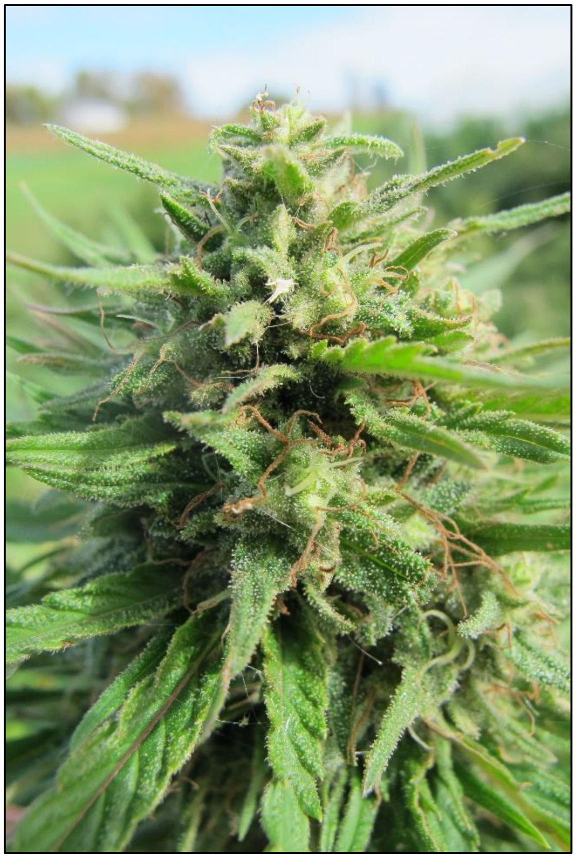
2019 Hemp Cannabidiol
Plant Spacing x Planting Date Trial



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THE UNIVERSITY OF VERMONT EXTENSION

2019 CANNABIDIOL HEMP PLANT SPACING X PLANTING DATE TRIAL

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Hemp is a non-psychoactive variety of cannabis sativa L. Hemp is a crop of historical importance in the U.S. and re-emerging worldwide as a popular crop as it is sought out as a renewable and sustainable resource for a wide variety of consumer and industrial products. Hemp that is grown for fiber, grain oil, or as an intended health supplement contains less than 0.3% tetrahydrocannabinol (THC). When hemp is grown to produce cannabidiol (CBD) as an intended health supplement, CBD concentrations are relatively high, with concentrations ranging between 8-15%. Hemp for CBD production is grown more intensively, similar to vegetable production, and can be grown indoors or in the field. To help farmers succeed, agronomic research on hemp being grown for CBD extraction is needed in our region. In 2019, the University of Vermont Extension's Northwest Crops and Soils Program evaluated three plant spacing arrangements (1x1', 3x3', 5x5') and planting dates (10-Jun, 17-Jun, and 24-Jun) to determine best management practices for hemp grown for CBD production in this region.

MATERIALS AND METHODS

Hemp was grown at Borderview Research Farm in Alburgh, Vermont (Table 1) to evaluate the impact of plant spacing and planting date on CBD flower yield. The experimental design was a randomized complete block with split plots with 3 replicates. The main plots were planting date and subplots were plant spacing. Female plants grown from clonal propagation of the variety *Ceiba* were planted on 10-Jun, 17-Jun, and 24-Jun into plots with 1 x 1', 3 x 3', and 5 x 5' spacings, respectively, with 12 plants per plot. Plant populations on a per acre basis are displayed in Table 2. Cuttings were taken on 29-Apr, 1-May, and 6-May to provide clones for each of the 3 planting dates. At the time of each planting date, plots were fertilized with 957 lbs ac^{-1} Pro-Gro (5-3-4, North Country Organics) and 957 lbs ac^{-1} Pro-Booster (10-0-0, North Country Organics). The soil type was Benson rocky silt loam, and the previous crop was corn. An annual ryegrass cover crop was planted on 8-Jul between each replicate. Plots were manually weeded during establishment.

Table 1. Agronomic information for the CBD hemp plant spacing by planting date trial 2019, Alburgh, VT.

Location	Borderview Research Farm, Alburgh, VT
Soil type	Benson rocky silt loam, 8-15% slope
Previous crop	Corn
Variety	Ceiba
Plant spacing (feet)	1 x 1, 3 x 3, and 5 x 5
Planting date	10-Jun, 17-Jun, and 24-Jun
Fertilization	144 lbs N ac^{-1}, 28.7 lbs P ac^{-1}, 38.3 lbs K ac^{-1}
Harvest date	17-Oct

Table 2. Plant population per acre for each plant spacing.

Plant spacing, ft x ft	Population*, plants ac^{-1}
1 x 1	43,560
3 x 3	4,840
5 x 5	1,742

*Population does not account for alleys or roads.

On 17-Oct, plant height was measured from the two middle plants of each plot. The plants were harvested by hand on 17-Oct, and two whole plants from the center of the plot were weighed. Once the plant was broken down into smaller branched sections, larger “fan” or “sun” leaves were removed, while smaller leaves were left attached since they subtend from the flower bract. Flower buds were removed by hand and by a Munch Machine Mother Bucker (Dauenhauer Manufacturing Company, Toppenish, WA). The buds were then trimmed in a Gladiator trimmer (Centurion Pro Solutions, Maple Ridge, BC). Wet bud weight, unmarketable bud weight, and stem weight were recorded. Flower buds were deemed unmarketable based on the presence of disease and soil contamination. The flower buds were then dried at 80^{o} F until dry enough for storage without molding. A subsample of flower bud from each plant spacing at each planting date was dried in a small dehydrator, in order to calculate the dry matter yields.

Hemp flower subsamples from each plot were sent to ProVerde Laboratories (Milford, MA) for cannabinoid profile analysis. Analysis was done with an Ultra-Performance Convergence Chromatography System (UPC2) from Waters Corp., which utilizes carbon dioxide as the primary mobile phase component. In this report, CBD profiles are reported as total potential CBD, which accounts for CBD concentrations after decarboxylation.

Data were analyzed using a general linear model procedure of SAS (SAS Institute, 2008) when datasets were complete. Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure where the F-test was considered significant, at p<0.10. When data were missing, the Mixed Procedure of SAS (SAS Institute, 2008) was used. Treatment mean pairwise comparisons were made using the Tukey-Kramer adjustment at the 0.10 level of significance. Variations in genetics, soil, weather, and other growing conditions can result in variations in yield and quality. Statistical analysis makes it possible to determine whether a difference between treatments is significant or whether it is due to natural variations in the plant or field. At the bottom of each table, a p-value is presented for each variable (i.e. yield). The p-value refers to whether the treatment was statistically significant overall, while the letters are drawn from the means comparison. In the example to the right, treatment C was significantly different from treatment A, but not from treatment B. A lack of significant difference is indicated by shared letters.

Treatment	Yield
A	6.0^{b}
B	7.5^{ab}
C	**9.0^{a}**
P -value	<0.10

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 3). A cool and wet spring continued with below average temperatures in June. The month of July was hot and dry when compared to the 30-year average, followed by a slightly cooler than normal August and September. Rainfall and temperature were above average during the month of October. Overall, there were an accumulated 2211 Growing Degree Days (GDDs) this season, which is 197 above the 30-year normal, with much of the heat coming mid-season.

Table 3. Seasonal weather data collected in Alburgh, VT, 2019.

Alburgh, VT	June	July	August	September	October
Average temperature (°F)	64.3	73.5	68.3	60.0	50.4
Departure from normal	-1.46	2.87	-0.51	-0.62	2.22
Precipitation (inches)	3.06	2.34	3.50	3.87	6.32
Departure from normal	-0.63	-1.81	-0.41	0.23	2.72
Growing Degree Days (Base 50°)	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.

Interactions between planting date and spacing

There were few statistical interactions between planting date and plant spacing. Interactions included stem weight (p =0.075), plant weight (p =0.0303), leaf weight (p =0.0415), and unmarketable flower buds per acre (p = 0.029). The 10-Jun planting date had the largest plant weight in the 1 x 1’ spacing, and as spacing increased, the 10-Jun plant weights were reduced. Spacings 3 x 3’ and 5 x 5’ had heavier plant weights on 17-Jun, though for 3 x 3’ spacing the 17-Jun weight was statistically similar to the 24-Jun weight. The 3 x 3’ and 5 x 5’ spacings also had the highest stem weights on 17-Jun. There were no statistically significant interactions between marketable yields or total potential CBD concentrations.

Plant spacing results

The impact of plant spacing on plant biomass is displayed in Table 4. The 3 x 3’ and 1 x 1’ plant spacing produced significantly taller plant heights than the 5 x 5’ spacing (104 cm). The 5 x 5’ spacing produced the heaviest plant weight, 16.5 lbs, and the heaviest stem weight (3.76 lbs), which were significantly higher than the other spacing treatments.

Table 4. Plant spacing effect on plant weight and height, Alburgh, VT, 2019.

Plant spacing	**Height**	**Whole plant**	**Stem weight**		**Wet bud weight**		**Wet bud yield**	**Leaf weight**	
ft x ft	**cm**	**lbs plant^{-1}**	**lbs plant^{-1}**	**%**	**lbs plant^{-1}**	**%**	**lbs ac^{-1}**	**lbs plant^{-1}**	**%**
1 x 1	123^{a}	2.42^{c}	0.527^{c}	23.0	0.575^{c}	24.9	**25058^{a}**	1.31^{c}	**55.0**
3 x 3	**127^{a}**	8.23^{b}	2.23^{b}	**27.2**	2.01^{b}	24.7	9742^{b}	3.99^{b}	48.2
5 x 5	104^{b}	**16.5^{a}**	**3.76^{a}**	22.6	**4.41^{a}**	**27.5**	7682^{b}	**8.30^{a}**	49.9
P-value (0.10)	0.005	<0.0001	<0.0001	NS	<0.0001	NS	0.008	<0.0001	NS
Trial mean	118	9.04	2.21	24.3	2.33	25.7	14161	4.53	51.0

Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.
NS- Not significant.

Wet flower bud weight per plant was significantly greater in the 5 x 5' spacing at 4.41 lbs plant^{-1}, followed by the 3 x 3' and 1 x 1' spacing (2.01 lbs plant^{-1}, 0.575 lbs plant^{-1}), which significantly differed from each other. Similar trends were observed with leaf weight, with the 5 x 5 spacing having significantly more leaves by weight than the two other treatments. However, regardless of plant spacing, total plant biomass was approximately 50% leaf material, and approximately 25% flower buds (Table 4).

Bud to stem and leaf to stem ratios did not differ by spacing (Table 5). The 5 x 5' spacing had significantly more dry matter flower yield on a per plant basis than the other spacing treatments, at 0.759 lbs plant^{-1} (Table 5). While the 1 x 1' spacing yielded significantly less bud dry matter per plant (0.119 lbs plant^{-1}), the 1 x 1' spacing yielded significantly greater dry matter yields on a per acre basis compared to the other treatments. The 1 x 1' spacing yielded 5072 lbs ac^{-1}, while the trial average for all spacing treatments was 2714 lbs ac^{-1}. Unmarketable dry matter flower yield on per acre basis was the highest in the 1 x 1' spacing treatment, at 1145 lbs ac^{-1}. Total potential CBD did not statistically differ by plant spacing.

Table 5. Plant spacing effect on biomass ratios and flower yields, Alburgh, VT, 2019.

Plant spacing	Bud:Stem	Leaf:Stem	Dry matter bud yield		Unmarketable dry matter bud yield	Total potential CBD
ft x ft			lbs plant^{-1}	lbs ac^{-1}	lbs ac^{-1}	%
1 x 1	1.14	**2.55**	0.119^{c}	**5072^{a}**	**1145^{a}**	**10.8**
3 x 3	1.00	1.91	0.362^{b}	1750^{b}	5.28^{b}	9.97
5 x 5	**1.27**	2.29	**0.759^{a}**	1322^{b}	203^{b}	10.1
P-value (0.10)	NS	NS	<0.001	0.002	0.091	NS
Trial mean	1.14	2.26	0.413	2714	451	10.3

Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.
NS- Not significant.

Planting date results

The 17-Jun planting date resulted in taller and heavier plants compared to the 10-Jun planting date (Table 6). The 17-Jun planting date had an average height of 128 cm, significantly greater than 111 cm and 115 cm for the 10-Jun and 24-Jun dates. Whole plant biomass was 10.4 lbs plant^{-1}, significantly greater than the 10-Jun date. The 17-Jun planting date had an average stem weight of 2.72 lbs, which was similar to the 10-Jun planting date, 2.05 lbs, and was significantly greater than 24-Jun planting date (1.86 lbs).

Table 6. Planting date effect on plant weight and height, Alburgh, VT, 2019.

Planting date	Height	Whole plant	Stem weight		Wet bud weight		Wet bud yield	Leaf weight	
	cm	lbs plant^{-1}	lbs plant^{-1}	%	lbs plant^{-1}	%	lbs ac^{-1}	lbs plant^{-1}	%
10-Jun	111^{b}	7.79^{b}	2.05^{ab}	24.9	2.29	**30.4^{a}**	**18092**	3.56^{b}	47.0^{b}
17-Jun	**128^{a}**	**10.4^{a}**	**2.72^{a}**	**26.2**	**2.39**	24.4^{b}	13583	**5.27^{a}**	49.4^{b}
24-Jun	115^{b}	8.94^{ab}	1.86^{b}	21.1	2.32	22.3^{b}	10807	4.77^{a}	**56.7^{a}**
P-value (0.10)	0.052	0.0356	0.0505	NS	NS	0.0775	NS	0.0335	0.0782
Trial mean	118	9.04	2.21	24.1	2.33	25.7	14161	4.53	51.0

Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.
NS- Not significant.

Stem weights as a percentage of total weight ranged from 21.1 to 26.2% and did not differ statistically. Flower bud weight and leaf weight percentage had statistically different values across planting dates; wet flower composed 30.4% of the 10-Jun plants, which was significantly different from 17-Jun (24.4%) and 24-Jun (22.3%). The 24-Jun planting date was 56.7% leaves in weight, differing from 10-Jun and 17-Jun (47%, 49.4% respectively). 17-Jun had the highest bud yield on a per plant basis, 2.39 lbs plant^{-1}. The 10-Jun planting date was the top performer on a per acre basis, yielding 18,092 lbs ac^{-1} of wet buds. Bud to stem ratios were statistically similar, and the 24-Jun planting date had a significantly higher leaf to stem ratio than the other planting dates (Table 7).

Table 7. Planting date effect on biomass ratios and flower yields, Alburgh, VT, 2019.

Planting date	Bud:Stem	Leaf:Stem	Dry matter bud yield		Unmarketable dry matter bud	Total potential CBD
			lbs plant^{-1}	lbs ac^{-1}	lbs ac^{-1}	%
10-Jun	**1.32**	1.93^{b}	**0.470**	**3927**	25.1^{b}	**11.2^{a}**
17-Jun	0.96	1.92^{b}	0.404	2461	166^{ab}	11.0^{a}
24-Jun	1.13	**2.94^{a}**	0.365	1868	**1163^{a}**	8.64^{b}
P-value (0.10)	NS	0.0351	NS	NS	0.0732	0.0014
Trial mean	1.14	2.26	0.413	2752	451	10.3

Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.
NS- Not significant.

In general, planting dates did not vary greatly in flower yields on a wet or dry matter basis (Table 6; Table 7). While not statistically significant, the 10-Jun planting date did result in higher dry matter per acre yields (Table 7), yielding 3927 lbs ac^{-1}. Unmarketable flower yields were significantly higher on the 24-Jun planting date than the 10-Jun planting date. Interestingly, the average total potential CBD concentrations for the 10-Jun and 17-Jun planting dates (11.2%, 11.0% respectively) were significantly higher than the CBD concentration for the 24-Jun planting date of 8.64%.

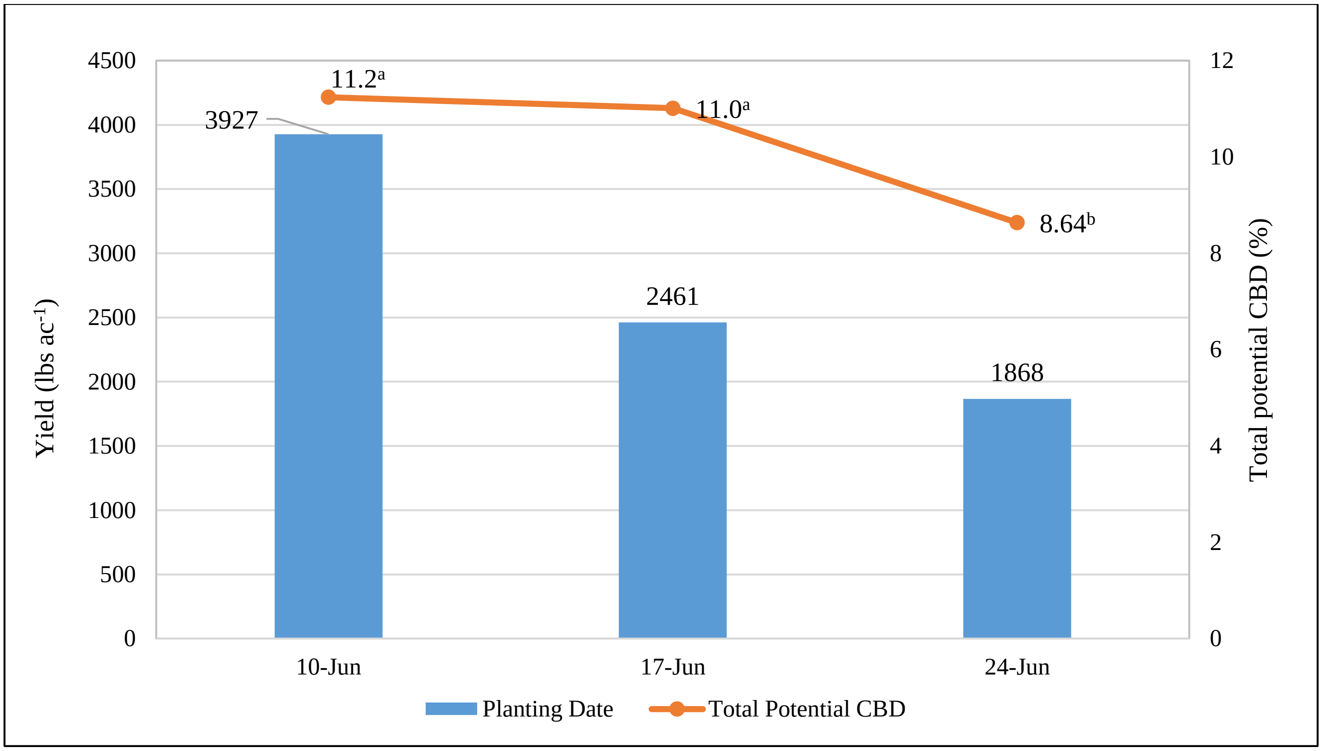

Figure 1. Flower dry matter yields and total potential CBD by planting date, Alburgh, VT 2019. Treatments with the same letter are statistically similar at the 0.10 level.

DISCUSSION

There were few interactions between planting date and plant spacing indicating that hemp spacing responded similarly regardless of planting date. Spacing results were as expected; the 5 x 5' spacing produced larger plant weights and flower yields per plant, while the 1 x 1' spacing produced significantly higher yields on a per acre basis, yielding 5072 lbs ac^{-1} of flower buds on a dry matter basis. This was almost four times as much as the 5 x 5' spacing, and almost three times as much as the 3 x 3' spacing.

Although the 1' x 1' plant spacing can garner higher yields, there are other factors that must be considered to determine optimum spacing. As an example, initial cost for plant material, regardless of labor, could prove to be prohibitive for growers seeking to plant at 1 x 1' spacing. Seed sourced at a price of $1 seed or clones at $5 plant could prove to be cost prohibitive due to a cost of $43,560 or $217,800 ac^{-1} respectively for plant material alone. At current market biomass pricing (~$1 per pound per %CBD) the 50% increase in yield still does not outweigh the added costs from plant material. It is also important to note that while yields may be higher for 1 x 1' and 3 x 3' spacing, flower bud quality and uniformity may vary greatly especially while compared to 5 x 5' spaced plants that may receive greater or more uniform exposure to light, better allowing flowers to fully develop along stems. A crop grown at 1 x 1' spacing could have the potential for reduced labor inputs and more efficient cultivation in a biomass production system utilizing mechanical harvest equipment. Despite higher per acre yields plant material, market pricing, and labor costs associated with planting at the 1 x 1' density need to be considered to assess the feasibility of this growing scheme. Furthermore, this does not address other inputs such as irrigation, fertilizer, field preparation, drying, and processing among other things. It should be noted that there were also higher levels of unmarketable yield at the denser planting, which was likely a result of increased disease pressure. The CBD concentrations did not differ by spacing.

This trial indicates that adequate yield can be obtained from hemp when planted throughout the month of June. The unusually cold weather may have slightly stunted the plants in the 10-Jun planting date. The highest total potential CBD concentrations at the 10-Jun and 17-Jun planting date were likely due to a longer vegetative growth period before the equinox, allowing the plant to direct energy to reproductive growth soon after the equinox passed. Hemp is a photoperiod sensitive plant and produces vegetative growth as day length increases and switches to reproductive growth as day length decreases. Later planting dates may have resulted in continued vegetative growth after day length began to decrease, due to later transplanting and establishment. This suggests that total potential CBD concentrations will be higher in hemp plants planted earlier in the season, even if yields are reduced by weather or other factors. It is important to remember that these results only represent one season of data, and this field season was notable for a particularly cold spring.

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