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Agronomic Research on Hemp in Manitoba*

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Hemp (*Cannabis sativa* L.) has been the subject of great interest in Canada (and in many other countries) in recent years, focused on the potential of hemp as a "new" crop. Ironically, hemp is of course a very old crop, and, as in many other western countries, it has a long history in Canada.

In the late 19th and early 20th centuries, hemp was a familiar sight at the premises of many eastern European immigrants—the plants often served as windbreaks and the seed was used for food. In the 1920s, the Dominion Experimental Farm (predecessor of today's Agriculture and AgriFood Canada) was involved in hemp research, as part of their fiber crops program which focused mainly on fiber flax. Efforts focused on cultivar evaluation, production agronomy, harvest, and retting procedures. There was some commercial area of hemp in Manitoba at that time, rising to a peak of over 400 ha in the Portage la Prairie area in 1928, used to manufacture cordage. By the mid-1930s area had declined to zero due to economic factors.

Hemp cultivation was banned in 1938 under new federal narcotics regulations. However, in response to a resurgence of interest in the cultivation, processing, and marketing of hemp products, and after a period of cultivation and evaluation under research licenses, the Canadian government was successfully lobbied for change. Industrial Hemp Regulations were introduced in March 1998, enabling licensed commercial cultivation of appropriate cultivars. Approximately 2000 ha were sown in Canada in the 1998 growing season, about 600 ha of which was in the province of Manitoba.

Industrial Hemp Regulations are administered by Health Canada. These regulations require that individuals or companies be licensed to import and export, grow, process, or sell hemp seed or products. For example, a license allows a grower to buy seed from a licensed importer or seed grower, grow the crop at a given location, harvest fiber or grain, and sell the grain to a licensed processor. Anyone more than 18 years of age with no drug-related convictions in the previous 10 years may apply for a license.

Health Canada will not license cultivation of less than 4 ha, except in special circumstances. Growers must give the G.P.S. (ie. Global Positioning System) coordinates of the location where they plan to grow hemp. The location must be at least 1 km from school grounds or other place frequented by persons less than 18 years of age.

Growers must use pedigreed seed of a cultivar approved by Health Canada. The OECD (Organization for Economic Cooperation and Development) List of Cultivars Eligible for Certification is the main basis for approving cultivars. Health Canada's main concern is that cultivars should produce less than 0.3% THC in leaves and flower parts. Growers are required to have a sample tested by an approved lab to determine the THC content under their conditions. Also, growers must keep detailed records of hemp purchases, sales, and other movements.

MANITOBA HEMP RESEARCH 1995–1998

Hemp research trials were conducted in Manitoba in 1995–1998, with the following objectives: (1) evaluate cultivars of hemp for their agronomic suitability for Manitoba; (2) evaluate seed and stalk yield in small-plot and large-scale (> 0.5 ha) trials; (3) gain experience in sowing and harvesting the crop; (4) evaluate quality of seed and fiber for various potential uses; (5) observe for potential disease, insect or other agronomic problems; (6) estimate economic feasibility of hemp production in Manitoba, at farm-gate level. Trials took place at various locations representing several different agroclimatic regions in Manitoba.

Agronomic Research—Small-plot Trials

Small-plot, randomized complete block trials were utilized to examine cultivar performance and suitability in 1995–1997. Unreplicated applications of herbicide and seed-placed fertilizer were used on occasion to provide an initial indication of suitability. In 1998, cultivar by seeding rate, and herbicide tolerance trials were initiated.

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Table 1. Agronomic characteristics and Δ^9-THC content for hemp cultivars grown at fiber density (400 seeds/m^2) at two Manitoba locations in 1996.

	Wawanesa MB 1996			Morden MB 1996		
Cultivar	Height (m)	Stalk yield (kg/ha)	Δ^9-THC (%)	Height (m)	Stalk yield (kg/ha)	Δ^9-THC (%)
Zolotonosha 11	2.11 c[z]	7860 bc	<0.05	2.18 b	5160 b	<0.05
Zolotonosha 13	2.12 bc	7920 bc	<0.05	2.30 bc	4540 b	<0.05
Polish 1[y]	2.07 c	8150 bc	0.13	2.27 bc	5200 b	0.06
Polish 2[y]	2.07 c	7260 c	0.17	2.23 c	4400 b	<0.05
Fedora 19	2.08 c	8440 b	0.10	2.20 c	4890 b	0.08
Felina 34	2.19 b	10710 a	0.06	2.37 b	7290 a	0.07
Uniko B	2.35 a	10520 a	0.30			
Kompolti	2.33 a	10450 a	0.21	2.52 a	7200 a	0.18
Futura 77	2.31a	11160 a	0.15	2.48 a	7330 a	0.06
Average	2.18	9160		2.32	5750	
CV (%)	2.6	7.2		3.4	13.4	

[z]Mean separation by protected LSD (5%).
[y]Lines believed to be of Polish origin but of unverified pedigree.

Table 2. Agronomic characteristics and Δ^9-THC content for hemp cultivars grown at seed density (100 seeds/m^2) at two Manitoba locations in 1996.

	Wawanesa MB 1996		Morden MB 1996	
Cultivar	Seed yield (kg/ha)	Δ^9-THC (%)	Seed yield (kg/ha)	Δ^9-THC (%)
Zolotonosha 11	930 bc[z]	<0.05	1056	<0.05
Zolotonosha 13	885 bc	<0.05	1074	<0.05
Polish 1 [y]	820 c	0.05	1528	0.07
Polish 2 [y]	691 c	0.11	1561	0.22
Fedora 19	1567 a	0.12	1783	0.11
Felina 34	1228 ab	0.08	1963	0.09
Average	1020		1494	
CV (%)	20.4		26.9	

[z] Mean separation by protected LSD (5%).
[y] Lines believed to be of Polish origin but of unverified pedigree.

Cultivar trial data from two locations in 1996 are presented (Tables 1 and 2). Separate cultivar trials were conducted for stalk and seed yield evaluations, with seeding rates of 400 and 100 seeds/m^2, respectively. The first five cultivars listed (Table 1) were similar in flowering date and were cut for stalk yield evaluation in the early flowering stage on August 7 (57 days after sowing on June 10). The next four cultivars were later to flower and were all cut on August 15 (65 days after sowing). In general, the later flowering cultivars were taller and yielded considerably higher, since they had an extra eight days of growth. If high quality fiber production is the objective, clearly the late cultivars are preferred from a productivity perspective. However, the issue of relative fiber quality among these cultivars has yet to be explored. Further trials are necessary to determine optimum seeding rate for fiber production in Manitoba. All cultivars were sampled at early flowering to determine Δ^9 - THC content; in this particular trial, all tested below the maximum allowable level of 0.30%, except 'Uniko B' which tested at 0.30%.

It was recognized early on that growing hemp as an oilseed crop would have significant potential for Manitoba. Therefore, cultivar trials were conducted with the specific aim of evaluating several earlier maturing cultivars for their seed production potential (Table 2). To promote branching, flowering and seed set on these fiber type cultivars, the plots were sown at a much lower density–100 seeds/m^2. The stands were acceptable but variable, and the average stand at harvest time was only about 30% of the seeds sown (not shown). Considering the late sowing, seed yields were excellent, with the 'Fedora 19' and 'Felina 34' exhibiting the highest yields.

With most commercial production interest in 1998 focussing on hemp for grain or dual-purpose (grain and fiber), trials (factorial design with four replications) were established to determine optimum seeding rates for four cultivars of interest. Limited data is available at the time of this writing, but yield data for two locations is presented (Table 3). The cultivar by seeding rate interaction was not significant, and within the range tested, seeding rates did not differ in yield. At one location (Carman), cultivars differentiated themselves with respect to yield, with the slightly later-maturing and taller 'Fedora 19' yielding the most grain.

Additional Field Observations

Weed pressure. A good stand emerging ahead of weeds is crucial to the ability of hemp to compete with weeds, especially with the low seeding rate (100 seeds/m^2) used for grain hemp production. In areas where stand was poor (sown too shallow for moisture conditions or excessive moisture in low areas of field), competition from weeds was severe (no quantitative estimate was made).

Disease incidence. Particular weeds may cause more than just competitive loss. Wild mustard (*Sinapis arvensis*) infected with *Sclerotinia sclerotiorum* sometimes provided the source of inoculum for stem rot lesions on adjacent hemp plants. These lesions caused wilting and death of the upper portion of the plant and rendered the plant more susceptible to lodging due to stem breakage; well-developed sclerotia approximately 3 mm in diameter became evident in the hollow of affected stalks. Hemp has shown itself to be quite susceptible to *Sclerotinia*, which will certainly have rotational implications for Manitoba where canola and other susceptible crops are major considerations. *Botrytis cinerea* has also been observed causing a grey moldy infection in the inflorescence, but the incidence has been negligible.

Insect incidence. The 1995 growing season found areas of the province being severely affected by Bertha armyworm (*Mamestra configurata*), a cyclical pest of canola and other crops. One of the hemp research plot locations was in an affected area, and Bertha armyworm caused severe defoliation of hemp plants. This pest is currently at low population levels, but in six to eight years the population in Manitoba will rise again, and hemp is certain to be affected. Other problem insects observed include *Lygus* spp. plant bugs, grasshoppers, and European corn borer (*Ostrinia nubilalis*). Feeding and damage was observed, but not at what would be considered economic levels. Whether or not any of these will be of economic consequence is yet to be determined.

Pollinators. Honey bees were observed foraging for pollen in hemp plots, even though there appeared to be no honey bee colonies within the immediate area (i.e. 2 km^2). Honey bees were by far the most abundant, pol-

Table 3. Seed yield of hemp in cultivar × seeding rate trials at Manitoba locations in 1998.

	Yield (kg/ha)[z]			
	Seeding rate (seeds/m^2)			
Location Cultivar	75	100	125	Mean
Carman MB				
USO 14	1260	1160	1130	1180
USO 31	1330	990	1180	1170
Fasamo	1190	1360	1350	1300
Fedora 19	1770	1720	1850	1780
Mean	1390	1310	1380	1360
Laurier MB				
USO 14	900	850	930	890
USO 31	660	850	840	780
Fasamo	900	660	790	780
Fedora 19	870	720	890	820
Mean	830	770	860	820

[z] Cultivar main effect significant at 1% at Carman MB, seeding rate or cultivar × seeding rate not significant in either trial.

len foragers in the plots during our field observation. Hemp pollen was collected from the hemp flowers and compared to the pollen collected from the honey bees verifying that the pollen collected by the honey bees was indeed hemp. Bumble bees were observed in the vicinity of the hemp plots, but no active foraging behavior was recorded during our observations. Although no bumble bee foraging was observed in the sites, bumble bees were observed gathering pollen in a hemp field elsewhere in the province. A sample of pollen was collected from the bumble bees and found to contain hemp pollen. Although some of the insects observed were in direct contact with hemp pollen, the question that remains to be answered, is whether these same insects will also visit the female parts (or flowers) of the hemp plant.

Seed Oil Quality Evaluations

Manitoba hemp research initiated in 1995 was based on the premise that hemp represented a potential new fiber crop opportunity. However, it became clear that another opportunity was perhaps more readily accessible—that of growing hemp as an oil seed crop, with the stalk/fiber as a secondary harvest. Such a dual purpose scenario is familiar on the Canadian prairies, particularly with oil seed flax, and more recently wheat (strawboard). Therefore, the main focus of subsequent research shifted to examining seed oil quality, on the premise that hemp could become more quickly established in Manitoba has oil seed crop, and from that position the longer-term development of fiber processing and marketing could take place.

Hempseed samples were analyzed for fatty acids, antioxidants, and sterols (Table 4). The data confirm that hempseed oil is of merit nutritionally because of its relatively high level of polyunsaturates, the approximate 3:1 ratio of omega-6 and omega-3 fatty acids, and the presence of significant gamma-linolenic acid (GLA) and antioxidant levels. Without more data, we cannot be conclusive with respect to varietal or environmental differences. However, an examination of data to date suggests that varietal differences are present for some components and may be more significant than environmental differences (Fig. 1). Several cultivars sourced in the Ukraine or Poland had levels of GLA in the range of 2.5–3.0% or more, for the original source seed and for seed grown from it at two locations in Manitoba. Three cultivars sourced in Romania (‘Secuieni 1’, ‘Lovrin 110’, and ‘Irene’) had lower GLA (1.2–1.5%).

Table 4. Fatty acid, anti-oxidant, and sterol profiles, and composite seed analysis for Manitoba hempseed samples taken in 1996 and 1997; sample size is 36 except for composite seed analysis where sample size is 12.

Oil/Composite component	Range	Mean	SD
Fatty acids (% of oil)			
16:0	5.9–6.6	6.2	0.20
16:1	0.1–0.2	0.2	0.04
18:0	2.4–3.4	2.7	0.27
18:1	10.5–16.3	12.9	1.34
18:2ω6	54–57.7	55.6	0.85
α-18:3ω3	15.1–17.9	16.7	0.74
γ-18:3	1.2–3.8	2.6	0.62
20:0	0.7–1	0.8	0.06
20:1	0.3–0.4	0.4	0.02
22:0	0.3–0.4	0.3	0.05
24:0	0.1–0.2	0.2	0.03
Saturates	9.6–11.1	10.3	0.43
Monounsaturates	11–16.9	13.4	1.36
Polyunsaturates	71.1–78	75.0	1.58
ω6 to ω3 ratio	3.1–3.7	3.3	0.14
Antioxidants (ppm)			
α-tocopherol	4.3–25.6	11.3	4.70
β-tocopherol	6.8–25.8	11.4	4.25
γ-tocopherol	678.4–1101.3	829.6	102.72
δ-tocopherol	19.8–68.3	41.3	11.65
α-tocotrienol	15.4–51.6	26.9	8.14
Total antioxidants	748.1–1231.8	920.5	122.38
Sterols (ppm)			
β-sitosterol	2384.2–4203.6	3113.5	445.49
Stigmasterol	101.2–242.3	183.6	30.81
Campestrol	726.3–1401.3	1062.2	140.76
Brassicasterol	31.8–122.3	65.9	22.95
Composite seed analysis (%DM)			
Protein	22.8–26.1	24.1	1.09
Fat	20.8–25.1	22.5	1.46
Fiber	23.8–28.6	26.3	1.48
Soluble fiber	4.9–5.9	5.3	0.27

Cost of Production Analysis

Cost of production and breakeven analyses are provided in Table 5 for the situation we believe to be most readily accessible for Manitoba: growing hemp for grain, with secondary harvest of the low-grade stalks remaining after the grain has been harvested.

Production cost for hemp in this scenario is relatively high, even compared with canola, which among the annual field crops in Manitoba is among the more expensive to grow. Several factors contribute to the higher production costs. Seed, which currently must be imported annually as pedigreed seed, is very expensive—when pedigreed seed production can take place locally, we would hope that seed costs would go down. Machinery operating costs are estimated as higher, based on the toll that the tough fibrous stalks will take on bearings and chains and knives. Industrial hemp regulations require that samples be taken an analyzed for THC content, and while there was no licensing cost in the first season, it is expected that Health Canada will introduce a licensing fee for subsequent seasons.

Even though the production cost is high, this does not render hemp unworthy of consideration from a grower's perspective. The break even analysis suggests that growers can expect to make a sufficient return. Even though this season's hemp grain price of \$Cdn1.10–1.30/kg is certain to the reduced for subsequent seasons, grain yields in 1998 often exceeded 1100 kg/ha. Therefore, it appears that it will not be difficult to sustain growers' interest in hemp despite the significant "hassle" factors associated with growing hemp vs. growing other annual field crops.

FIRST COMMERCIAL PRODUCTION EXPERIENCE 1998

Approximately 70 growers sowed a total of about 600 ha of hemp in Manitoba in 1998, primarily under contract to three companies. On this, about 100 ha was seed multiplication of a German cultivar, 'Fasamo'. The balance was grown as dual purpose crop. The area was dominated by French and Ukrainian cultivars. In general, this first experience was encouraging—but it was definitely a learning experience.

Unusually heavy rainfall in June resulted in conditions of excess moisture stress in some heavier textured fields with poor internal drainage. Hemp plants in affected areas became chlorotic and stunted, and in some cases died altogether. While it had been recommended to growers to avoid sowing in such fields, the experience reinforces the sensitivity of hemp to excess moisture stress especially in the early stages of growth. An additional consequence is that some of the moderately affected areas where the stand was reduced and the growth stunted also suffered from additional weed growth and competition.

Otherwise crop growth was excellent, and the real challenge came at harvesting time. Numerous approaches were taken, many successfully given a crop averaging 2.2 to 3 m in height. Most approaches were much less successful when the crop exceeded 3 m in height. The basic approach was to direct combine using a conventional combine with the header raised to maximum height. For threshing, this approach was the most consistently successful, although in some circumstances, rotary combines were also used successfully. Generally speaking, threshing was easier when grain moisture was still relatively high (> 25%), although grain quality (fewer immature seeds evident in the dried sample) improved with lower moistures at harvest. As the stalk material dried, it became more prone to wrapping on chains and bearings in the combine, and growers quickly learned to watch for such problems developing—wrapped material is prone to burning, putting the entire combine at risk. For crops of less than 2 m in height, swathing and combining with a pick up header about a week or ten days later was also successful. After combining, remaining stalk was cut with a mower or a swather, and baled with round balers. Wrapping of fiber was also a problem at this stage, necessitating the installation of guards to protect bearings, belts, and chains.

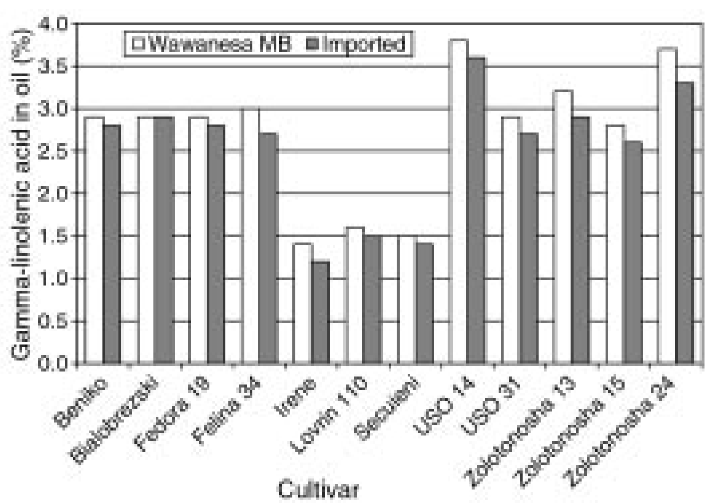

Fig 1. Percent of oil as gamma-linolenic acid for hempseed; samples drawn from seed imported for planting, and from resulting seed grown at Wawanesa MB in 1997.

Grain yields exceeded expectations, typically ranging from 800 to 1200 kg/ha on a clean, dry (10% moisture) basis. Yields as high as 1900 kg/ha were reported.

Table 5. Estimated cost of production and break-even analysis for hemp grown as a dual purpose crop in Manitoba; typical canola values supplied for comparison. Assumes field of 8 ha in size for per field costs (licensing, sampling, and analytical fees).

Operating proforma	Hempseed ($Cdn/ha)	Residual stalk ($Cdn/ha)	Canola ($Cdn/ha)
Operating costs			
Seed	197.60		59.28
Fertilizer	64.96		79.16
Chemicals			72.87
Fuel	27.17	9.88	27.17
Machinery operating costs	49.40	14.82	24.70
Crop/hail insurance	14.82		30.63
Other costs	18.53		18.53
Land taxes	13.59		13.59
Licensing fee	30.88		
Sampling and analytical fees	30.88		
Drying costs	5.29		
Cleaning costs	34.58		
Interest on operating	16.31	0.36	11.73
Total operating costs	503.99	25.59	337.65
Fixed costs			
Land investment costs	43.97		43.97
Machinery depreciation	43.23	12.35	43.23
Machinery investment costs	17.29	18.53	17.29
Storage cost	5.29	5.29	5.29
Total fixed costs	109.77	36.16	109.77
Total operating and fixed	613.76	61.75	447.42
Labor	37.05	37.05	37.05
Total costs	650.81	98.80	484.47
Breakeven analysis—price			
Expected yield (kg/ha)	800	5000	1600
Breakeven price (/kg)			
Operating	0.63	0.01	0.21
Operating and fixed	0.77	0.01	0.28
Total	0.81	0.02	0.30
Breakeven analysis—yield			
Expected price (/kg)	0.66	0.03	0.31
Breakeven yield (kg/ha)			
Operating	762	853	1094
Operating and fixed	928	2058	1449
Total	984	3293	1569

HEMP RESEARCH NEEDS

Although we have arrived at the stage of commercial cultivation, much research is still required in order for hemp to become successfully established as a specialty crop in Manitoba. It is envisioned that industry, growers, provincial and federal governments, and university researchers will all have a role in this research. This applies both to hemp as a grain/dual purpose crop and as a fiber crop.

Several cultivars are available and perform reasonably well. However there is a need for further cultivar evaluation and the development of cultivars specifically adapted to western Canada and to the production practices and market requirements for Prairie production. Current agronomic recommendations are based more on rules of thumb than on solid research, so seeding rate, seeding date, and fertility research is required. Weed management is another area of required research, primarily with respect to strategies to maximize the competitive ability of the crop, but also in the evaluation of herbicides as a production tool.

Experience in Manitoba and elsewhere have shown that the crop is not disease- and insect-free as has been sometimes claimed. Therefore, disease and insect management strategies also require examination. Harvest timing and techniques require both research and the ingenuity of growers. Management effects on quality of grain and its derived products, and stalk and its derived products must also be examined.

Finally it is important to recognize that much of the talk of the marketability of hemp derived products is in fact talk of *potential* market. Successful establishment of the crop will also require a great deal of investment of energy in product and market development.