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Low-THC Hemp Research in the Black and Brown Soil Zones of Alberta, Canada

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In the past three years, there has been a renewed interest in the production of fiber hemp (*Cannabis sativa* L., Cannabinaceae) in Alberta. This effort has sparked a great deal of interest and speculation regarding the crop's potential. Since 1995 fiber hemp research plots have been grown in various parts of Alberta to evaluate the potential of this crop for both seed and fiber production (Blade 1998). Research licenses were granted by the Health Protection Branch of Health Canada, the branch of the federal government charged with enforcing legislation concerning this species. In March, 1998, Health Canada announced that commercial production of low-THC hemp would be allowed through a licensing process.

Hemp is an annual herbaceous plant which flourishes in temperate regions (Bosca and Karus 1998). All cultivars tested in Alberta have been low-THC (delta-9-tetrahydrocannabinol) genotypes. Canada has adopted the 0.3% THC standard established by the European Union and the OECD as the concentration which separates non-psychoactive strains suitable for legal fiber production from those which are illegally grown for their properties of intoxication. The 0.3% THC designation is very conservative. Most narcotic strains range from 8–10% THC, with cleaned, high potency material reaching as high as 30% THC. It is postulated that THC was useful to the plant by providing protection from UV-B exposure. The cannabinoid complex (which includes THC) of compounds is secreted by epidermal resin glands which are most numerous on and around the reproductive structures. This makes sense, since the reproductive structures require the highest level of protection. Low-THC cultivars secrete resin, but it is composed of non-intoxicating substances.

Fig. 1. Morley Blanch and Prof. John Toogood inspect the spectacular growth of low-THC hemp in the research plots at the Blanch farm.

Plant growth is very vigorous (Fig. 1, 2). Fiber hemp can reach heights of up to 9 m, but the usual average under commercial production is 2–4 m. The crop has been subject to intensive breeding programs in Poland, Rumania, Hungary, France, the Ukraine, and several other European countries. Breeders have attempted to increase bast fiber yield and quality. One method has been to select monoecious strains (male and female reproductive organs located on the same plant) which eliminates the problem of different maturities between male and female plants. Due to the fact that flowering is dictated by day length, most land races have been selected to mature in early autumn, to take full advantage of the temperate growing season. Breeders also prefer to select for long internodes and a hollow stem, which increase the quality of the fiber.

Fig. 2. The distinctive leaf morphology of *Cannabis sativa* at three weeks after emergence.

The plant consists of a single main stalk, with an external sheath of bast fiber and an interior core of white, fibrous hurd. The plant has been used for a wide cultivar of purposes including rope-making, textiles, paper production and construction materials; the seed has been used as a source of high quality oil (both for industrial and edible uses) and protein (22%).

HISTORY

It is believed that hemp originated somewhere in Central Asia. There is evidence of hemp use as a food grain as well as for fish nets, clothing and rope 6500 years ago in China. The crop gradually moved into Europe, and the first reports of hemp growing in the New World began in Chile in 1545. Hemp was so important to the navies of England and the American colonies that farmers were legislated to dedicate a portion of their land to the production of the crop. George Washington and Thomas Jefferson were hemp growers; shortly after independence, US taxes could be paid with hemp if farmers chose to do so. Area of hemp in the former Soviet Union peaked at almost a million hectares in the early part of this century, but has declined to approximately 60,000 ha in the Ukraine and western parts of Russia. In 1992, the world's largest producers of hemp fiber were India (45,000 t) and China (24,000 t).

Hemp was a popular crop in Eastern and Central Canada throughout the 18th and 19th centuries. During the period 1923–1942 there was an extensive research effort by the Canada Department of Agriculture to test agronomic management, processing, and some crop improvement at approximately 30 locations across Canada. A concise report on the trials including: seeding methods, date of planting, plant breeding efforts, harvesting methods, and processing procedures is available. The hemp acreage in Canada decreased during this time period due to the high cost of production and because of strong competition by other fiber crops produced in the tropics.

In 1938 the Canadian government made the cultivation of *Cannabis sativa* illegal (through the Opium and Narcotics Act), although a small amount of production was allowed during the war years. In 1994, the first license in decades was granted for a low-THC hemp research plot in southern Ontario. This prompted the current research effort taking place in Alberta since 1995.

METHODOLOGY

Cultivar screening tests were done (1996–97) in Brooks (dryland and irrigated) and Gwynne (dryland). Precipitation at Brooks was 207 mm during the growing season; at Gwynne during the same period the rainfall was 658 mm. The trials were seeded as soon as the required research licenses were received from the Health Protection Branch of Health Canada. The Brooks trials were planted on June 12 and the Gwynne trials were seeded on May 16. Cultivars tested included (by country of origin): Poland (Beniko, Bialobrezeski), Ukraine (Zolotonosha lines, USO lines), Hungary (Kompolti, Unico), Romania (Irene, Lovrin 110, Secuieni) and France (Fedora 19, Felina 34, Futura 77) (Fig. 3).

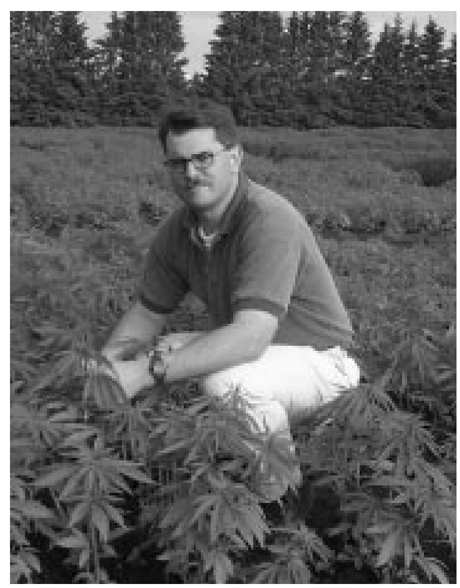

Fig. 3. Dr. Stan Blade surveys a French low-THC hemp cultivar in a varietal evaluation trial.

Harvesting at each location was done by hand using sharp knives at physiological maturity. Weights were taken and samples of stalk were dried in a forced air drier for moisture determination. Seed was hand-threshed, or run through a stationary small-plot combine. Selected small seed samples were selected for oil extraction and analysis. Analysis of variance was done using SAS, and LSD at the 95% probability level was used for mean separation.

The evaluation of the textile properties were done by determining the linear density of fibers. Common units of linear density are tex (weight in grams of 1,000 m of fiber) or denier (weight in grams of 9,000 m of fiber). The tensile strength of single fibers 70 mm long is measured with an Instron Universal tester using a gauge length of 40 mm and test speed of 200 mm/min. The force (Newtons) needed to break each fiber is determined, as will as the extension (%) at break. The average tenacity (N tex^{-1}) of 25 fibers from each hemp sample was determined.

RESULTS

THC levels

The Health Canada regulations require that all hemp have a THC level of less than 0.3%. In 1996 THC levels were < 0.05–0.30. In 1997, THC levels were < 0.01–0.65%. The only cultivar above the required minimum was re-evaluated in 1998, since there were concerns about seed quality and purity of the cultivar in question.

Cultivar Evaluation

The Gwynne site (Table 1) had much higher productivity than Brooks. This was due to higher levels of precipitation and an extended period of warm weather. The total biomass ranged between 8.92–17.32 t/ha. The low yield of Zolotonosha 24 was caused by poor germination which resulted in a reduced plant stand. Following 72 h of drying at 100°C the moisture content was calculated to be approximately 57%. The significant difference in biomass yield between cultivars indicated that further screening may identify specific cultivars which are well-suited to Alberta conditions.

The seed yields at Gwynne ranged between 563–1341 kg/ha. This result was very interesting, because one goal of the trial was to investigate whether seed production was possible in Alberta. The results indicated that seed produc-

Table 1. Total biomass, seed weight, individual plant weight and height of ten low-THC hemp cultivars grown at Gwynne, AB in 1997.

Cultivar	Total biomass (t/ha)	Seed weight (kg/ha)	Plant weight (g/plant)	Height (cm)
Beniko	13.74	1016	70.6	229
Irene	16.17	1169	50.1	220
Lovrin 110	11.82	563	52.2	227
Secuieni	17.33	1341	72.1	233
USO 31	11.8	1024	59.7	203
USO 14	11.91	925	50.1	189
Zolotonosha 15	15.97	1094	90.6	228
Zolotonosha 24	8.92	685	109.4	202
Zolotonosha 13	15.53	1070	60.2	201
Bialobrezeski	11.33	973	42.5	196
LSD (0.05)	3.62	511	26.9	32

Table 2. Total biomass and stalk yield of hemp cultivars grown at Brooks in 1996.

	Total biomass (t/ha dry matter)				Stalk yield	
	Sept. 12		Oct. 28		(Sept. 12, Irrig.)	
Cultivar	Irrigated	Dryland	Irrigated	Dryland	% of total biomass	Dry matter (kg/ha)
Zolotonosha 11 (LR)[z]	7.3	7.4	9.0	8.4	46.9	3450
Zolotonosha 11	8.6	7.5	9.1	7.8	51.8	4469
Zolotonosha 13 (LR)	7.2	6.8	7.3	6.8	46.9	3368
Zolotonosha 13	8.4	7.9	10.4	7.7	50.9	4271
Kompolti (LR)	11.5	8.8	11.9	10.8	66.7	7648
Kompolti	11.2	9.3	14.1	12.1	68.3	7616
Beniko	9.4	8.4	7.1	8.4	51.1	4787
Fedora 19	9.0	8.7	8.8	9.2	53.1	4767
Felina 34	9.8	8.4	7.8	8.0	51.9	5077
Futura 77	10.1	8.9	10.5	9.4	60.6	6145
Unico	10.2	-	7.8		63.4	6448
Mean	9.3	8.2	9.4	8.8	55.6	
LSD .05	2.2	1.5	4.2	2.6	3.7	
C.V. (%)	13.9	10.4	26.5	17.0	3.9	

[z]LR = Low rate of seeding

tion was possible. The seed was harvested from only the upper portion of the stem (80 cm) to make harvesting and threshing easier. It is estimated that, averaged across all cultivars, the sampling method collected approximately 95% of total seed production.

At the Brooks site the cultivar Kompolti produced the highest total above ground biomass yield both under irrigated and dryland conditions (Table 2). Plants seeded at higher rates and under irrigation, produced higher biomass yield than those plants seeded at the low seeding rate and under dryland, respectively. The total biomass yields ranged from 7–14 t/ha of dry matter. The stalk yields from this total biomass ranged from 3400–7600 kg/ha. These yields are somewhat less than the higher biomass and stalk yields reported from Europe. This is, however, quite comparable to some European yields in spite of the hail damage suffered by the plants in mid-July. The difference between irrigated and dryland biomass yields were less than expected, possibly due to residual water available in the summerfallow for the dryland crop.

Most of the cultivars matured early enough to produce viable seeds. The irrigated plants yielded better than their dryland counterparts (Table 3). Potential seed yields ranged from 216–1322 kg/ha with ‘Fedora 19’, ‘Zolotonosha 11’ and ‘Zolotonosha 13’ giving the highest yields. ‘Kompolti’ which gave the highest biomass and stalk yield was the lowest seed yielder. Plants seeded at the lower rates appeared to yield better than those seeded at the higher seeding rates. Plants in the outside guard rows yielded much higher than those plants in the inside rows indicating that the plants potential can be increased given more favorable growing conditions.

Oil Analysis

The hemp seed contains approximately 25–35% oil. Analysis of seed oil from the different cultivars together with a typical canola oil is shown in Table 4. The predominant fatty acid was linoleic 54.6–56.1%, followed by linolenic 17.8–19.2%, and oleic 11.8–12.8%. It is interesting to note that the oil also contains 1.5–2.2% of gamma linolenic acid. Only slight differences in oil composition was noted among the cultivars. The high percentage (73.7–74.6%) of the polyunsaturated fatty acids (linoleic + linolenic) indicates a good, nutritious but unstable oil. This compares with canola oil that has high (55.6%) monounsaturated fatty acid in the oil. The presence of the gamma linolenic acid makes hemp oil even more nutritionally desirable. This fatty acid is the important component found in evening primrose and borage seed oils. The analysis also indicated high levels of various anti-oxidants, including tocopherols and sterols.

Fiber Analysis

The hemp samples tested from Alberta grown hemp (Table 5) were evaluated for some of the primary characteristics associated with fiber quality. The tensile strength was measured to be 1.6 g d-tex^{-1} at 33 days after planting, and reached an optimum (3.0 g d-tex^{-1}) at the August 7 measurement. This coincided

Table 3. Seed yield of different hemp cultivars grown at Brooks in 1996.

	Seed yield (kg/ha)			
	Samples harvested from inside rows with borders		Samples harvested from outside guard rows	
Cultivar	Irrigated	Dryland	Irrigated	Dryland
Zolotonosha 11 (LR)[z]	1326	750	1339	1417
Zolotonosha 11	1186	694	1470	1301
Zolotonosha 13 (LR)	1322	801	1593	1741
Zolotonosha 13	988	834	1591	1556
Kompolti (LR)	216	377	475	441
Kompolti	347	329	647	750
Beniko	787	685	2170	1670
Fedora 19	1491	1145	2900	2676
Felina 34	890	1066	2123	2762
Futura 77	863	848	2235	2155
Unico	596	--	1130	--
Mean	910	753	1607	1647
LSD .05	467	369	634	1030
C.V. (%)	30.1	28.6	23.1	36.5

[z]LR = Low rate of seeding

Table 4. Fatty acid composition of the seed oil of different hemp cultivars grown at Brooks in 1996. Canola data obtained from Dr. Terry Rachuk, Canadian Agra Foods Inc., Nisku, Alberta.

	Fatty acid composition (%)						
Fatty acid	Felina 34	Beniko	Fedora 19	Futura 77	Zolotonosha 11(LR)	Zolotonosha 13(LR)	Typical canola
Palmitic (16:0)	5.4	5.5	5.5	5.6	5.4	5.6	3.2
Palmitoleic (16:1)	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Stearic (18:0)	2.8	2.8	2.8	3.1	2.9	2.9	1.2
Oleic (18:1)	11.8	12.2	12.0	12.8	12.1	12.2	55.6
Linoleic (18:2)	56.1	56.4	56.1	54.6	55.6	55.6	21.7
Gamma linolenic (γ 18:3)	2.1	2.1	2.0	1.5	2.2	2.2	--
Linolenic (∝18:3)	18.5	17.8	18.1	19.2	18.4	18.1	12.9
Arachidic (20:0)	0.8	0.8	0.8	0.8	0.4	0.8	0.6
Eicosenic (20:1)	0.4	0.4	0.4	0.4	0.4	0.4	2.2
Behenic (22:0)	0.3	0.3	0.3	0.6	0.3	0.3	0.3
Lignoceric (24:0)	0.2	0.2	0.2	0.2	0.2	0.2	0.4
Others	1.4	1.3	1.6	1.3	1.5	1.5	--
Erucic	--	--	--	--	--	--	1.5

with the time of flowering. As described in the literature, the tensile strength of the Alberta-grown fiber decreased following flowering (Batra 1985). The parameters for hemp fiber were well within the range generally observed for hemp. The results indicated similar characteristics to flax fiber. The extension at break was lower than reported figures for cotton.

Table 5. Fiber yield, tex, tenacity, and breaking extension of 'Kompolti' hemp.

Retting time (d)	Fiber yield (%)	Tex (g/km)	Tenacity (cN tx^{-1})	Extension at break (%)
4	30	4	31 ± 5	2.7
4	31	4	41 ± 9	2.4
5	27	3	40 ±9	0.8
5	17	3	40 ± 6	2.2

Can hemp compete with flax or cotton for fine textiles? There are many factors to consider, not the least of which is the cost and difficulty of processing the fiber into fine yarns. Considering only fiber properties, hemp is remarkably similar to flax, a fiber that is prized for many of its characteristics—its beautiful luster, light resistance, absorbency and dyeability.

SUMMARY

The preliminary research reported here indicated that low-THC hemp can be produced in Alberta. Current European cultivars are available that have acceptable levels of THC which are low enough to be acceptable for industrial purposes. Several cultivars were identified as excellent seed or fiber lines. Lower seeding densities resulted in higher seed yields; higher planting rates resulted in greater fiber yields. The composition of the seed oil indicated a high level of polyunsaturated fatty acids, as well as high levels of anti-oxidants. Fiber testing indicated that the time of harvest will determine the quality of the fiber, and that hemp grown in Alberta has interesting fiber characteristics.

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