NORTHWEST CROPS & SOILS PROGRAM

2023 Industrial Hemp Fiber Seeding Rate Trial

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THE UNIVERSITY OF VERMONT EXTENSION

2023 INDUSTRIAL HEMP FIBER SEEDING RATE 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 is 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 stalks contain two types of fiber: bast and hurd. The bast fibers are the long fibers found in the bark layer of the hemp stalk and are best suited for textiles, nonwoven textiles, rope, insulation, bio-composites for vehicles, or paper. The hurd fiber comprises the woody core of the stem and are suited for building materials, such as hempcrete and particle boards, bedding materials, and absorbents.

For decades, U.S. entrepreneurs have been importing hemp fiber from China, and Eastern Europe. Industrial hemp is poised to be a "new" cash crop and market opportunity for Vermont farms. It is also 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. Research needs to be conducted to determine best cropping practices for the region. In this trial, we evaluated the impact of four seeding rates on hemp fiber yield and quality.

MATERIALS AND METHODS

Table 1. Agronomic information for the industrial hemp fiber variety trial 2023, Alburgh, VT.

Location	**Borderview Research Farm, Alburgh, VT**
Soil type	Benson rocky silt loam over shaly limestone, 3-8% slope
Previous crop	Spring Grains
Plot size (ft)	5 x 20
Variety, Source	Futura 83, KonopiUS Seeds
Seed Contact	Robin Destiche (robin@konopius.com)
Planting date	25-May
Row spacing	7"
Planting equipment	Great Plains NT60 Cone Seeder
Seeding rate (lbs ac^{-1})	21, 44, 55, 80
Mowing date	8/11

A trial was conducted at the Borderview Research Farm in Alburgh, Vermont (Table 1) to evaluate the impact of seeding rate on fiber yield. The experimental design was a randomized complete block with five replications. The variety used for testing was Futura 83 (KonopiUS Seeds). The four seeding rates trialed in this experiment were 21 lbs ac^{-1}, 44 lbs ac^{-1}, 55 lbs ac^{-1}, and 80 lbs ac^{-1}, and the target populations were, 485,623, 1,000,000, 1,246,433, and 1,821,087 live seeds ac^{-1} respectively. Seeds were sown on 25-May into 5'x 20' plots.

On 8-May, approximately 2.5 weeks prior to planting, the trial field received 300 lbs ac^{-1} 19-19-19. Fertility amendments were based on soil test results. On 25-May, plots were seeded with a Great Plains NT60 cone seeder, and on 1-Jun plant emergence populations were recorded by counting the number of plants in a foot-long section of the row, three times per plot. On 11-Aug in accordance with full flowering, wet weight harvest yields were calculated by sampling the hemp biomass within a 0.25 m^2 quadrat. Harvest moisture was calculated by taking a subsample of hemp biomass and drying it at 105º F until it reached a stable weight. Heights and stem diameters were recorded from five randomly selected plants within each plot before they were run through a custom-built decorticator (Image 1). While the stalks were still fresh, they were weighed and decorticated to separate the bast and hurd fibers. As the stalks passed between the two moving gears, hurd fiber broke away and dropped to a bucket placed underneath. The bast and hurd were weighed to determine ratios and differences.

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

The seeding rate trial 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 seed rate treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

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 an 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). June exhibited cloudy weather with relatively standard rainfall. July's rainfall saw a staggering departure from normal with 10.8 inches of precipitation, 6.74 inches more than the 30 year average. Much of Vermont experienced persistent rain in tandem with hazy conditions caused by Canadian wildfire smoke over the course of July and August. Despite the heavy rainfall, the well-saturated research farm did not experience the heavy flooding that wrought havoc on many other farms in the state. Overall, from May to September there were 23.4 inches of rain and 2038 Growing Degree Days (GDDs) accumulated, which was 124 GDDs below normal.

Table 2. Seasonal weather data collected in Alburgh, VT, 2023.

Alburgh, VT	May	June	July	August
Average temperature (°F)	57.1	65.7	72.2	67.0
Departure from normal	-1.28	-1.76	-0.24	-3.73
Precipitation (inches)	1.98	4.40	10.8	6.27
Departure from normal	-1.78	0.14	6.69	2.73
Growing Degree Days (Base 50°F)	303	483	712	540
Departure from normal	1.00	-41.0	17.0	-101

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 (1991-2020) from Burlington, VT.

Table 3. The impact of seeding rate on plant characteristics and harvest yield of fiber hemp, Alburgh, VT 2023.

Seeding Rate lbs ac^{-1}	**Plant height** cm	**Stem diameter** mm	**Dry matter yield** lbs ac^{-1}	**Dry matter yield** Tons ac^{-1}	**Harvest population** plants ac^{-1}	**Harvest population** plants ft^{-2}	**Bast fiber** %	**Hurd fiber** %
21	**218**	**9.17**	**17,393**	**8.70**	265,474	6.09	**21.5**	78.5
44	171	6.09	13,434	6.72	517,997*†	11.9*	17.6	**82.4**
55	198	6.38	16,223	8.11	725,196*	16.6*	20.6	79.3
80	167	5.55	15,702	7.85	**770,521**	**17.7**	20.3	79.7
LSD (p=0.10) ‡	**NS§**	**NS**	**NS**	**NS**	**271,641**	**6.24**	**NS**	**NS**
Trial Mean	**188**	**6.80**	**15,688**	**7.84**	**569,797**	**13.1**	**20.0**	**80.0**

†*Treatments marked with an asterisk did not perform statistically different than the top performing treatment shown in **bold** (p=0.10).
‡LSD; least significant at the p=0.10 level.
§NS – There was no statistical difference between treatments in a particular column (p=0.10).

The trial results by fiber hemp seeding rate are summarized in Table 3. Our goal with this experiment was to observe the impact of four different seeding rates on plant characteristics and yield. Determining a seeding rate for fiber hemp can vary greatly depending on end-use. Those growing for both fiber and grain, or dual purpose, might plant at a low seeding rate, while very high seeding rates are utilized for high quality spinning fiber. Generally, seeding rate will impact the size of the plants inversely; as the seeding rate increases the average size of the plants decrease due to crowding. Our trial showed this basic trend (Table 3), but ultimately, there was no statistically significant difference in plant height or stem diameter across the four treatments due to variation within the replications. There was also no significant difference observed in terms of yield, though the highest yield recorded came from seeding rate 21 lbs ac^{-1}, at 8.7 tons ac^{-1}. All seeding rates also produced statistically similar ratios of bast fiber. Curiously, the 44 lbs ac^{-1} treatment was outperformed in all categories by the 55 lbs ac^{-1} treatment, though no statistically significant difference was observed between them at any point in the data set.

One category where a statistical difference was observed was in population counts. The 80 lbs ac^{-1} treatment produced the most plants at 770,521 plants ac^{-1} (Table 3). Both the 44 and 55 lbs ac^{-1} treatments produced statistically similar stands to that of the 80 lbs ac^{-1} treatment. The 21 lbs ac^{-1} treatment produced only 265,474 plants ac^{-1}, which was less than half of the populations of the two most densely populated treatments. That said, with less than half the stand density of its counterparts, the 21 lbs ac^{-1} treatment yielded more biomass than any other treatment in this trial. This data suggests that in general, maximizing biomass yield depends on growing larger plants, not more plants.

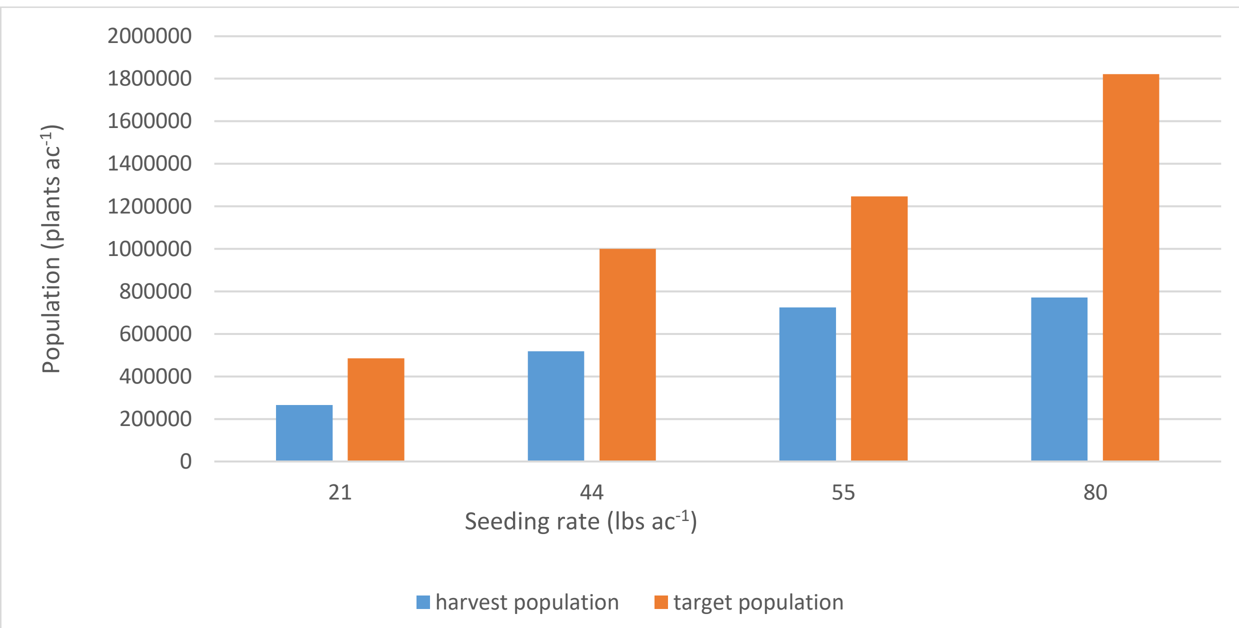

Figure 1. Observed Populations at Harvest vs. Target Populations of the 2023 Fiber Hemp Seeding Rate Trial

Figure 1 depicts the observed populations of live plants ac^{-1} for each seeding rate alongside its target population. Seeding rates were adjusted to account for germination rate. Avipel, a nonlethal, organic chemical bird repellent, was also applied to the seed prior to planting. From the time of planting on 25-May, the trial plots did not see rain for twelve days until 6-Jun, when 0.44 inches of precipitation fell. It is possible that this stretch of dry weather, at the critical moment of germination, could have contributed to reduced stand density.

DISCUSSION

In the 2023 growing season, the UVM extension Northwest Crops and Soils Program initiated a fiber hemp seeding rate trial to evaluate the impact of seeding rate on fiber quality and plant characteristics. This trial marked our first look at the impacts of seeding rate on fiber hemp. The growing season was wet, with 7.78 inches of rain above average, and also cool, with 124 less accumulated Growing Degree Days than normal. May, June, July, and August were all cooler than normal, and the combination of cool and dry conditions towards the end of May may have affected establishment. July saw 6.69 inches of rain above the 30 year average, which saturated the soil for much of the growing season.

In our trial, planting fiber hemp variety Futura 83 at seeding rates of 21, 44, 55, and 80 lbs ac^{-1} did not produce statistically significant differences in heights, stem diameters, dry matter yields, or bast:hurd content. However, it did produce a statistically significant difference in population counts. Population counts across all seeding rates were lower than target populations (Figure 1), yet biomass yields were encouraging. According to the National Hemp Report issued by the USDA in early 2023, the average yield for 2022 fiber hemp was estimated at 3,070 lbs ac^{-1}. In our trial, the average dry matter yield across all seeding rates was 15,688 lbs ac^{-1} (Table 3). This was also more than double our 2022 average dry matter yield of 7,486 lbs ac^{-1}. Plant heights averaged 188cm, which was 56 cm above the 2022 variety trial average of 132cm, and may have been influenced by the increased rainfall and weather conditions experienced over the course of the growing season.

Hemp plants grown exclusively for fiber are usually cut or harvested at peak flowering before many seeds have begun to set, typically around 70 days. Plants will largely still be green and less mature than those harvested for grain or dual production. Hemp fiber production also requires a retting process prior to baling and processing in order to separate the fibers. Retting is akin to a controlled rot, and most often takes place in the field, but can also occur by submerging the plants in water. By leaving the plants on the ground after they have been cut, the plant cell tissues that bind the bast fiber to the hurd break down. The speed of the field retting process is influenced by moisture and temperature, which directly impacts microbial activity responsible for breaking down the lignin, pectin, and hemicellulose binding the fibers. Warm and moist conditions, like those typical of the late Vermont summer, will encourage increased microbial activity and thus speed the retting process, which can take anywhere from 7-45 days. If the climate is too dry at this time, the stalks will dry out and field retting will not occur naturally. The stalks must also be turned periodically to ensure an even retting process. With these factors in mind, some specific equipment, as well as a modest yet acute visual literacy of the retting process is required in order to effectively harvest and process quality hemp fiber. That being said, yields from this trial indicate that hemp fiber can be grown and harvested in the Northeast with favorable outcomes.

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