NORTHWEST CROPS & SOILS PROGRAM

2022 Industrial Hemp Fiber Variety Trial

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THE UNIVERSITY OF VERMONT EXTENSION

2021 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 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 fiber consists of two types: 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 decades, 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 hemp fiber varieties to determine best cultivars for the region.

MATERIALS AND METHODS

Table 1. Agronomic information for the industrial hemp fiber variety trial 2022, Alburgh, VT.

Location	**Borderview Research Farm Alburgh, VT**
Soil type	Benson rocky silt loam over limestone, 8-15% slope
Previous crop	Summer Annuals
Plot size (ft)	5 x 20
Planting date	24-May
Row spacing	7"
Planting equipment	Great Plains NT60 Cone Seeder
Seeding rate (live seeds m^{-2})	400
Mowing date	12-Aug

A trial was conducted at the Borderview Research Farm in Alburgh, Vermont (Table 1) to evaluate the impact of variety on fiber yield. The experimental design was a randomized complete block with four replications. There were seventeen hemp varieties evaluated (Table 2) in the trial. Seeding rates were adjusted for germination rates and a mortality rate of 30%. The typical seeding rate used when growing hemp for fiber is usually 55-65 lbs ac^{-1}, and even up to 80 lbs ac^{-1} for thin spinning fiber. Based on an assumed mortality rate and variable seed germination rates, seeding rates ranged from 68.8 - 161 lbs ac^{-1} (400 live seeds m^{-2} or approximately 37.2 seeds sq ft^{-2}) on 24-May into 5'x 20' plots.

Table 2. Hemp varieties evaluated in the industrial hemp fiber trial 2022, Alburgh, VT.

Variety	Days to seed maturity	Seed supplier
Bialobrzeskie	130	International Hemp
Carmenecta	120	International Hemp
CFX-1	105+	Hemp Genetics International
CFX-2	103+	Hemp Genetics International
Enectarol	115	International Hemp
Fedora 17	130	Hemp Seed Warehouse
Felina 32	130	Hemp Seed Warehouse
Ferimon 12	130	Hemp Seed Warehouse
Fibror 79	130-150	Konopius Seeds
Futura 75	100-110	HempIt
Futura 83	140-160	Hemp Seed Warehouse
Muka 76	102-108	Konopius Seeds
Orion 33	140	Hemp Seed International
Santhica 27	135	Konopius Seeds
Santhica 70	140	Konopius Seeds
USO 31	122-127	Hemp Seed International
Xianwei	110	Trilogene Seeds

Prior to planting on 24-May, the trial plots received 200 lbs ac^{-1} 7-18-36. Fertility amendments were based on soil test result. On 24-May, plots were seeded with a Great Plains NT60 cone seeder, and on 7-Jun, plant emergence populations were recorded by counting the number of plants in a foot-long section of the row, two times per plot. From 19-Jul to 11-Aug, in accordance with full flowering, five randomly selected plant heights and stem diameters were extracted from within each plot prior to mowing. During the same time, 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 105° F until it reached a stable weight. On 3-Aug and 4-Aug, five plants were 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. The bast and hurd were weighed 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 was cool and wet seeing below average temperatures and above average precipitation. From seeding and establishment in May until harvest in August, there were 2157 Growing Degree Days (GDDs) accumulated, which was 2 GDDs below normal.

Table 3. Seasonal weather data collected in Alburgh, VT, 2022.

Alburgh, VT	May	June	July	August
Average temperature (°F)	60.5	65.3	71.9	70.5
Departure from normal	2.09	-2.81	-0.54	-0.20
Precipitation (inches)	3.36	8.19	3.00	4.94
Departure from normal	-0.40	3.93	-1.06	1.40
Growing Degree Days (Base 50°F)	394	459	674	630
Departure from normal	93	-64	-20	-11

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, 2022.

Variety	Plant height	Stem diameter	Dry matter yield	Harvest population	Harvest population	Bast fiber	Hurd fiber
	cm	mm	lbs ac^{-1}	plants ac^{-1}	plants ft^{-2}	%	%
Bialobrzeskie	143	5.40	8,187	696,059	16.0	32.8	67.2
Carmenecta	154*	5.90	5,888	291,374	7.00	34.2	65.9
CFX-1	67.0	3.40	3,363	550,372	13.0	-	-
CFX-2	60.0	3.40	3,552	667,731	15.0	-	-
Enectarol	157*	5.00	10,339*	1,222,150*	28.0*	31.5	68.5
Fedora 17	125	4.40	6,866	1,270,712*	29.0*	31.5	68.6
Felina 32	135	4.90	8,221	1,294,994*	30.0*	32.3	67.7
Ferimon 12	134	6.00	8,119	841,746	19.0	31.2	68.8
Fibror 79	122	4.50	7,261	1,125,026*	26.0*	**41.1**	58.9
Futura 75	149	**7.30**	5,130	157,827	4.00	38.2*	61.8
Futura 83	155*	5.10	**10,710**	1,052,182*	24.0*	40.5*	59.5
Muka 76	154*	4.90	9,677*	942,917	22.0	38.6*	61.4
Orion 33	120	4.80	8,980*	1,299,040*	30.0*	32.4	67.6
Santhica 27	130	5.40	8,940*	**1,384,024**	**32.0**	40.3*	59.7
Santhica 70	**171**	6.10	7,674	841,746	19.0	35.7	64.3
USO 31	133	5.90	7,717	704,153	16.0	38.1*	61.9
Xianwei	132	4.40	6,645	481,576	11.0	25.6	**74.4**
LSD (p=0.10) ‡	17.1	0.874	2286	341,847	7.85	4.49	4.5
Trial Mean	132	5.10	7486	871,978	20.0	34.9	65.1

†*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.

Overall, our goal was to produce a dense stand of plants with stem diameters comparable to that of a pencil or chopstick (6mm). 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 thinner plants that stretch upwards to compete for sunlight in the canopy. For example, Futura 75 had the largest stem diameter in the trial with an average of 7.3 mm, and the lowest harvest population of 157,827 plants ac^{-1} (Table 4). The low emergence of the Futura 75 variety was likely due to poor germination, and the sparseness of the stand created space for the plants to bulk up. Plants with thicker stems will have a higher ratio of hurd fiber, or in other words, a thicker woody core. This is not optimal for textile production, but is well suited for some other industrial applications. A variety that saw a more desirable yield was Santhica 27 at 1,384,024 plants ac^{-1}, or about 32 plants ft^{-2}, and an average stem diameter of 5.4 mm. These results trend more towards the ideal for textile applications because at this smaller size, the amount of bast fiber on the stalk is maximized while so too is the amount of overall biomass (bast and hurd) produced. As aforementioned, bast fiber is the part of the stalk used in textile production, while hurd fiber is suited for nonwoven applications, and thus is a

profitable byproduct of textile production. Varieties that performed statistically similar to Santhica 27 in terms of harvest population include Orion 33, Futura 83, Fibror 79, Felina 32, Fedora 17, and Enectarol.

The variety with the highest ratio of bast fiber to hurd fiber was Fibror 79; a French variety bred specifically for fiber and recognizable by its distinct yellow stem. The stalks of Fibror 79 contained 41.1% bast fiber and averaged a thickness of 4.5 mm. While the bast fiber ratio of this variety exceeded typical expectations, the slight size of the plants did not maximize overall biomass yields, as represented by a dry matter yield of 7261 lbs ac^{-1}. Plants with slightly larger stem diameters would have been able to support taller plants that would yield more fiber overall. Bast to hurd ratio data was not collected for the two CFX varieties included in the trial because the stems were too small to be separated properly by our decorticator. These varieties are primarily bred for grain production and tend to complete their lifecycle very quickly without growing tall to maximize fiber yields. They will not be included in future fiber trials. Plant heights also varied across the seventeen varieties with Santhica 70 having the tallest average plant height at 171 cm, surpassing other top performers including Muka 76, Futura 83, and Enectarol. The overall best performance in the 2022 fiber research trials belongs to the French variety Futura 83. This variety was among the tallest at 155cm, produced one of the densest stands at 24 plants ft^{-2}, had the second highest ratio of bast fiber at 40.5%, and the greatest dry matter yield at 10,710 lbs ac^{-1}. 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 will hinge 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.

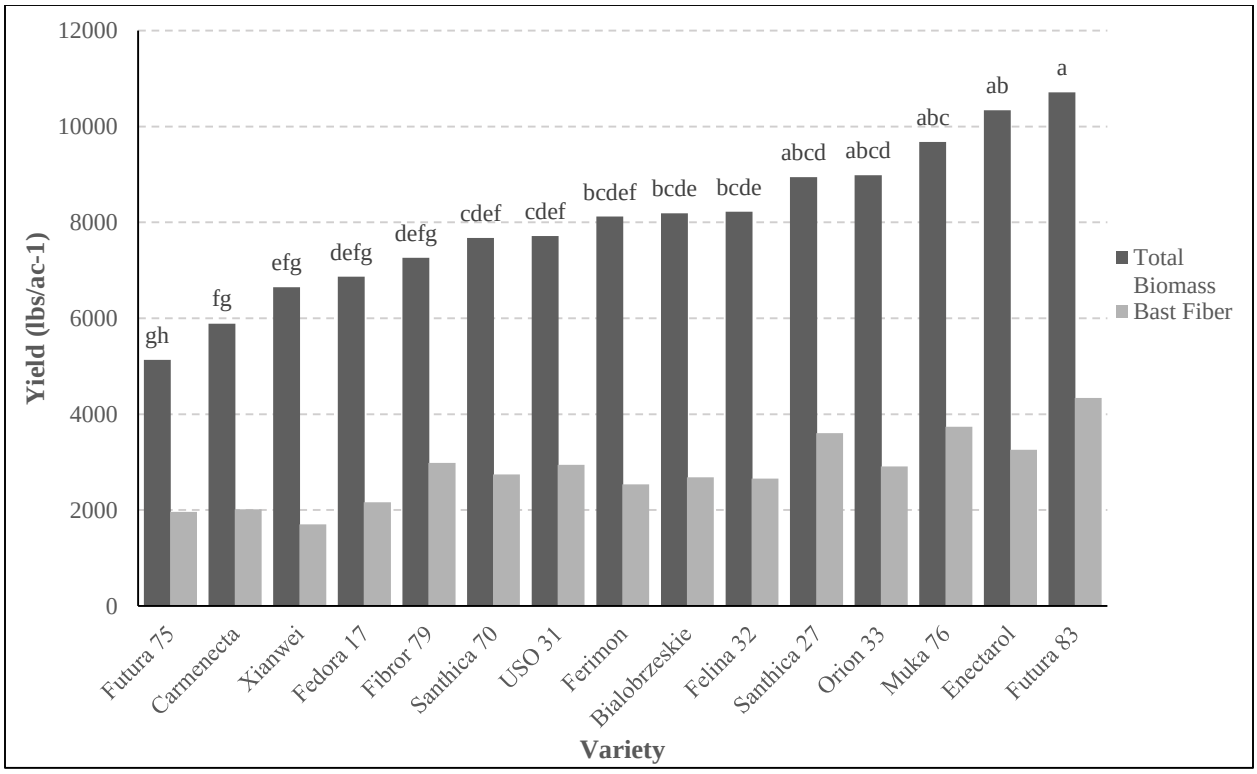

Figure 1. Dry matter biomass yields and bast fiber yields for hemp fiber variety trial Alburgh, VT, 2022. Varieties with the same letter are statistically similar (p=0.10).

Figure 1 shows the total fiber yields per acre for each of the varieties based on their performance in this trial. The lighter gray bars represent the portion of each harvest that would account for bast fiber against the total harvest in dark gray. The remaining biomass would be comprised of hurd fiber. Typically, industrial hemp stalk is made up of 20-30% bast fiber. In our trials, every variety except Xianwei surpassed 30% bast fiber (Table 4), with three varieties landing in the 40% range. This was likely a result of heavy seeding rates, as previously described. The graph in Figure 1 makes clear that even if one is planting and growing specifically for bast fiber, the majority of the harvest will still consist of hurd fiber and thus, having processing facilities in place for both types of fiber will result in the largest financial return for farmers. In our trial, the variety with the greatest yield of biomass was Futura 83. Other varieties that yielded statistically similarly were Enectarol, Muka 76, Orion 33, and Santhica 27. Last year, Futura 75 was a top performer for us, but using the same seed two years in a row proved to be disappointing for the variety, even when a decline in germination was anticipated and adjusted for.

DISCUSSION

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.

The average dry matter yield across all seventeen varieties in the 2022 fiber trials was 7486 lbs ac^{-1}, with some varieties surpassing that value by over a ton (Table 4). According to the National Hemp Report issued by the USDA in early 2022, the average yield for 2021 hemp grown for fiber was estimated at 2620 lbs ac^{-1}. Across all varieties, 34.9% of yields were comprised of bast fiber. Depending on variety and planting density, bast fiber typically represents 20-30% of the total fiber content. Population counts varied greatly and were generally lower than desired as a result of poor germination. On average, plants were 132 cm tall, which could be as little as half of the desired height of fiber plantings in ideal growing conditions, depending on the desired quality of fiber for end-use. Plant heights may also have been impacted by the cooler than average temperatures seen by most of the growing season and especially in June. Early season weed pressure and bird predation may have also influenced populations and are other considerations for growing hemp.

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