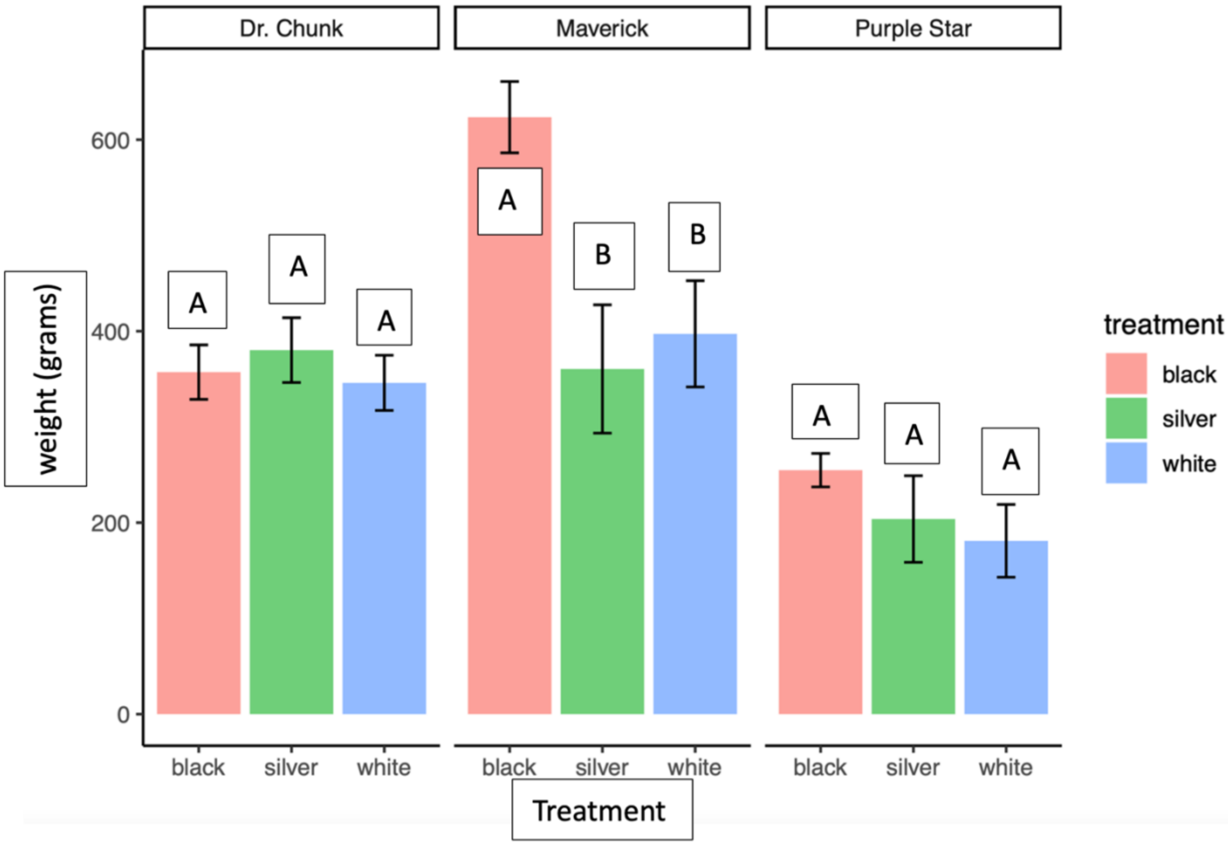


Figure 36e: Total CBD percentages in each treatment section.

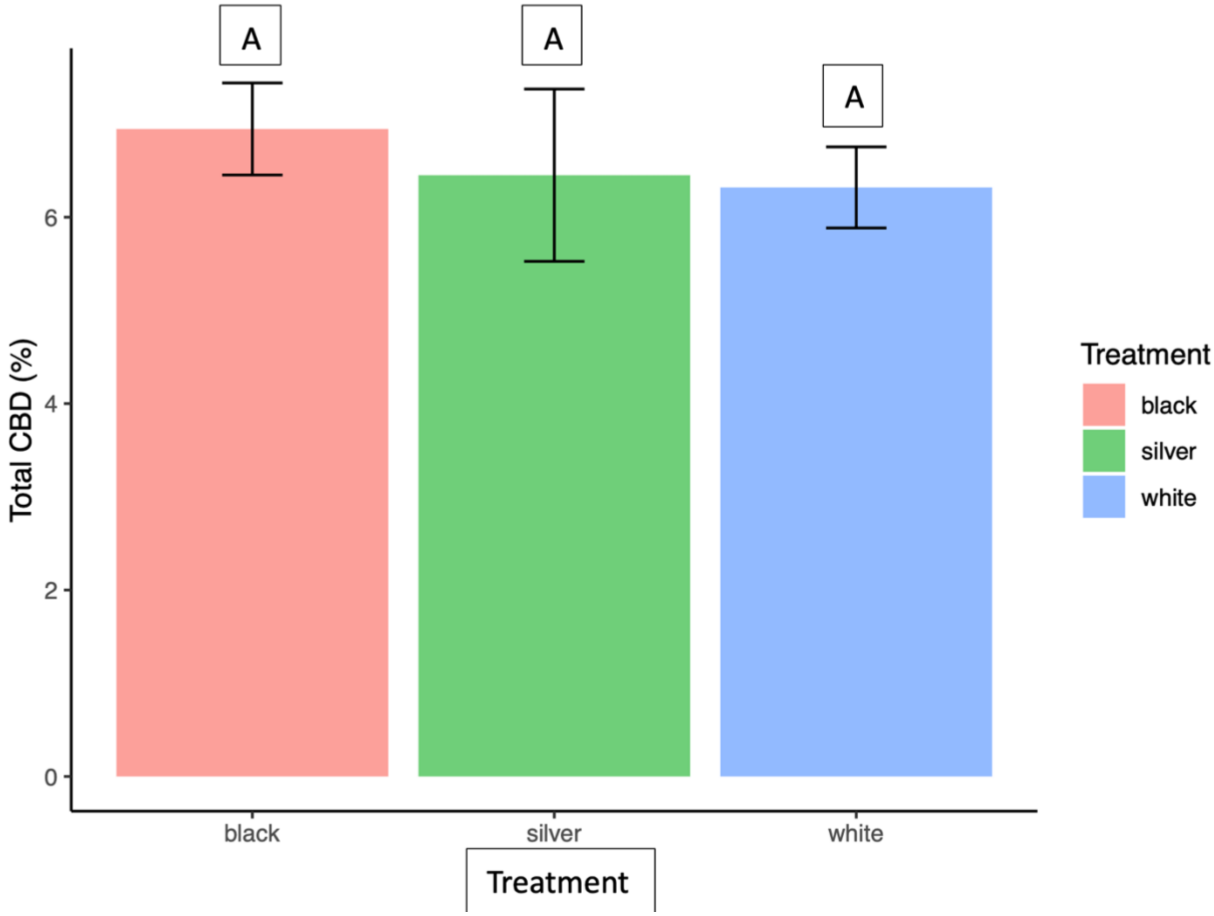


Figure 36f: Total cannabinoid percentages in each treatment section.

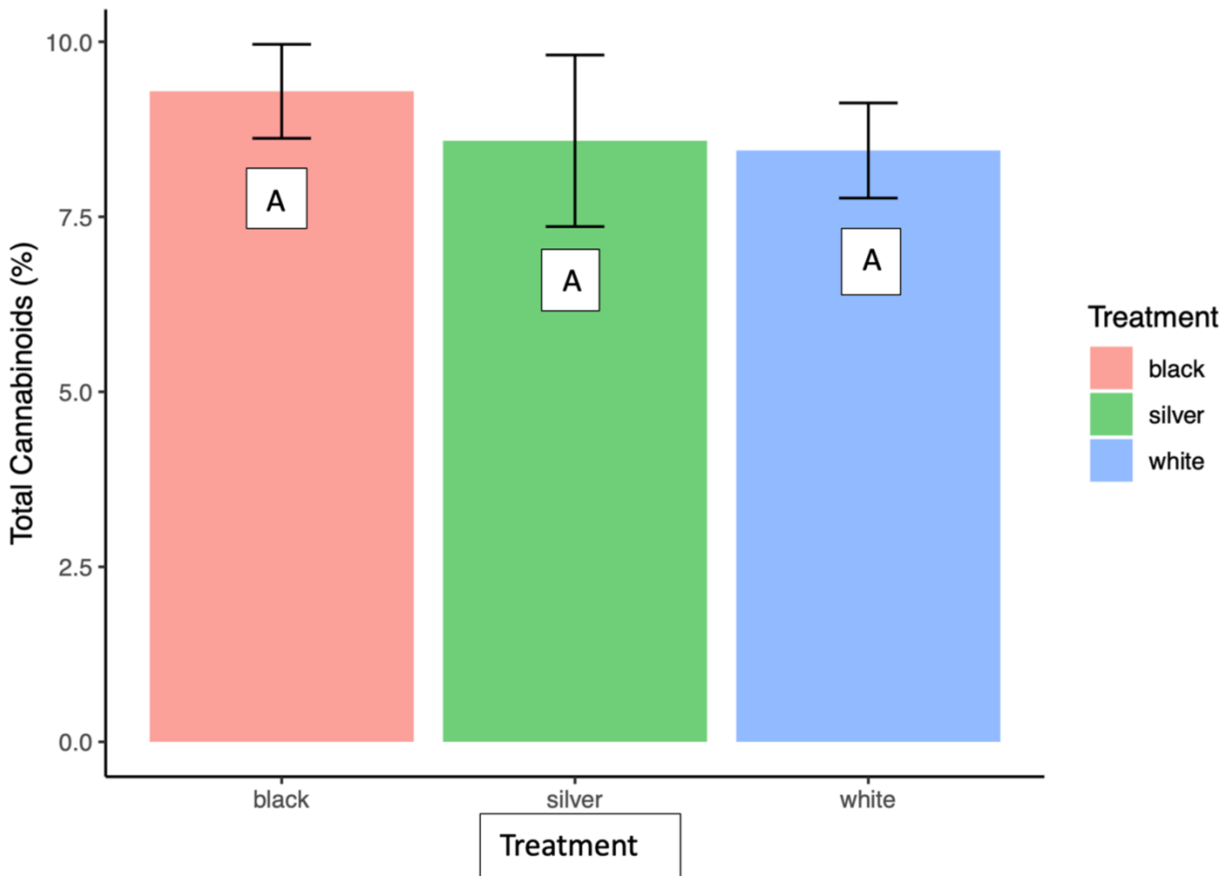


Figure 36g: Electrical conductivity average by treatment.

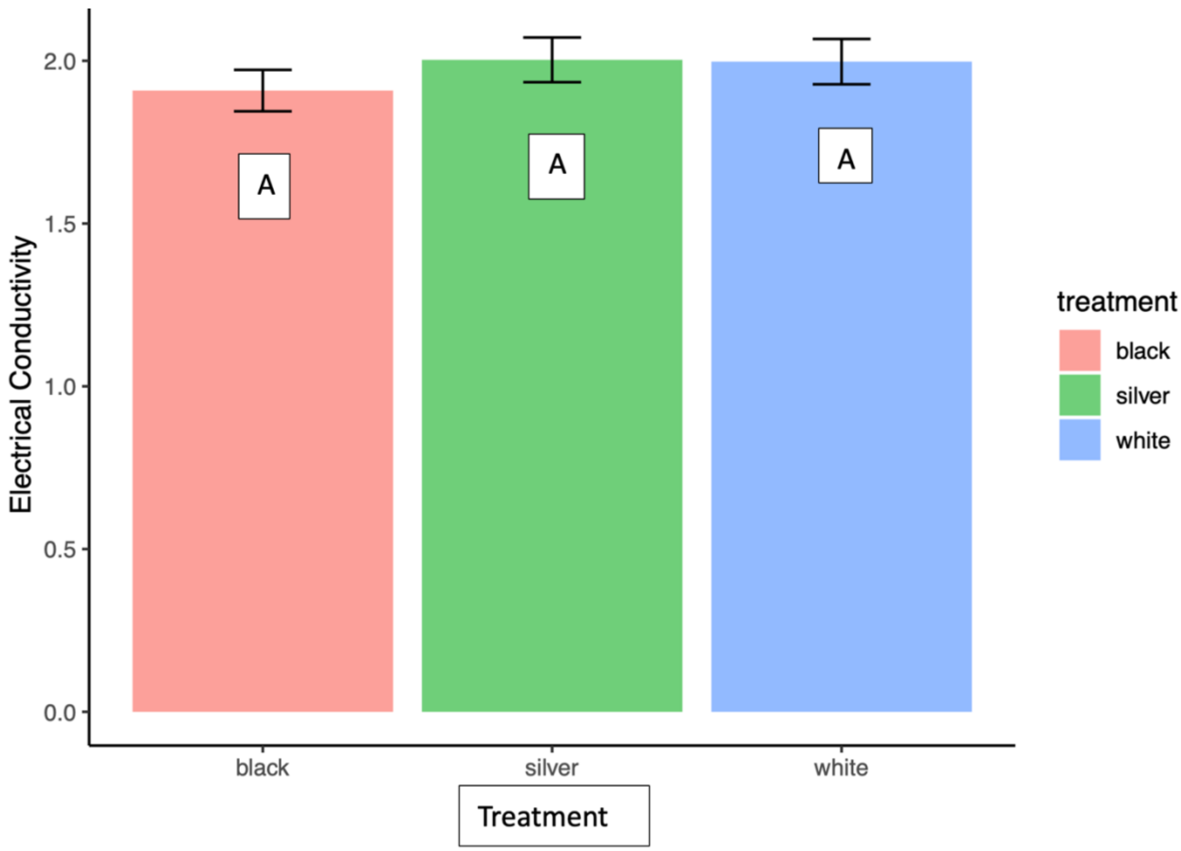
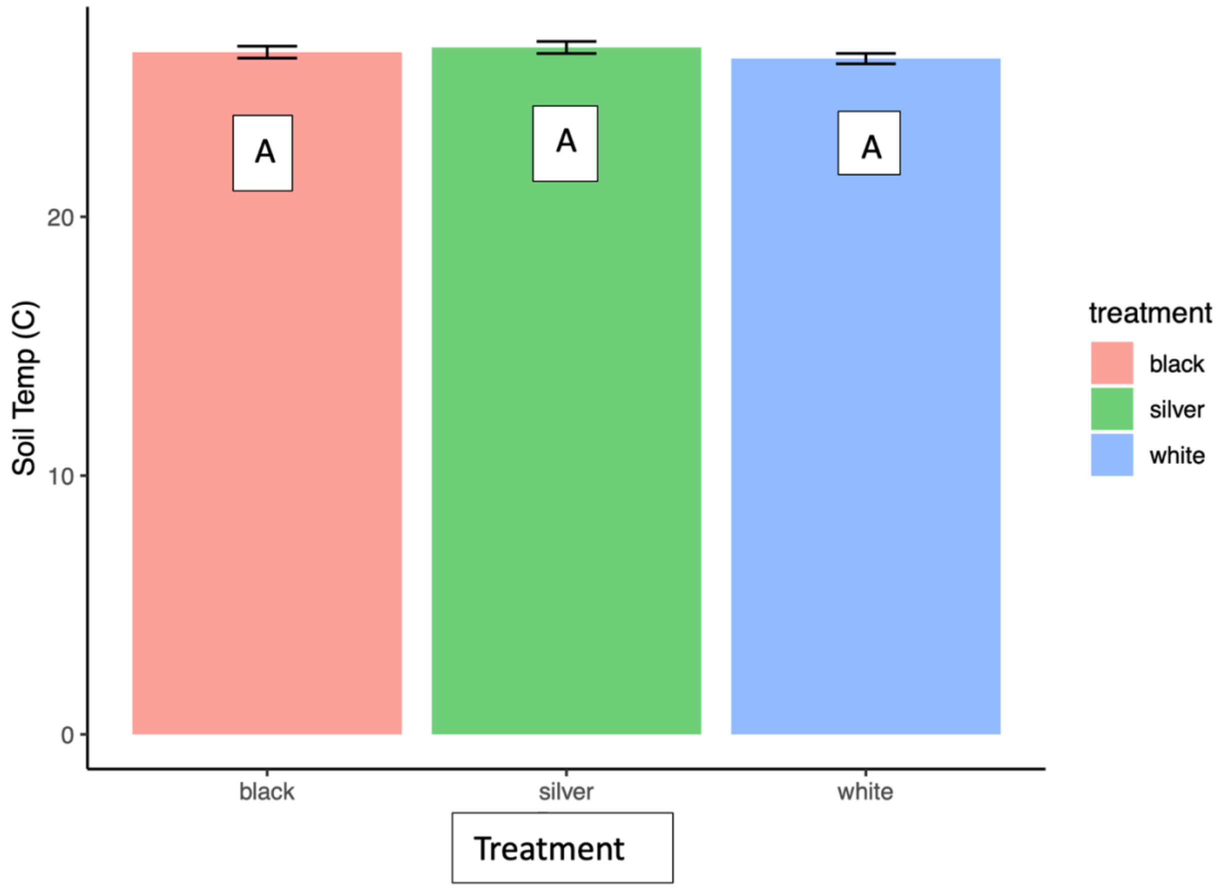


Figure 36h: Soil temperature averages by treatment.



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