2019 Hemp Flower
Indoor/Outdoor Cultivation Trial

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2019 HEMP FLOWER INDOOR/OUTDOOR CULTIVATION TRIAL

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Hemp is a non-psychoactive variety of *Cannabis sativa L*. The crop is one of historical importance in the U.S. and re-emerging worldwide importance as medical providers and manufacturers seek hemp as a renewable and sustainable resource for a wide variety of consumer and industrial products. Hemp grown for all types of end-use (health supplement, fiber, and seed) contains less than 0.3% tetrahydrocannabinol (THC). Hemp varieties intended to produce a health supplement contain relatively high concentrations of a compound called cannabidiol (CBD), potentially 10-15%. CBD has purported benefits such as relief from inflammation, pain, anxiety, seizures, spasms, and other conditions. The CBD is the most concentrated in the female flower buds of the plant; however, it is also in the leaves and other plant parts as well.

To produce hemp for flower, the plant is generally grown intensively as a specialty crop and the flowers are cultivated for maximum growth. The various cannabinoids and terpenes concentrated in the flower buds are often extracted and incorporated into topical products (salves, lip balm, lotion) and food and is available in pill capsules, powder form, and more, which can be found in the market today. To help farmers succeed, agronomic research on hemp is needed in the United States. University of Vermont, in partnership with the CASE Institute (https://www.caseinstitute.org/), evaluated Boax hemp variety under two growing conditions for their growth habit, flower yields, and flower quality. Growing conditions for Boax variety included two types of conditions, 1) "indoors" under a plastic hoop house and 2) "outdoors" without cover. Plastic hoop houses or "caterpillar tunnels" can be an inexpensive alternative to typical high tunnels and can provide greater control over environmental conditions for crops (Image 1).

Image 1. Plastic hoop house Alburgh, VT, 2018.

MATERIALS AND METHODS

The impact of indoor versus outdoor production of hemp for flower production was evaluated at Borderview Research Farm in Alburgh, VT. The experimental design was a randomized complete block with 4 replicates. Plots consisted of 5 plants spaced 5' apart in the row and between rows (Table 1). Treatments consisted of cultivation method: 1) Under plastic hoop house "Indoor" and 2) Outdoors without cover "Outdoor" (Image 1).

Table 1. Agronomic information for the hemp variety trial 2019, Alburgh, VT.

Location	Borderview Research Farm Alburgh, VT
Soil type	Benson rocky silt loam, 3-5% slope
Previous crop	Organic corn
Plant spacing (ft)	5 x 5
Planting date	19-Jun
Harvest date	23-Oct
Fertilization	120 lbs N ac^{-1}, 60 lbs K ac^{-1}

To produce clones for the experiment, seed material was planted into 72-cell trays containing Fort Light potting mix (Vermont Compost Company, Montpelier, VT) on 9-Mar and placed in the UVM Greenhouses (Burlington, VT). Greenhouse temperatures were maintained at 70-75º F during the day and 68-72º F at night and received 18 hours of supplemental light at 400 W/m^2 from 1000W metal halide fixtures. Seedling were transplanted into 6" round pots from Dillen International (Twinsburg, OH) on 27-Mar and plugs were dusted with Blue Sky Organics Myco-Grow (Vernon, BC, Canada). On 18-Apr, female plants were transplanted into 9" pots from Nursery Supplies Inc. (Jacksonville, FL). At transplant, plant starts received supplemental fertility in the form of Greenhouse Feeding BioGrow (7-2-4) (Amsterdam-Zuidoost, Netherlands). On 7-May, mother plants were selected for clonal propagation and transplanted into #3 squat pots from Nursery Supplies Inc. (Jacksonville, FL). Plants were fertilized with BioGrow, and covered with Black Dirt Farm Vermicompost-Inoculated Mulch (Greensboro Bend, VT). On 1-Jun, cuttings were taken from each of the mother plants and allowed to soak in H_2O for 3-4 hours to increase turgidity before being introduced to the EZ-Clone aerocloner (Sacramento, CA). Aerocloners were filled with 12 gallons DI H_2O and 240 mL Clonex Liquid Solution (Lansing, MI). Cuttings were removed from H_2O soak, cut fresh at a 45-degree angle (approximately 1/4" below a node), and dipped up to 2" in Clonex Rooting Hormone Gel (Lansing, MI). Cuttings were placed in aerocloner with at least 2 nodes below neoprene collar and at least 3 leaves above. Pump was set on timer for 15 min ON / 15 min OFF continuously with T5 lighting (approximately 18" from cuttings) set for 18 hours ON / 6 hours OFF. For one week, cuttings were allowed to callus and begin root formation, with a reservoir temperature of approximately 75º F and pH between 5.6-6.0. After 7 days, reservoir was emptied, cleaned, and refilled with 12 gallons of fresh DI H_2O and 360 mL Clonex Liquid Solution. Pump, lighting, timers, temperature, and pH remained the same. After 14 days, cuttings were fully rooted (approximately 2" roots emerging from callused stem) and transplanted into Fort Light potting mix (Vermont Compost Company) in trays of 1801 pots.

On 19-Jun, clones were transplanted into black plastic mulch with drip tape. Fertility amendments were based on soil test results received from the University of Vermont Agricultural and Environmental Testing Laboratory (Burlington, VT). The field was fertilized with 120 lbs N ac^{-1} over the course of six weeks via fertigation. Nitrogen was applied in the form of ammonium nitrate plus sulfur (28-0-0) distributed evenly through 1000 gallons of water using a Dosatron unit. In addition, potassium chloride (0-0-62) was applied at a rate of 100 lbs ac^{-1} just following planting. Based on soil test results, no further nutrients were required for production of hemp. Irrigation was applied on a weekly basis at a rate of 8000 gallons of water per acre delivered via drip tape. Irrigation duration and amount was modified based on weekly rainfall.

For each plant harvested, the whole plant weight was recorded. Plants harvested on 23-Oct were broken down into smaller branched sections and larger "fan" or "sun" leaves were removed by hand, while smaller leaves were left attached since they subtend from the flower bract. Remaining stems were then bucked using the Munch Machine Mother Bucker (Toppenish, WA) (Image 1) and remaining leaf material and buds were collected. Wet bud and leaf material was then processed through the Centurion Pro Gladiator Trimmer (Maple Ridge, BC, Canada) (Image 2).

Image 1. Munch Machine Mother Bucker (Toppenish, WA).

Wet bud weight and unmarketable bud weight were recorded. The flower buds were then dried at 80º F or ambient temperature with airflow until dry enough for storage without molding. A subsample of flower bud from each plot was dried in a small dehydrator and wet weights and dry weights were recorded in order to calculate the percent moisture of the flower buds. The percent moisture at harvest was used to calculate dry matter yields. Flower subsample was then sent to Nutraceuticals Science Laboratory (Waterbury, VT) for cannabinoid analysis.

Image 2. Centurion Pro Gladiator Trimmer (Maple Ridge, BC, Canada).

The data were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$). Data was analyzed using the PROC MIXED procedure in SAS with the Tukey-Kramer adjustment, which means that each variable was analyzed with a pairwise comparison (i.e. 'variety 1' statistically outperformed 'variety 2', 'variety 2' statistically outperformed 'variety 3', etc.). Relationships between variables were analyzed using the GLM procedure.

Variations in yield and quality can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among treatments is real or whether it might have occurred due to other variations in the field. At the bottom of each table a p-value is presented for each variable that showed statistical significance (p-value ≤ 0.10). In this case, the difference between two treatments within a column is equal to or greater than the least significant difference (LSD) value and you can be sure that for 9 out of 10 times, there is a real difference between the two treatments. In this example, hybrid 3 is significantly different from hybrid 1 but not from hybrid 2. Hybrid 2 and hybrid 3 have share the same letter ‘a’ next to their yield value, to indicate that these results are statistically similar. The difference between hybrid 3 and hybrid 2 is equal to 1.5, which is less than the LSD value of 2.0. This means that these hybrids did not differ in yield. The difference between hybrid 3 and hybrid 1 is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yields of these hybrids were significantly different from one another. The letter ‘b’ next to hybrid 1’s yield value shows that this value is significantly different from hybrid 2 and hybrid 3, which have the letter ‘a’ next to their value.

Treatment	Yield
Hybrid 1	6.0 b
Hybrid 2	7.5a
Hybrid 3	**9.0**a
LSD (p-value ≤ 0.10)	2.0

Participants of State Hemp Programs intending to grow are required to follow state and federal regulations regarding hemp production and registration. Growers must register within their intended state for production and must adhere to most current or active rules and regulations for production within a grower’s given state. Regulations are subject to change from year to year with the development and approval of proposed program rules and it is important to note that regulations may vary across state lines and may be impacted by pending federal regulations. Please refer to this https://agriculture.vermont.gov/sites/agriculture/files/documents/PHARM/hemp/Industrial_Hemp_Rule_%20SOS_05172019.pdf for a detailed outline of proposed rules in Vermont. Additional information regarding the Vermont Agency of Agriculture, Food and Markets (VAAFM) Hemp Program can be found on the VAAFM website here: https://agriculture.vermont.gov/public-health-agricultural-resource-management-division/hemp-program.

RESULTS

Seasonal precipitation and temperature were recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 2). The month of July was hot and dry when compared to the 30-year average, followed by a slightly cooler than normal August. June, July and October saw higher than normal temperatures whereas August and September were slightly below normal. July and August were below average precipitation amounts with the tail end of the season receiving a well above average amounts of precipitation. Overall, there were an accumulated 2211 Growing Degree Days (GDDs) this season, approximately 197 more than the historical average, with much of the heat coming mid-season. Hemp plants received supplemental irrigation to account for precipitation deficits throughout the growing season, as needed.

Table 2. Seasonal weather data collected in Alburgh, VT, 2019.

Alburgh, VT	June	July	August	September	October
Average temperature (°F)	69.2	73.5	68.3	60.0	50.8
Departure from normal	0.84	2.84	-0.53	-0.62	0.14
Precipitation (inches)	1.71	2.34	3.50	3.87	3.85
Departure from normal	0.33	-1.81	-0.41	0.23	1.88
Growing Degree Days	446	716	568	335	146
Departure from normal	-29	76	-13	17	146

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

Whole plant weight, bud weight, stem, weight and leaf weight were all measured at harvest to evaluate the growth characteristics of Boax variety under indoor and outdoor growing conditions (Table 3). Throughout each of these evaluated characteristics there were no observed, significantly different metrics across the board. While differences were not significant, indoor treatment did appear to have overall heavier plants at 25.2 lbs plant^{-1} compared to outdoor treatment at 21.3 lbs plant^{-1} in addition to greater wet bud weight, stem weight, and leaf weight. This also impacted overall ratios of plant material where the outdoor treatments had the lowest stem weight at 6.65 lbs plant^{-1} and highest Bud:stem and Leaf:stem ratios at 1.3.

Table 3. Hemp plant growth metrics, Alburgh, VT, 2019.

Treatment	**Whole plant weight**	**Wet bud weight**		**Stem weight**		**Leaf weight**		**Bud:stem**	**Leaf:stem**
	lbs plant-1	**lbs plant-1**	**% total**	**lbs plant^{-1}**	**% total**	**lbs plant^{-1}**	**% total**		
Indoor	25.2	8.00	32.4	8.25	32.1	8.90	35.4	1.0	1.1
Outdoor	21.3	6.85	34.7	6.65	29.6	7.78	35.7	1.3	1.3
LSD (0.10)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trial mean	23.2	7.43	33.5	7.45	30.9	8.34	35.6	1.2	1.2

The top performing treatment (p=0.10) is shown in **bold**.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

At harvest a composite subsample of flower material was collected from each plot and dried down to determine flower dry matter and calculate dry matter flower yields (Table 4). Indoor growing conditions had a higher flower dry matter at 21.1% compared to outdoor conditions at 18.9%, but differences were not statistically different. While there were not differences in wet bud weights between treatments, there were differences in dry matter hemp flower yields between indoor and outdoor treatments. Indoor treatment had a dry matter yield of 1.67 lbs plant^{-1} compared to outdoor treatment at 1.48 lbs plant^{-1} with a trial mean of 1.48 lbs plant^{-1}. On a per acre basis, indoor treatments yielded 3163 lbs ac^{-1} compared to outdoor at 2451 lbs ac^{-1}. Unmarketable flower differences were not statistically significant for the trial yet slightly higher amounts were observed in the outdoor treatments, likely as a result of wind damaged, split plants and greater soil exposure compared to those grown under the high tunnel.

Table 4. Hemp flower bud yield, Alburgh, VT, 2019.

Treatment	Flower dry matter	Dry matter flower yield		Yield at 8% moisture	Unmarketable flower yield	
	%	lbs plant^{-1}	lbs acre^{-1}	lbs acre^{-1}	lbs plant^{-1}	lbs acre^{-1}
Indoor	21.1	1.67	**2910**	**3163**	0.125	218.5
Outdoor	18.9	1.29	2255	2451	0.209	364.6
LSD (0.10)	NS	0.36	628	683	NS	NS
Trial mean	20.0	1.48	2582	2807	0.180	292

The top performing treatment (p=0.10) is shown in **bold**.
NS – There was no statistical difference between treatments in a particular column (p=0.10).
† Dry matter yield is reported at 0% moisture.

At harvest, a composite sample from each production system (indoor versus outdoor) was analyzed for Total CBD and Total THC percentage by the Nutraceuticals Science Laboratory (Waterbury, VT). Results for cannabinoids are on a dry matter basis (0% moisture). Total CBD was highest for plants grown under indoor conditions yet the difference between indoor and outdoor grown plants for Boax variety was not significant. Indoor treatment plants showed total potential CBD of 16.8% compared to outdoor plants at 13.9%, with a trial average of 15.3 (Table 5). There was a significant difference between indoor and outdoor conditions for total potential THC with indoor conditions having a higher percentage at 0.614% compared to outdoor conditions at 0.482%.

Both indoor and outdoor growing systems produced hemp that was compliant with Vermont State Hemp Regulations for THC limits in the 2019 growing season. Acceptable potency for hemp in the State of Vermont is defined as one that has a Δ-9 THC concentration of 0.3% or less **and** a total potential THC concentration of 1.0% or less reported on a dry weight basis. Each condition in the trial also had a high ratio of CBD to THC with indoor condition at 27:1 and outdoor at 28:1. Each of the growing conditions within this trial would fall under the Type III definition for cultivars of *Cannabis sativa* L. where cultivars are CBD dominate and have a CBD:THC that is at least 20:1 under definitions proposed under Vermont Hemp Program Rules (5/17/19). Regulations can be found at (https://agriculture.vermont.gov/sites/agriculture/files/documents/PHARM/hemp/Industrial_Hemp_Rule_%20SOS_05172019.pdf)

Table 5. Hemp flower cannabinoids, Alburgh, VT, 2019.

Treatment	Total potential CBD	Total potential THC ‡
	% weight	% weight
Indoor	16.8	**0.614**
Outdoor	13.9	0.482
LSD (0.10)	NS	.120
Trial mean	15.3	0.548

The top performing treatment (p=0.10) is shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).

DISCUSSION

Both the indoor and outdoor treatments performed well in our Northeast climate. Based on growth habit alone, there were no major differences between treatments and covered indoor growing conditions did not appear to have much impact. Differences became more apparent in dry matter yields where plants may have had the opportunity to mature faster under indoor conditions and produce higher amounts of flower material per plant and thus a per acre.

While the differences in total potential CBD were not significant, they were higher for indoor treatments by nearly 3%. These differences were not as significant as those seen in our 2018 study, which showed over 4% increase in total potential CBD for Boax grown indoors over outdoors, yet 2019 values overall were much higher. A difference of 3-4% CBD could make a major difference when marketing hemp flower and could potentially command a higher price depending on markets. Total potential THC values were also compliant within 2019 Vermont State regulations, however it is important to note that regulations for production can vary greatly between states. Hemp must be grown in compliance with state and federal regulations. Please check with your state to determine rules and regulations required for hemp production.

Interest in using caterpillar tunnels or high tunnels has been growing for hemp flower production. Use of caterpillar high tunnels could provide unique opportunities for growers looking for more control and protection from various growing conditions. Structures and plastic cover could provide an early season boost in growth and season extender by creating a warmer environment for plants, or protection from high winds with a high value crop that may be susceptible to splitting trunks or branches. The tunnel constructed for use in this trial could offer a cost effective mean to increase yields and quality while providing greater control over growing conditions. Additional information on caterpillar tunnel construction and costs can be found here: https://www.uvm.edu/sites/default/files/Northwest-Crops-and-Soils-Program/CaterpillarFactSheet.pdf.

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