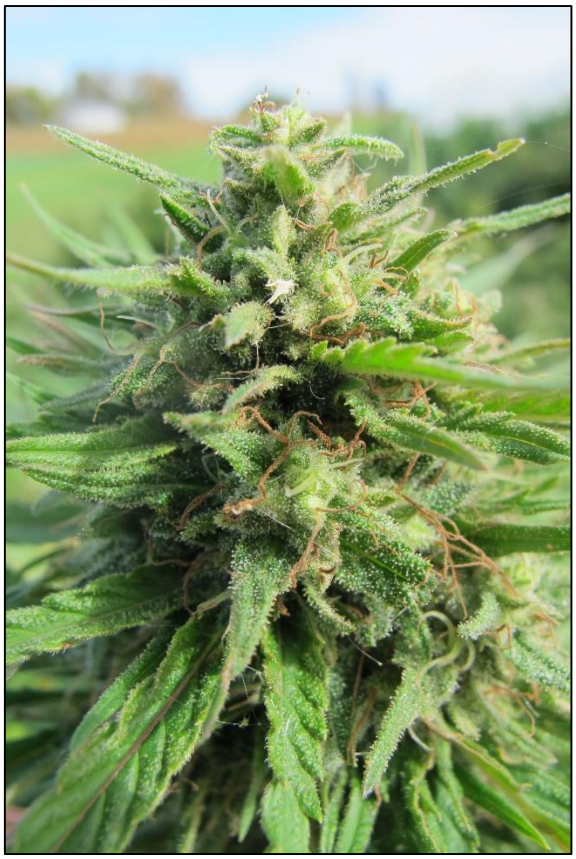
2020 Hemp Flower
Plant Spacing x Planting Date Trial



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2020 HEMP FLOWER 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 2020, the University of Vermont Extension's Northwest Crops and Soils Program evaluated three plant spacing arrangements (1x1', 3x3', 5x5') and planting dates (9-Jun, 16-Jun, and 23-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 'Boax' were planted on 9-Jun, 16-Jun, and 23-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 11-May, 18-May, and 26-May to provide clones for each of the 3 planting dates. On 5-Jun, all plots were fertilized with 180 lbs N ac^{-1}, 20 lbs P ac^{-1}, 72 lbs K ac^{-1}, using Kreher's (8-2-2) (Kreher's Family Farm; Clarency, NY) Pro-Booster (10-0-0) (North Country Organics; Bradford, VT) and sulfate of potash (0-0-52). Fertility amendments were based on soil test results (University of Vermont Agricultural and Environmental Testing Laboratory, Burlington, VT). All soil fertilizer applications were products approved for use in certified organic systems. The soil type was Benson rocky silt loam, and the previous crop was soybeans. An annual ryegrass/white clover cover crop mix 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 2020, Alburgh, VT.

Location	**Borderview Research Farm, Alburgh, VT**
Soil type	Benson rocky silt loam, 3-5% slope
Previous crop	Soybean
Variety	Boax
Plant spacing (feet)	1 x 1, 3 x 3, and 5 x 5
Planting date	9-Jun, 16-Jun, and 23-Jun
Fertilization	180 lbs N ac^{-1}, 20 lbs P ac^{-1}, 72 lbs K ac^{-1}
Harvest date	22-Oct, 23-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 22-Oct, plant height was measured from the two middle plants of each plot. The plants were harvested by hand on 22-Oct and 23-Oct, and two whole plants from the center of the plot were weighed. Two plants per plot were harvested by hand using bypass loppers or chainsaw depending on stem size. The whole plant weight was recorded. Then each plant was 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 BuckmasterPro Bucker (Maple Ridge, BC, Canada) and remaining leaf material and buds were collected. Wet bud and leaf material was then run through the CenturionPro Gladiator Trimmer (Maple Ridge, BC, Canada). Wet bud weight and unmarketable bud weight were recorded. The flower buds were then dried at 80° 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. Metrics were collected for each of the harvested plants within each plot and a plot average was calculated.

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). The growing season was defined by hot and dry conditions throughout the summer months, punctuated by a handful of larger, infrequent rain events seen largely in August. June was especially dry during the transplant and establishment period for our hemp trials with below average precipitation in much of the growing season. Average temperatures during the growing period were 4.11 degrees higher than the 30-year average for the season with a 5.5% higher growing degree day accumulation for the year.

Table 3. Seasonal weather data collected in Alburgh, VT, 2020.

Alburgh, VT	June	July	August	September	October
Average temperature (°F)	66.9	74.8	68.8	59.2	48.3
Departure from normal	1.08	4.17	0.01	-1.33	0.19
Precipitation (inches)	1.86	3.94	6.77	2.75	3.56
Departure from normal	-1.77	-0.28	2.86	-0.91	0.00
Growing Degree Days (Base 50°F)	516	751	584	336	126
Departure from normal	35	121	2	-24	-6

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 plant width (p=0.0397), stem weight (p=0.0549), wet flower weight (p=0.0313), unmarketable flower (p=0.0551), and flower dry matter (p=0.0952).

Plant spacing results

The impacts of plant spacing on plant growth metrics are displayed in Tables 4 and 5. Each metric for whole plant weight, plant width, and plant height all showed significant differences across treatments. Greatest whole plant weights and widths were observed in the 5’ plant spacing and showed decreasing values as spacing decreased. The 5’ treatment had and average plant weight of 16.2 lbs plant^{-1} and was significantly greater than the other treatments with the 1’ treatment reaching only 1.98 lbs plant^{-1} on average. Plants given greater spacing also showed greatest lateral growth, however those planted closest at 1’ spacing were tallest when compared to the other treatments.

Table 4. Impacts of plant spacing on whole plant weight, width, and height. Alburgh, VT, 2020.

Treatment Spacing	Plant weight lbs plant^{-1}	Plant width cm	Plant height cm
1' x 1'	1.98 c†	59.8 c	**150 a**
3' x 3'	7.23 b	97.7 b	148 ab
5' x 5'	**16.2 a**	**140 a**	142 c
LSD (0.10)	1.65	7.77	7.57
Trial Mean	8.48	99.1	147

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.

The impact of plant spacing on plant growth metrics is displayed in Table 5. For those metrics having significant differences across plant spacing treatments (all but flower weight percentage) there were generally observable linear increasing or decreasing trends associated with an increase or decrease in plant spacing. As expected, those plants with the highest plant weights at the 5' spacing also had highest overall stem weights, flower weights, and leaf weights at 5.17, 5.09, and 5.97 lbs plant^{-1} respectively. These values decreased as plant spacing also decreased. The 1' plant spacing treatment showed the highest percentage of stems by weight at 39.0% and was statistically similar to the 3' plant spacing, whereas the 5' plant spacing had the highest percentage of leaf material at 36.3%. When looking at the percentage of flower by weight, there were no significant differences across spacing treatments.

Table 5. Plant spacing effect on fractionated plant components, Alburgh, VT, 2020.

Treatment	Stem weight	Stem weight	Flower weight	Flower weight	Leaf weight	Leaf weight	Bud:stem	Leaf:stem
Spacing	lbs plant^{-1}	%	lbs plant^{-1}	%	lbs plant^{-1}	%		
1' x 1'	0.762 c†	**39.0 a**	0.069 c	33.9	0.521 c	27.1 b	0.881 ab	0.791 b
3' x 3'	2.71 b	37.1 a	2.14 b	29.4	2.38 b	33.4 ab	0.806 b	0.942 ab
5' x 5'	**5.17 a**	31.4 b	**5.09 a**	32.3	**5.97 a**	**36.3 a**	**1.08 a**	**1.35 a**
LSD (0.10)	0.740	0.052	0.357	NS¥	1.51	8.28	0.208	0.496
Trial Mean	2.88	35.8	2.64	31.9	2.96	32.3	0.922	1.028

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

Plant spacing effects on yields are displayed in Table 6. Yields are calculated based on plant spacing and adjusted plants per acre basis. Looking solely at plant spacing treatments, the 1' plant spacing had by far the highest overall flower yields which were roughly ten times the 3' and 5' spacing yields at 22,008 lbs ac^{-1} at 8% moisture. The flower dry matter was also highest for the 1' plant spacing at 23.8% and was significantly higher than the other two spacing treatments. This may have also indicated slightly earlier dry down and maturation of flowers for those planted at 1' spacing. Unmarketable flower was highest for the 5' plant spacings at 0.203 lbs plant^{-1} which was largely as a result of lodging and diseased flower that had touched the ground.

Table 6. Plant spacing effect on biomass ratios and flower yields, Alburgh, VT, 2020.

Treatment	Unmarketable flower yield	Flower dry matter	Dry matter flower yield	Yield at 8% moisture
Spacing	lbs plant^{-1}	%	lbs ac^{-1}	lbs ac^{-1}
1' x 1'	0.034 b†	**23.8 a**	**20247 a**	**22008 a**
3' x 3'	0.043 b	19.7 b	2024 b	2200 b
5' x 5'	**0.203 a**	20.1 b	1749 b	1901 b
LSD (0.10)	0.054	2.01	2712	2948
Trial Mean	0.094	21.2	8007	8703

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.

Planting date results

The 9-Jun planting date resulted in heavier, taller, and wider plants compared to the latter two planting dates (Table 7). Whole plant weight was statistically similar to the 16-Jun planting date but was significantly higher than the 23-Jun planting date. Across each of these, there was a decrease in values associated with later planting dates.

Table 7. Planting date effect on plant weight and height, Alburgh, VT, 2020.

Planting date	Plant weight lbs plant^{-1}	Plant width cm	Plant height cm
9-Jun	**9.62 a**†	**104 a**	**155 a**
16-Jun	8.96 a	98.7 ab	150 a
23-Jun	6.87 b	95.1 b	135 b
LSD (0.10)	1.66	7.77	7.57
Trial Mean	8.48	99.1	147

†Within a column treatments marked with the same letter were statistically similar (p=0.10). Top performers are in **bold**.

Greatest differences were once again observed from between the first two planting dates and the last when looking at the fractionated components of the plants (Table 8). For stem weight, flower weight, leaf weight, and leaf to stem ratio, the 9-Jun and 16-Jun planting dates were statistically similar when compared to the 23-Jun planting date. Highest overall stem weight and percentages were observed in the 16-Jun planting date at 3.49 lbs plant^{-1} and 40.9% respectively. Highest values for flower weight and percentage of floral material were seen in the 9-Jun planting date at 3.03 lbs plant^{-1} and 34.4% respectively. Overall, the amounts of flower decreased from the first planting date. While there were no significant differences in leaf weight between planting dates, the percentage of leaf material for plants was significantly higher at the third planting date at 42.8%.

Table 8. Planting date effect on fractionated plant components, Alburgh, VT, 2020.

Treatment Planting Date	Stem weight lbs plant^{-1}	Stem weight %†	Flower weight lbs plant^{-1}	Flower weight %	Leaf weight lbs plant^{-1}	Leaf weight %	Bud:stem	Leaf:stem
9-Jun	3.31 a†	36.5 a	**3.03 a**	**34.4 a**	3.28	29.2 b	0.987	0.890 b
16-Jun	**3.49 a**	**40.9 a**	2.98 a	34.2 a	2.48	24.9 b	0.843	0.630 b
23-Jun	1.84 b	30.1 b	1.91 b	27.1 b	3.12	**42.8 a**	0.935	**1.56 a**
LSD (0.10)	0.74	0.052	0.357	5.57	NS¥	8.28	NS	0.496
Trial Mean	2.88	0.358	2.64	31.9	2.96	32.3	0.922	1.03

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

Flower dry matter and yields are displayed in Table 9. Across the three planting dates, there were no observable differences in flower yields or unmarketable flower. Flower dry matter was significantly different across treatments with highest observed values seen from the 23-Jun planting date at 22.7%

Table 9. Planting date effect on flower dry matter and yields, Alburgh, VT, 2020.

Treatment Planting Date	Unmarketable flower yield lbs plant^{-1}	Flower dry matter %	Dry matter flower yield lbs ac^{-1}	Yield at 8% moisture lbs ac^{-1}
9-Jun	0.081	20.4 b†	7864	8548
16-Jun	0.115	20.6 b	8510	9250
23-Jun	0.084	**22.7 a**	7646	8311
LSD (0.10)	NS	2.01	NS¥	NS
Trial Mean	0.094	21.2	8007	8703

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

DISCUSSION

Hemp is a photoperiod sensitive plant and produces vegetative growth as day length increases and switches to reproductive growth as day length decreases. This trial indicates that adequate yield can be obtained from hemp when planted throughout the month of June. Greatest difference in plant proportions were observed between the first two and last planting dates. This last week in June may be a key planting date where adequate yields can still be obtained, however pushing this date further out may have more significant impacts on flower yields overall. Continued, later planting dates may have greater impacts on yields when prolonging planting into July as plants would likely not have adequate time for vegetative growth to bear flowers. Later planting dates may have resulted in continued vegetative growth after day length began to decrease, due to later transplanting and establishment.

When looking at plant spacings, there were similarly clear differences observed across each treatment. While 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. Regardless of seed or clone costs, higher planting density would ultimately result in increased material costs on top of associated labor costs. Quality considerations would also need to be considered as greater planting density could result in less marketable flower, or even potential for increased disease pressure resulting from poor airflow. Plants grown at 5 x 5' spacing 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. Furthermore, this does not address other inputs such as irrigation, fertilizer, field preparation, drying, and processing among other things. While cannabinoid concentrations were not analyzed this year, past years of research showed that plant spacing did not impact the overall cannabinoid concentrations. Conversely, when looking at planting dates, those planted at the later date resulted in overall lower concentrations of cannabinoids indicating a lack of time for trichomes and associated cannabinoids to fully develop.

ACKNOWLEDGEMENTS

The UVM Extension Northwest Crops and Soils Program would like to thank Roger Rainville and the staff at Borderview Research Farm for their generous help with the trials. This project was supported by and was funded through our This work was funded by the Northeastern IPM Center through Grant #2018-70006-2882 from the National Institute of Food and Agriculture, Crop Protection and Pest Management, Regional Coordination Program. We would like to acknowledge Henry Blair, Catherine Davidson, Hillary Emick, and Lindsey Ruhl for their assistance with data collection and data entry. This information is presented with the understanding that no product discrimination is intended and neither endorsement of any product mentioned, nor criticism of unnamed products, is implied.

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