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2017 INDUSTRIAL HEMP FIBER 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 reemerging in worldwide importance as manufacturers seek hemp as a renewable and sustainable resource for a wide variety of consumer and industrial products. The fiber has high tensile strength and can be used to create a variety of goods. Hemp consists of two types of fiber: bast and hurd. The bast fiber are the long fibers found in the bark of hemp stalks and are best suited for plastic bio-composites for vehicles, textiles, rope, insulation, and paper. The hurd fiber are short fibers found in the core of the stem and are suited for building materials, such as hempcrete and particle boards, bedding materials, and absorbents.

For twenty years, U.S. entrepreneurs have been importing hemp from China, Eastern Europe and Canada. Industrial hemp is poised to be a “new” cash crop and market opportunity for Vermont farms that is versatile and suitable for rotation with other small grains and grasses. To help farmers succeed, agronomic research on hemp is needed, as much of the historical production knowledge for the region has been lost. In this trial, we evaluated 2 hemp fiber varieties over 4 planting dates to determine best planting dates for the region.

MATERIALS AND METHODS

Table 1. Agronomic information for industrial hemp fiber planting date trial 2017, Alburgh, VT.

Location	**Borderview Research Farm Alburgh, VT**
Soil type	Covington silty clay loam, 0-3% slope
Previous crop	Dry beans
Plot size (ft)	5x20
Planting dates	20-May, 29-May, 5-Jun, 12-Jun
Emergence dates	31-May, 8-Jun, 15-Jun, 23-Jun
Row spacing	7”
Planting equipment	Great Plains NT60 Cone Seeder
Planting rate (live seeds m^{-2})	250
Mowing date	24-Aug

Trials were conducted at Borderview Research Farm in Alburgh, Vermont (Table 1) to evaluate the impact of planting date on hemp fiber yield. The experimental design was a randomized complete block with split plots and four replications. The main plots were planting dates of 20-May, 29-May, 5-Jun, and 12-Jun.

Table 2. Hemp varieties evaluated in the industrial hemp fiber planting date trial 2017, Alburgh, VT.

Variety	Seed company	Days to maturity
Beniko	Schiavi Seeds	120
Carmagnola	Schiavi Seeds	160-170

The subplots were two hemp varieties, one each of short and long maturity (Table 2). Plot size was 5 x 20 feet. Seeding rates were adjusted after accounting for germination rates and a mortality rate of 30%. The typical seeding rate used by hemp fiber growers is between 40-50 lbs ac^{-1}. On 6-Jul, the trial was fertilized with 100 lbs ac^{-1} of nitrogen, 60 lbs ac^{-1} of phosphorus, and 60 lbs ac^{-1} of potassium. Fertility amendments were based on soil test results. All fertility amendments were approved for use in organic systems.

A month after planting, plant populations were recorded by counting the number of plants in a foot-long section of a row, three times per plot. Infection rates from the disease *Sclerotinia sclerotiorum* were recorded 1.5 months after planting, at female flower development stage, and just before harvest on 17-Aug by counting the number of infected plants per plot. Pest pressure from arthropods was recorded at those times as well, by counting the number and variety of each arthropod present on two leaves from five plants per plot. Plant heights were measured just prior to harvest by measuring three randomly selected plants per plot. On 23-Aug, wet weight harvest yields were calculated by sampling the hemp biomass within a $0.25m^2$ quadrat. Harvest moisture was calculated by taking a subsample of hemp yield and drying it at 105° F till it reached a stable weight. On 24-Aug the fiber plants were mowed using a 5-foot sickle bar mower and allowed to ret in the field for approximately three weeks.

Image 1. Custom built decorticator, Alburgh, VT, 2017.

After retting, the stalks were decorticated to separate the bast and hurd fibers, using a custom built decorticator (Image 1). As the stalks passed between the two moving gears, hurd fiber broke away and dropped to the floor or a bucket, placed underneath.

The data were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and planting date and variety treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$). Across planting dates, 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 3. Seasonal weather data collected in Alburgh, VT, 2017.

Alburgh, VT	May	June	July	August
Average temperature (°F)	55.7	65.4	68.7	67.7
Departure from normal	-0.75	-0.39	-1.90	-1.07
Precipitation (inches)	4.10	5.60	4.90	5.50
Departure from normal	0.68	1.95	0.73	1.63
Growing Degree Days (base 50°F)	245	468	580	553
Departure from normal	47	-7	-60	-28

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.

Throughout the growing season, temperature and precipitation fluctuated away from the 30-year historical averages. May-August was wetter than normal, receiving 4.99 more inches of precipitation as compared to historical averages (Table 3). Temperatures in May-August were cooler than normal by an average of 1° F per month. Overall, there were an accumulated 2293 Growing Degree Days (GDDs) from May to August, approximately 48 more than the historical average.

Field Results by Planting Date

Table 4. The impact of planting date on plot characteristics and harvest yield of industrial hemp fiber, Alburgh, VT, 2017.

Planting date	Height @ harvest	Stem diameter	Population	Dry matter yield	Moisture @ harvest	Bast fiber
	cm	mm	plants ac^{-1}	lbs ac^{-1}	%	%
20-May	142*	4.24	107	13,136	66.8	18.5
29-May	159*	**5.62***	128	17,180	66.8	22.0
5-Jun	**162***	5.18*	102	12,419	69.4	23.1
12-Jun	127	4.04	118	7,197	68.0	26.1
LSD (0.10)	22.8	1.16	NS	NS	NS	NS
Trial mean	147	4.77	114	12,483	67.8	22.4

*Treatments marked with an asterisk performed similarly to the top performing treatment (p=0.10) shown in **bold**.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

The 29-May planting date had the highest yield, however, yields from the other planting dates were statistically similar (Table 4). The 29-May and 5-Jun planting dates performed well for both height (159 and 162 cm, respectively) and stem diameter (5.62 and 5.18 mm, respectively). There was no significant difference between planting dates for populations, harvest moisture, or bast fiber content.

Table 5. The impact of planting date on disease and arthropod presence in industrial hemp fiber at female flower development, Alburgh, VT, 2017.

Planting date	Aphids	Leafhopper	Spiders	Japanese beetles	Tarnished plant bug	Physical damage
	# $plant^{-1}$	# $plant^{-1}$	# $plant^{-1}$	# $plant^{-1}$	# $plant^{-1}$	# $plant^{-1}$†
20-May	0.050	0.075	0.025	0.000	0.025	**0.200***
29-May	0.050	0.200	0.000	0.025	0.050	0.500*
5-Jun	0.175	0.100	0.000	0.025	0.025	1.00
12-Jun	0.200	0.050	0.025	0.025	0.050	1.08
LSD (0.10)	NS	NS	NS	NS	NS	0.333
Trial mean	0.119	0.106	0.013	0.019	0.038	0.694

†Physical damage from insect pests was recorded as the average number of damaged leaves per plant.
*Treatments marked with an asterisk performed similarly to the top performing treatment (p=0.10) shown in **bold**.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Aphid, leafhopper, spider, Japanese beetle, and tarnished plant bug presence was low during the female development stage and not significantly different between planting dates (Table 5). Physical damage caused by insect pests was significantly lower for the 20-May and 29-May planting dates; however, damage to plants was extremely low across all planting dates.

Table 6. The impact of planting date on disease and arthropod presence in industrial hemp fiber prior to harvest (17-Aug), Alburgh, VT, 2017.

Planting date	Sclerotinia infection	Aphids	Leafhopper	Spiders	Japanese beetles	Tarnished plant bug	Physical damage
	% of plants	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}†
20-May	0.125	0.950	0.050	0.025	0.075	0.000	0.300
29-May	0.000	2.43	0.000	0.025	0.125	0.000	0.325
5-Jun	0.125	1.43	0.075	0.000	0.000	0.000	0.325
12-Jun	0.000	1.05	0.025	0.050	0.050	0.025	0.175
LSD (0.10)	NS	NS	NS	NS	NS	NS	NS
Trial mean	0.063	1.46	0.038	0.025	0.063	0.006	0.281

†Physical damage from insect pests was recorded as the average number of damaged leaves per plant.
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Sclerotinia sclerotiorum, infection (Image 2) was present later in the season, however, levels were low and not significantly different between planting dates (Table 6). The aphid populations also increased, while leafhopper populations decreased. There was no significant difference between planting dates for levels of spiders, Japanese beetle, tarnished plant bug presence or insect physical damage.

Image 2. *Sclerotinia sclerotium* infection on industrial hemp, Alburgh, VT, 2016.

Field Results by Variety

Table 7. The impact of variety on plot characteristics and harvest yield of industrial hemp fiber, Alburgh, VT, 2017.

Planting date	Height @ harvest	Stem diameter	Population	Dry matter yield	Moisture @ harvest	Bast fiber
	cm	mm	plants ac^{-1}	lbs ac^{-1}	%	%
Beniko	122	3.89	472,526	10,422	68.3	77.0
Carmagnola	**173**	**5.64**	447,491	14,544	67.2	78.2
LSD (0.10)	16.2	0.820	NS	NS	NS	NS
Trial mean	147	4.77	460,008	12,483	67.8	77.6

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

When comparing between varieties across all planting dates, Carmagnola outperformed Beniko for plant height and stem diameter (Table 7). There were no significant differences between the varieties for population, dry matter yield, harvest moisture, and bast fiber content.

Table 8. The impact of variety on disease and arthropod presence in industrial hemp fiber at female flower development, Alburgh, VT, 2017.

Planting date	Aphids	Leafhopper	Spiders	Japanese beetles	Tarnished plant bug	Physical damage
	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}†
Beniko	0.100	0.100	0.013	0.013	0.050	**0.550**
Carmagnola	0.138	0.113	0.013	0.025	0.025	0.838
LSD (0.10)	NS	NS	NS	NS	NS	0.236
Trial mean	0.119	0.106	0.013	0.01	0.038	0.694

†Physical damage from insect pests was recorded as the average number of damaged leaves per plant.
Top performing treatment (p=0.10) shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).

At the time of female flowering, physical damage from insect pests was significantly lower for Beniko than for Carmagnola, however, damage overall was low (Table 8). Additional arthropod presence was low and not significantly different between varieties.

Table 9. The impact of variety on disease and arthropod presence in industrial hemp fiber prior to harvest (17-Aug), Alburgh, VT, 2017.

Planting date	Sclerotinia infection	Aphids	Leafhopper	Spiders	Japanese beetles	Tarnished plant bug	Physical damage
	% of plants	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}	# plant^{-1}†
Beniko	0.000	**0.750**	0.063	0.013	0.088	0.000	0.300
Carmagnola	0.125	2.18	**0.013**	0.038	0.038	0.013	0.263
LSD (0.10)	NS	1.01	0.044	NS	NS	NS	NS
Trial mean	0.063	1.46	0.038	0.025	0.063	0.006	0.281

†Physical damage from insect pests was recorded as the average number of damaged leaves per plant.
Top performing treatment (p=0.10) shown in **bold.**
NS – There was no statistical difference between treatments in a particular column (p=0.10).

Just prior to harvest, aphid infestation was significantly lower for Beniko while leafhopper infestation was significantly lower for Carmagnola (Table 9). However, these infestation levels were low, along with the levels for leafhoppers, spiders, Japanese beetles, tarnished plant bug, and physical insect pest damage. A very low level rate of *Sclerotinia sclerotiorum* infection became apparent in Carmagnola, while Beniko did not show infection. Neither variety had the infection earlier in the season, at the time of female flowering.

Field Results by Planting Date x Variety

There was no significant interaction between planting date and variety for yield. This means varieties performed similarly regardless of planting dates.

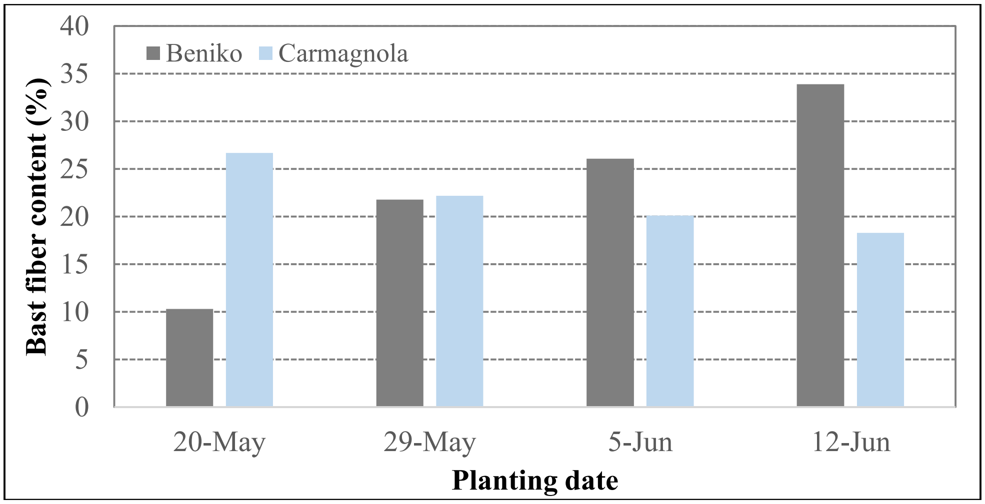

Figure 1. The effect of planting date and variety on bast fiber content (p-value = 0.0014), Alburgh, VT, 2017.

There was a significant interaction between planting date and variety for bast fiber content. The variety Carmagnola had higher bast fiber contents compared to Beniko for the May planting dates and lower contents for the June planting dates, essentially showing opposite responses to the impact of planting date. The fiber content of Beniko consistently increased while Carmagnola decreased with later planting dates (Figure 1).

DISCUSSION

Yield and Quality

All hemp varieties at all planting dates matured by the end of the growing season. Generally, the male flowers (pollen source) appeared 60 days after planting and completed pollen drop 10 days later. Seed development began after pollen drop for Beniko (120 DTM) and about 10 days later for Carmagnola (160-170 DTM). The hemp was mowed when plants were still young and green and seed was less than 50% ripe. For hemp fiber intended for textile use, it is best to mow the crop when the male plants are shedding pollen, since at that stage the bast fiber is not heavily lignified. Some hurd buyers prefer the hemp not to be retted, since the process changes the fiber color. If retting is not required, windrows of hemp stalks can be baled when the straw is 12-16% moisture. Rotary rakes can be used to help the hemp dry.

Average dry matter yield across all planting dates and varieties was 12,483 lbs ac^{-1} and was well-above average yields from Canada, which range from 5000-6000 lbs ac^{-1}. The dry matter yield reported in the project includes all plant material harvested, including leaves and seed heads, which may not be included in the reported Canadian yields. The second planting day, 29-May, had the highest yield of 17,180 lbs ac^{-1} although this was not significantly higher than the other planting dates. It is possible that the 29-May planting had an advantage since it had more time to grow, yet did not experience cool, wet early spring conditions for as long as the 20-May planting. Across all planting dates and varieties, bast fiber comprised 22.4% of the stalk compared to the hurd fiber. Depending on variety and planting density, bast fiber typically represents 20-30% of the total fiber content. The average population was 113.7 plants m^{-2}, which was lower than the target population of 250 plants m^{-2}. Poor early season establishment seen in this trial emphasizes the need to evaluate strategies to improve germination and early season vigor (i.e. seed treatments, seeding rates, starter fertilizers). The average height across varieties was 1.47 m, while a desirable height is 2 m or greater. However, the taller varieties may leave more possibility for lodging. The lack of heat during the early and mid-part of the season may have contributed to shorter plants.

Pest Pressure in Hemp: Disease, insects, weeds

Hemp has the potential to host a number of diseases and insects. For the most part, hemp growing regions have not indicated that disease and arthropod pests are of economic significance. During the growing season, a survey of pest incidence was conducted to gain a better understanding of any pressures that exist on hemp in the region. Aphids infested the hemp more heavily during later stages of plant development and but did not seem to affect plant yields, since most vegetative growth had already been completed. Similarly, *Sclerotinia sclerotiorum* infection increased later in the season, but did not seem to affect yields. Early season weeds can pose a threat to hemp populations, however, due to the higher seeding rate it seemed the weeds were less competitive with the fiber hemp as compared to grain hemp. The primary weeds observed in the hemp trials were lamb’s quarter, ragweed, and foxtail. Currently, there are no pesticides (herbicides, insecticides, fungicides, nematicides, etc.) registered for hemp in the U.S, so growers must follow best practices to reduce the impact of pests, especially weeds. It is important to remember that these data represent only one year of research, and in only one location. More data should be considered before making agronomic management decisions. Additional research needs to be conducted to evaluate varieties under more growing conditions.

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