2018 Cannabidiol Hemp Plant Spacing x Planting Date Trial

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2018 CANNABIDIOL HEMP PLANT SPACING X PLANTING DATE 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). Some hemp varieties intended to produce a health supplement contain relatively high concentrations of a compound called cannabidiol (CBD), potentially 10-15%. The compound CBD has purported benefits such as relief from inflammation, pain, anxiety, seizures, spasms, and other conditions. The CBD compound 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 grow hemp for CBD production, the crop is generally grown intensively as a specialty crop and the flowers are cultivated for maximum growth. The CBD oil is 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. Industrial hemp is poised to be a “new” cash crop and market opportunity for Vermont farms that is versatile and suitable as a rotation crop with other specialty crops, small grains, and grasses.

To help farmers succeed, agronomic research on hemp being grown for CBD extraction is needed in our region. We evaluated three plant spacings (1x1’, 3x3’, 5x5’) and planting dates (14-Jun, 21-Jun, and 27-Jun) to determine best management practices for hemp grown for CBD production in this region.

MATERIALS AND METHODS

The CBD 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. Female plants grown from clonal propagation of the CBD variety, Boax, were planted on 14-Jun, 21-Jun, and 27-Jun (Image 1).

Table 1. Agronomic information for the CBD hemp plant spacing by planting date trial 2018, Alburgh, VT.

Location	**Borderview Research Farm Alburgh, VT**
Soil type	Benson rocky silt loam, 8-15% slope
Previous crop	Silage corn
Plant spacing (ft)	1x1, 3x3, and 5x5
Planting date	14-Jun, 21-Jun, and 27-Jun
Fertilization	150 lbs N ac^{-1}, 70 lbs P ac^{-1}, 70 lbs K ac^{-1}
Harvest date	16-Oct

Image 1. The CBD hemp plant spacing by planting date trial plots, Alburgh, VT, 2018.

On 27-Jun, the plots were fertilized with 100 lbs N ac^{-1}, 70 lbs P ac^{-1}, 70 lbs K ac^{-1}, using Kreher's poultry manure (5-4-3) and Pro-Gro (5-3-4). An additional 50 lbs N ac^{-1} was applied on 20-Jul in the form of sodium nitrate (16-0-0). On 15-Oct, plant height was measured from the two middle plants of each plot. The plants were harvested by hand on 16-Oct by first using a chainsaw to cut down the entire plant. The whole plant weight was recorded. Then the plant was broken down into smaller branched sections and 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 using the EZTrim Debudder (Broomfield, CO). Wet bud weight and unmarketable bud weight were recorded. The flower buds were then dried at 80° 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 and wet weights and dry weights were recorded in order to calculate the percent moisture of the flower buds. The percent moisture was used to calculate dry matter yields.

For each planting date and plant spacing, 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. 'planting date 1' statistically outperformed ‘planting date 2’, ‘planting date 2’ statistically outperformed ‘planting date 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 LSD value is presented for each variable (i.e. yield). Least Significant Differences (LSDs) at the 0.10 level of significance are shown, except where analyzed by pairwise comparison (t-test). Where the difference between two treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure that for 9 out of 10 times, there is a real difference between the two treatments. Treatments that were not significantly lower in performance than the top-performing treatment in a particular column are indicated with an asterisk. In this example, hybrid C is significantly different from hybrid A but not from hybrid B. The difference between C and B 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 C and A 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 asterisk indicates that hybrid B was not significantly lower than the top yielding hybrid C, indicated in bold.

Treatment	Yield
A	6.0
B	7.5*
C	**9.0***
LSD	2.0

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).

Table 2. Seasonal weather data collected in Alburgh, VT, 2018.

Alburgh, VT	June	July	August	September	October
Average temperature (°F)	64.4	74.1	72.8	63.4	45.8
Departure from normal	-1.38	3.51	3.96	2.76	-2.36
Precipitation (inches)	3.70	2.40	3.00	3.50	3.50
Departure from normal	0.05	-1.72	-0.95	-0.16	-0.07
Growing Degree Days (base 50°F)	447	728	696	427	81
Departure from normal	-27	88	115	109	81

Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Alburgh precipitation data from August-October was provided by the NOAA data for Highgate, VT. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

The summer months were considered hot and dry when compared to the 30-year average. July through September were an average of 3.41° F warmer and received only 60% of normal precipitation. The tail end of the season received an expected amount of precipitation; however, it was cooler than historical averages. Overall, there were an accumulated 2379 Growing Degree Days (GDDs) this season, approximately 366 more than the historical average, with much of the heat coming mid-season. There was no additional water applied to hemp plants outside of natural rainfall.

Plant spacing results

Table 3. Plant spacing effect on plant weight and height, Alburgh, VT, 2018.

Plant spacing	Plant weight	Plant height
ft x ft	**lbs plant^{-1}**	**Cm**
1 x 1	0.640cŧ	75.8
3 x 3	4.66b	81.2
5 x 5	**9.11a**	79.4
LSD (0.10)	**0.734**	**NS**
Trial mean	**4.80**	**78.8**

ŧ Within a column treatments marked with the same letter were statistically similar (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

The 5'x5' spaced plants weighed significantly more than the 1'x'1 and 3'x3' spaced plants, since these plants had more room to grow per plant (Table 3). The average weight of a 5'x5' spaced plant was 9.11 lbs.

Table 4. Plant spacing effect on flower yield, Alburgh, VT, 2018.

Plant spacing	Dry matter flower yield†	Unmarketable dry matter flower yield†	Dry matter flower yield†	Unmarketable dry matter flower yield†
ft x ft	**lbs plant^{-1}**	**lbs plant^{-1}**	**lbs ac^{-1}**	**lbs ac^{-1}**
1 x 1	0.084cŧ	**0.00a**	**3669a**	**7.16a**
3 x 3	0.600b	0.003a	2894b	12.4a
5 x 5	**1.35a**	0.049b	2354c	86.6b
LSD (0.10)	**0.093**	**0.019**	**411**	**35.9**
Trial mean	**0.678**	**0.017**	**2973**	**35.4**

† Dry matter is at 0% moisture.
ŧ Within a column treatments marked with the same letter were statistically similar (p=0.10).

On a per acre basis, the 1'x1' had the best yield and least amount of unmarketable flower buds (Table 4). The 1'x1' spacing yielded 3669 lbs ac^{-1} of dry flower bud. The 3'x3' spacing had a comparably low amount of unmarketable flower buds. On a per plant basis, the 5'x5' spacing had the best yield of 1.35 lbs plant^{-1} and also had the highest amount of unmarketable flower buds. This larger plant had more branches that were near or touching the ground. Given the rainy fall, the lower branches and flower buds of these hemp plants became contaminated with soil. Hence, the unmarketable yield was primarily due to soil contaminated of the flower buds.

Planting date results

The plants planted on 14-Jun and 21-Jun weighed more than the plants planted on 27-Jun (Table 5). This is likely due to the earlier plantings experiencing a longer growing season.

Table 5. Planting date effect on plant weight and height, Alburgh, VT, 2018.

Planting date	Plant weight	Plant height
	lbs plant^{-1}	Cm
14-Jun	**5.38aŧ**	82.1
21-Jun	4.83ab	80.5
27-Jun	4.20b	73.8
LSD (0.10)	**0.734**	**NS**
Trial mean	**78.8**	**4.80**

ŧ Within a column treatments marked with the same letter were statistically similar (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

When averaged across all plants spacings, there were no significant differences observed between planting dates for flower yield (Table 6). There was a significant plant spacing * planting date interaction indicating that plant spacing responded differently between plant dates. Data was analyzed for statistical significance by each individual planting date.

Table 6. Planting date effect on flower yield, Alburgh, VT, 2018.

Planting date	Dry matter flower yield†	Unmarketable dry matter flower yield	Dry matter flower yield	Unmarketable dry matter flower yield
	lbs plant^{-1}	lbs plant^{-1}	lbs ac^{-1}	lbs ac^{-1}
14-Jun	0.740	0.0151	2920	38.9
21-Jun	0.672	0.0223	3243	39.4
27-Jun	0.621	0.0149	2755	27.9
LSD (0.10)	**NS**	**NS**	**NS**	**NS**
Trial mean	**0.678**	**0.0174**	**2973**	**35.4**

† Dry matter is at 0% moisture.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Results for each planting date

Within the 14-Jun planting, the 5'x5' spaced plants showed the best yields and highest amount of unmarketable buds, on a per plant basis (Table 7). There were no significant differences between the plant spacing on a per acre basis.

Table 7. Plant spacing effect on yield and plant weight for the 14-Jun planting, Alburgh, VT, 2018.

Plant spacing	Plant weight	Dry matter flower yield†	Unmarketable dry matter flower yield	Dry matter flower yield	Unmarketable dry matter flower yield
ft x ft	lbs plant^{-1}	lbs plant^{-1}	lbs plant^{-1}	lbs ac^{-1}	lbs ac^{-1}
1 x 1	0.507c	0.066c	**0.000493a**	2893	21.4
3 x 3	5.00b	0.682b	0.00531b	3303	25.7
5 x 5	**10.6aŧ**	**1.47a**	0.0397c	2563	69.1
LSD (0.10)	**1.04**	**0.0931**	**0.00335**	**NS**	**NS**
Trial mean	**5.38**	**0.740**	**0.0152**	**2920**	**116**

† Dry matter is at 0% moisture.
ŧ Within a column treatments marked with the same letter were statistically similar (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Within the 21-Jun planting, the 1'x1' spacing had the best yield and least amount of unmarketable buds, on a per acre basis (Table 8). The average yield for the 1'x1' spacing was 4647 lbs ac^{-1} of flower bud. The 3'x3'plant spacing had a comparably low amount of unmarketable buds, on a per acre basis. On a per plant basis, the 5'x5' spacing had the best yield, while the 1'x1' and 3'x3'spacing had the lowest amount of unmarketable flower bud.

Table 8. Plant spacing effect on yield and plant weight for the 21-Jun planting, Alburgh, VT, 2018.

Plant spacing	Plant weight	Dry matter flower yield†	Unmarketable dry matter flower yield	Dry matter flower yield	Unmarketable dry matter flower bud
ft x ft	lbs plant^{-1}	lbs plant^{-1}	lbs plant^{-1}	lbs ac^{-1}	lbs ac^{-1}
1 x 1	0.855c	0.107c	**0.00a**	**4647a**	**0.00a**
3 x 3	4.47b	0.567b	0.000531a	2742b	2.57a
5 x 5	**9.17a**ŧ	**1.34a**	0.0665b	2340b	116b
LSD (0.10)	**0.742**	**0.100**	**0.0458**	**657**	**79.3**
Trial mean	**4.83**	**0.672**	**0.0223**	**3243**	**35.4**

† Dry matter is at 0% moisture.
ŧ Within a column treatments marked with the same letter were statistically similar (p=0.10).

Within the 27-Jun planting, the 5'x5' spacing had the best yield and greatest amount of unmarketable buds on a per plant basis (Table 9).

Table 9. Plant spacing effect on yield and plant weight for the 27-Jun planting, Alburgh, VT, 2018.

Plant spacing	Plant weight	Dry matter flower yield†	Unmarketable dry matter flower yield	Dry matter flower yield	Unmarketable dry matter flower yield
ft x ft	lbs plant^{-1}	lbs plant^{-1}	lbs plant^{-1}	lbs ac^{-1}	lbs ac^{-1}
1 x 1	0.559c	0.0796b	**0.00a**	3468	**0.00a**
3 x 3	4.50b	0.545b	0.00181b	2637	8.76a
5 x 5	**7.53a**ŧ	**1.24a**	0.0429c	2159	74.8b
LSD (0.10)	**1.51**	**0.182**	**0.0284**	**NS**	**51.2**
Trial mean	**4.20**	**0.621**	**0.0149**	**2754**	**27.8**

† Dry matter is at 0% moisture.
ŧ Within a column treatments marked with the same letter were statistically similar (p=0.10).
NS – There was no statistical difference between treatments in a particular column (p=0.10).

These results suggest that the 1'x1' plant spacing would yield the most flower bud on a per acre basis. However, plant and labor costs associated with planting at the 1'x1' density need to be considered to assess the feasibility of this growing scheme. In addition, CBD concentration was not measured in this experiment and would be another factor to consider before implementation.

Table 10. 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.

Surprisingly, the 5’x5’ treatment generally had the greatest amount of unmarketable buds on a per acre and per plant basis. Flower buds were deemed unmarketable primarily due to soil contamination. These plants had numerous branches with some hanging very close to or on the ground. This allowed for easy soil contamination especially during the numerous rain events just prior to harvest. Closer plant spacings did not allow for as much branching and limited branches coming in contact with soil.

Although these results do not suggest that planting date would impact CBD hemp flower bud yields, the planting dates studied were relatively late and limited. Hemp is a photoperiod sensitive plant and produces vegetative growth as day length increases and switches to reproductive growth as day length decreases. The first planting date of 14-Jun was later than originally planned and close to the spring equinox (21-Jun), when day length would begin decreasing. These results suggest that mid to late June planting dates would produce comparable flower bud yields, considering that this time period is relatively close to the spring equinox. At the same time, it is worth noting that climatic variability may affect the yield benefit. For example, this year the 14-Jun planting yielded 165 lbs dry matter bud ac^{-1} more than the 27-Jun planting, while the 21-Jun planting yielded 488 lbs dry matter bud ac^{-1} more than the 27-Jun planting, even though it was planted 7 days after the 14-Jun planting. June was a relatively cold month, compared to historical averages, which may have stunted the 14-Jun planting.

While these results provide some suggestions for plant spacing and planting dates, it is important to remember that they represent only a one-year research trial.

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