NORTHWEST CROPS & SOILS PROGRAM

2023 Industrial Hemp Fiber Variety Trial

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THE UNIVERSITY OF VERMONT EXTENSION

2023 INDUSTRIAL HEMP FIBER VARIETY 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 is 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. In this trial, we evaluated fifteen hemp fiber varieties to determine best cultivars for the region.

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
Planting date	25-May
Row spacing	7"
Planting equipment	Great Plains NT60 Cone Seeder
Seeding rate (live seeds m^{-2})	450
Harvest date	See Table 2

In 2023, a trial was conducted at the Borderview Research Farm in Alburgh, Vermont (Table 1) to evaluate the impact of variety on fiber yield and quality. The experimental design was a randomized complete block with four replications. There were fifteen hemp varieties evaluated (Table 2) in the trials. The typical seeding rate used when growing industrial hemp is usually 55-65 lbs ac^{-1}, and even up to 80 lbs ac^{-1} for thin spinning fiber. In this experiment, seeding rates were adjusted for germination rate as well as thousand kernel weight, and ranged from 64.7- 148 lbs ac^{-1} with the intention of producing 450 live seeds m^{-2} or approximately 41.8 plants sq ft^{-2}. Plot size was 5'x20' in size.

Table 2. Hemp varieties evaluated in the industrial hemp fiber trial 2023, Alburgh, VT.

Variety	Date Harvested for Data Collection	Days to seed maturity	Seed supplier
Bialobrzeski	8-Aug	115	International Hemp
Carmenecta	22-Aug	140	International Hemp
Fedora 17	8-Aug	129-134	Konopius Seeds
Felina 32	8-Aug	133-138	Hemp Seed Warehouse
Ferimon 12	9-Aug	129-134	Hemp Seed Warehouse
Fiber 1	5-Sep	140-150	Kanda Seeds
Fibror 79	11-Aug	101-106	Konopius Seeds
Futura 83	9-Aug	110-118	Konopius Seeds
Muka 76	9-Aug	102-108	Konopius Seeds
Orion 33	8-Aug	120	Hemp Seed Warehouse
Santhica 70	9-Aug	97-102	Konopius Seeds
USO 31	8-Aug	122-127	Hemp Seed Warehouse
Yuma	25-Sep	160	Kanda Seeds
Yuma- S	28-Aug	140	Kanda Seeds
Yuma- T	28-Aug	140	Kanda Seeds

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. From 3-Jul to 25-Sep, 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 diameter were determined from five randomly selected plants from within each plot. Ten plants were also selected at random from each plot and 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. Whole stem weights and bast fiber weights were recorded to determine ratios and varietal differences.

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

The variety 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 variety treatments were

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

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 3). June exhibited cloudy weather with 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 catastrophic flooding 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 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 3. 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	-41	17	-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 4. The impact of variety on plant characteristics and harvest yield of industrial hemp fiber, Alburgh, VT, 2023.

Variety	Plant height	Stem diameter	Harvest population	Harvest population	Dry matter yield	Dry Matter Yield	Bast fiber	Hurd fiber
	cm	mm	plants ac^{-1}	plants ft^{-2}	lbs ac^{-1}	Tons ac^{-1}	%	%
Bialobrzeski	160	4.68	805,324	18.5	13,686	6.84	33.6*†	66.4
Carmenecta	233	7.12	465,388	10.7	15,730	7.87	14.1	85.9*
Fedora 17	168	4.73	627,262	14.4	15,520	7.76	27.7	72.3
Felina 32	173	5.46	712,246	16.4	15,626	7.81	27.4	72.6
Ferimon 12	158	4.88	**1,023,854**	**23.5**	15,211	7.61	32.2*	67.8
Fiber 1	**302**	**11.6**	542,279	12.5	**24,278**	**12.1**	11.6	88.4*
Fibror 79	183	7.12	586,794	13.5	16,565	8.28	32.7*	67.3
Futura 83	184	5.92	667,731	15.3	16,283	8.14	35.4*	64.7
Muka 76	167	5.10	789,137	18.1	19,063	9.53	**35.4**	64.4
Orion 33	207	8.08	400,639	9.20	16,637	8.32	21.3	78.7
Santhica 70	166	5.35	590,841	13.6	14,645	7.32	29.1*	70.9
USO 31	162	5.25	562,513	12.9	12,003	6.00	31.6*	68.4
Yuma	187	6.33	768,902	17.6	19,198	9.60	11.2	**88.8**
Yuma-S	185	6.79	716,293	16.4	17,333	8.67	14.3	85.7*
Yuma-T	191	5.96	683,918	15.7	14,790	7.39	15.1	84.9*
LSD (p=0.10)‡	**21.9**	**1.54**	**189,787**	**4.36**	**NS§**	**NS**	**7.69**	**7.69**
Trial Mean	**188**	**6.29**	**662,875**	**15.2**	**16,438**	**8.22**	**24.8**	**75.2**

†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).

With hemp being such a versatile plant, one must be clear on their goals for end-use from the start. Whether it's the choice of variety or seeding rate, agronomic practices will have a strong influence on the resulting crop. In our trial, our initial goal was to produce a dense stand of plants with stem diameters comparable to that of a pencil or chopstick (6-7mm). This is the recommended girth of plants grown for textile-quality bast fiber. Stem diameter can be manipulated by the density at which the seed is sown. More seed will result in a greater number of thinner plants that stretch upwards to compete for sunlight in the canopy without much lateral branching. Others might optimize their growing conditions for high biomass yield, using less seed for the production of bigger, more spacious plants. Others still might prioritize optimal hurd production, or dual cropping. In our trial, Fiber 1 had the largest stem diameters with an average of 11.6mm, and the greatest extrapolated dry matter yield of 12.1 tons ac^{-1} (Table 4). Plants with a higher ratio of hurd fiber will have a thicker woody core. This is not optimal for textile production but is well suited for other industrial applications. Yuma hit the average target stem diameter with the second highest dry matter yield in the trial. Yuma, however, is not bred for textile grade fiber and did not yield a favorable ratio of bast fiber. Yuma is better suited for hurd fiber production than for textile fiber.

French varieties including Ferimon 12, Fibror 79, Futura 83, and Muka 76, continue to be consistent and reliable performers in our region (Table 4). These varieties also produced some of the highest bast fiber yields in the trial. Fibror 79 has a unique genetic marker that colors the stem and foliage yellow, as seen on the cover page of this report. This is a characteristic that is unique to some fiber hemp varieties and is linked to a more tender and less hearty stalk than some. For these reasons, Fibror 79 had the most severe lodging compared to its more robust counterparts.

The tallest of the fifteen varieties in the 2023 fiber variety trial was Fiber 1 by Kanda Hemp with an average height of 302 cm, or 9.9 ft. No other varieties produced average heights of statistical similarity, with the second tallest variety, Carmenecta, averaging 233 cm. Fiber 1 also yielded the largest quantity of biomass, which was measured to be 12.1 tons per acre. Noting that Fiber 1 had a lower stand count than most at only 12.5 plants/sqft, it is evident that this high yield was the result of the towering stature of the plants and not the density of the stand. No matter what your primary end-use is for your industrial hemp fiber crop, bast and hurd fibers are each a profitable byproduct of the other and turning the highest profit hinges on maximizing yields of both. Important factors to account for during the growing season include genetics, soil fertility, germination rate, seeding rate, and harvest timing.

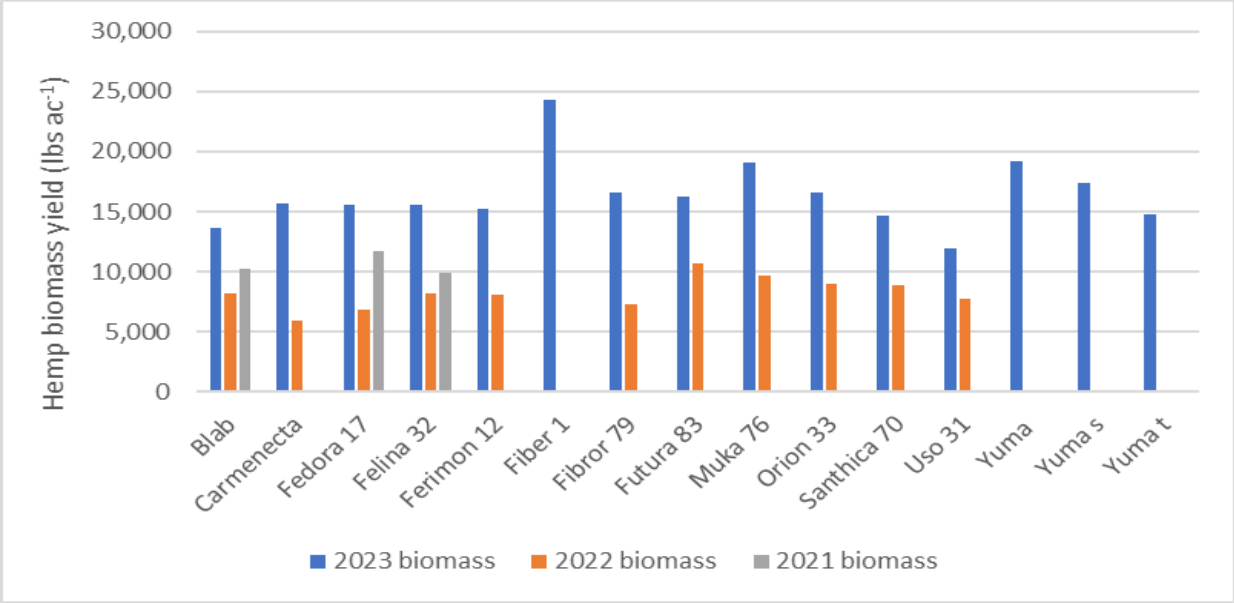

Figure 1. Dry matter biomass yields by variety and year for hemp fiber variety trials in 2021, 2022, and 2023 Alburgh, VT.

The hemp biomass yields in 2023 were significantly higher than in the two previous years (Figure 1). There were more growing degree days in the summer months of both 2022 and 2021, so to what can the higher yields be attributed?

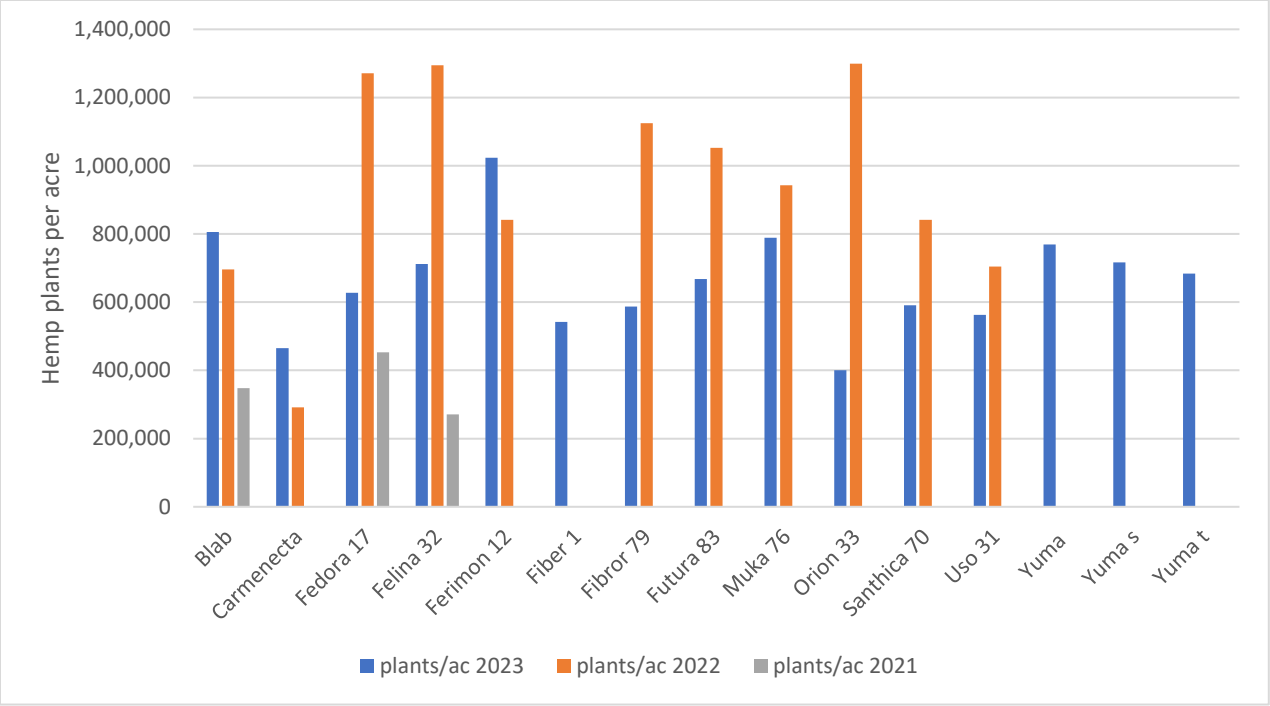

Figure 2. Plants per acre by variety and year for hemp fiber variety trials in 2021, 2022, and 2023 Alburgh, VT.

Despite the greater dry matter yields in 2023, 2022 generally had higher populations of plants per acre, meaning that 2023's greater yields were attributed to fewer, bigger plants, not more plants. It was visibly obvious to our team that the 2023 trials were significantly taller than in the previous year, as illustrated by Figure 3. We speculate that rainfall may have played a role in the size of the plants for the 2023 season. In the summer of 2023, our farm experienced 23.4 inches of rain, while in 2022 there were only 19.49 inches of rain during the growing season. The 2023 season also featured a very cloudy June, when the plants would have been in the critical early phases of vegetation that would demand they stretch upwards to capture as much sunlight as possible from the overcast skies. Inversely, plant heights in 2022 may have been impacted by cooler than average temperatures throughout most of the growing season.

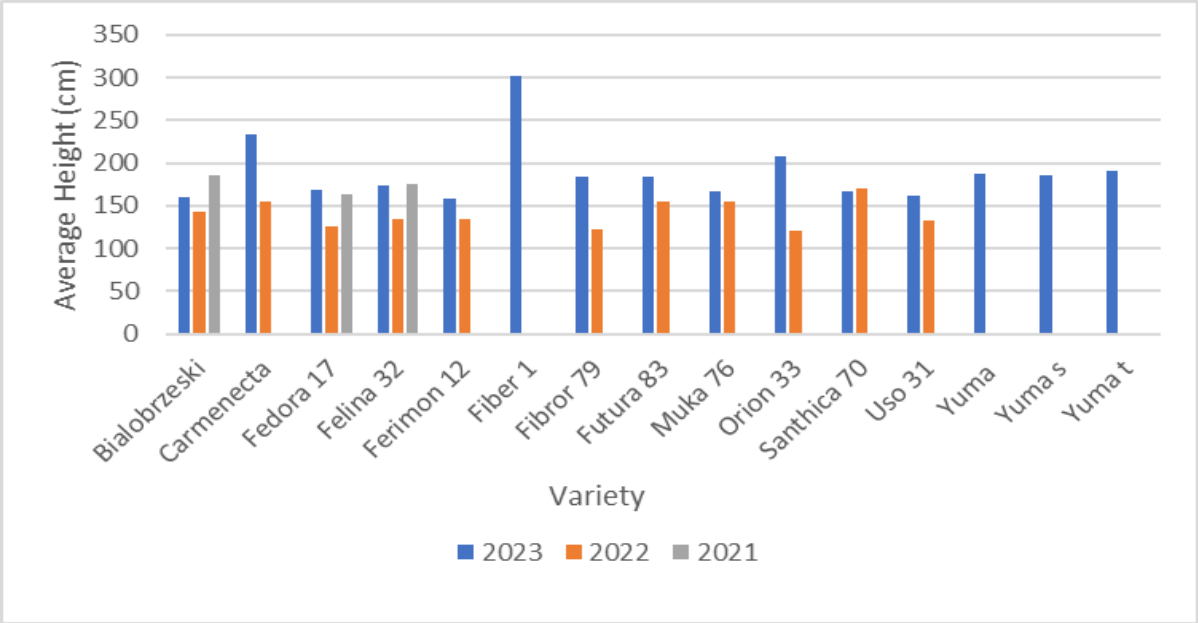

Figure 3. Average plant height in cm by variety and year for hemp fiber variety trials in 2021, 2022, and 2023, Alburgh, VT.

DISCUSSION

According to the National Hemp Report issued by the USDA in early 2023, the average yield for 2022 fiber hemp was estimated at 3070 lbs ac^{-1}. In our trials, the average dry matter yield across all varieties was 16,438 lbs ac^{-1} with one variety surpassing that value by almost four tons (Table 4). This was also more than double our 2022 average dry matter yield of 7486 lbs ac^{-1}, despite higher population counts in 2022. 2023 population counts varied greatly and were generally lower than original target populations. However, biomass yields were made up for in the taller stature of the resulting stands. Heights may have been influenced by the increased rainfall and weather conditions experienced by the region over the course of the growing season.

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