University of Wisconsin-Madison

July 2001 **Staff Paper No. 443**

Is Industrial Hemp Worth Further Study in the U.S.? A Survey of the Literature

By

T. Randall Fortenbery and Michael Bennett

AGRICULTURAL & APPLIED ECONOMICS

STAFF PAPER SERIES

Is Industrial Hemp Worth Further Study in the US?
A Survey of the Literature

T. Randall Fortenbery and Michael Bennett *

* Associate Professor and Graduate Student, respectively, Department of Agricultural and Applied Economics, University of Wisconsin – Madison.

Table of Contents

Executive Summary

There has been considerable interest recently in alternative cropping opportunities for US grain producers. One crop that has received significant interest has been industrial hemp. Hemp production has essentially been non-existent in the US since the 1950's. The purpose of this paper is to summarize the current state of knowledge relative to opportunities for domestic commercial hemp production.

Because of the limited experience with recent hemp production in North America, much of the current literature is based on un-tested assumptions and and/or outdated research. In general, however, it appears that hemp may be able to compete on the margin with more traditional crops. It is generally found to be slightly more profitable than traditional row crops, but less profitable than other specialty crops.

The key to the long-term success of commercial hemp production appears to lie with the development of improved harvesting and processing technologies. The current technologies relative to harvesting, transporting, and processing hemp are quite labor intensive, and result in relatively high per unit production and processing costs. This suggests that any current market opportunities would likely come from small niche markets (for example, specialized apparel) that could be quickly satiated with a relatively small amount of production. For the crop to be profitably adopted on a larger scale, technological improvements must be forthcoming.

Most consumer products currently made from commercial hemp can also be manufactured from other raw materials. For hemp to be widely used as an input, it must be cost competitive with other raw materials. The recent experience in Canada implies that commercial production on a large scale may not yet feasible because of the competitive position of alternative raw materials.

The literature does suggest environmental benefits from using hemp in a rotation with other crops. Less clear, however, is the extent to which some of the environmental benefits might dissipate if hemp became widely adopted in crop rotations. It is possible that widespread cultivation of hemp could result in pest infestations requiring chemical treatment, and such treatments could at least partially offset the initial environmental benefits of hemp. To date, however, arguments related to the longer term environmental benefits of hemp are mostly speculative.

I. Introduction

Over the past decade, industrial hemp has generated a great deal of interest from the general public, various state governments, private researchers and segments of the US business community. Those advocating its legalization have cited its environmental benefits – low pesticide and herbicide requirements and adaptability to a wide-range of agronomic conditions – and array of current and potential uses, as evidence of its value as an alternative cash crop for US farmers. They claim that industrial hemp could be profitable if it were allowed to develop like any other commercial agricultural enterprise.

Opponents of commercial hemp production suspect a hidden agenda – the legalization of marijuana – or argue that estimates of profitability are overblown or insufficient to justify the licensing and increased drug monitoring costs that would be associated with its cultivation.

In response to proponents of industrial hemp production, various state legislatures have initiated efforts to explore the prospects of legalization. Studies on the economic viability of industrial hemp have been produced for Arkansas, Hawaii, Illinois, Kentucky, Missouri, North Dakota, Oregon, and Vermont. In addition, USDA published a report in 2000 on prospects for commercial hemp production, the Congressional Research Service published a small report in 1992, and a number of papers have been written on the Canadian hemp industry. These studies have reached a variety of conclusions based on project design, regional economic conditions, and underlying assumptions about yields, fixed and variable costs, market conditions and price. Because industrial hemp has not been produced in North America for almost half a century, the studies have relied on assumptions and inferences in generating conclusions relative to potential US market opportunities. A thorough understanding of the market potential and profitability of industrial hemp in the US will require further economic, agronomic and engineering research. However, before such steps are taken, it is worth asking, *"Does current literature find industrial hemp to be a crop worth further research?"* This report will pull together existing literature on the economics of industrial hemp in order to address this question. Sections II and III will give some historical background and discuss the cultivation, harvesting and processing of hemp. Sections IV and V then summarize and discuss the literature's findings on the market prospects for the crop and its viability as a US cash crop. Section VI will briefly outline political considerations, and section VII will conclude.

II. A Brief History of Industrial Hemp.

Hemp is believed to be one of the first plants cultivated by man, predating flax and cotton. Various sources estimate that hemp was first cultivated some 4000 to 6000 years ago in China (Kraenzel et al., 1998; Vavilov, 1992). Trade and migration brought it to Europe, and by the 16th century it was widely grown for its fiber and seed (Johnson, 1999; USDA, 2000). Hemp was one of the most important crops in England during the 1700s, and was Russia's largest agricultural export crop in both the 1700s and 1800s. It was primarily used for cordage and sailcloth in the American, Canadian and European shipping industries (Roulac, 1997)

Hemp played an interesting role in US history. Both George Washington and Thomas Jefferson cultivated hemp (Roulac, 1997). According to Kraeznel (1998), the first two drafts of the Declaration of Independence were printed on paper made from hemp, colonial soldiers dressed in hemp fabric, the first US flag was sewn from hemp, and the first jeans, produced by Levi Garret and sold to miners in California, were made from it.

The puritans first brought hemp to New England in 1645 to grow for fiber. Cultivation spread to Virginia, Pennsylvania and, in 1775, to Kentucky, where it grew so well that a commercial cordage industry developed. Strong demand for cordage and sailcloth by the US navy resulted in the hemp industry expanding from Kentucky into Missouri and Illinois in the mid-1800s. By this time, more than 160 factories, employing several thousand workers, manufactured hemp bagging, bale rope and cordage in Kentucky alone (Roulac, 1997).

By the late 1800s the US hemp industry was in decline, however. Reasons include the development of the cotton gin (which reduced labor costs for Southern cotton production), the advent of steam and petroleum powered ships (which reduced the demand for cordage and sailcloth materials), and imports of cheaper jute and abaca. Abaca gradually replaced hemp for use in marine cordage due to the latter's lightness, ability to float on water, and greater resistance to salt water corrosion without being tarred (Dempsey, 1975; USDA, 2000; Roulac, 1997).

Though hemp production was tried in many other states during the late 1800s and early 1900s – including Wisconsin, California, North and South Dakota, Minnesota, Indiana, Ohio, Michigan, Kansas and Iowa – production steadily declined as demand waned. From the end of the Civil war until 1912 the vast majority of hemp produced in the US came from Kentucky (Wright, 1918).

Passage of the Marijuana Tax Act in 1937 placed all *Cannabis* under control of U.S. Treasury Department regulations due to fears of the plant's psychoactive properties. This effectively prohibited the cultivation of hemp in the US. However, when supplies of abaca and jute from the tropics were interrupted as a result of World War II, the ban on US production was temporarily lifted, and an emergency program to develop fiber hemp as a domestic substitute was quickly established. War Hemp Industries, Inc. – a quasi-official organization contracted by the USDA's Commodity Credit Corporation to produce fiber hemp and seed – constructed a number of hemp fiber processing mills in the Midwest. Production peaked in 1943-44, but rapidly declined after the end of the war due to reimposed legal restrictions on production and reestablishment of cheaper imports of jute and abaca. A small hemp fiber industry continued in Wisconsin until 1958. Since then, fiber hemp production in the US has been negligible (Wright, 1918; Dempsey, 1975; Ehrensing, 1998).

III. Plant Characteristics, Cultivation, Harvesting and Processing.

Plant Characteristics

Industrial hemp and marijuana are different varieties of the same species, *Cannabis sativa* L. Though often associated with each other, and generally identical in appearance, they differ significantly in their content of the psychoactive ingredient delta-9-tetrahydrocannabinol (THC). Whereas marijuana contains 3 to 15 percent THC on a dry-weight basis, industrial hemp contains less than 1 percent (Vantreese, 1997). Industrial hemp is often referred to as "true hemp" to distinguish it from the many other species commonly called hemp, such as abaca or Manila hemp (*Musa textiles*), sisal hemp (*Agave sisalina*), ambari hemp or kenaf (*Hibiscus cannabinus*), and sunn hemp (*Crotalaria juncea*) (Ehrensing, 1998; USDA, 2000).

Industrial hemp can be grown for its fiber, seed, or as a dual-purpose crop. It is a bast or long fiber plant, similar to flax, kenaf and jute, ranging in height from 3 to 19 feet. It has a rigid, herbaceous stalk with a hollow core, surrounded by an inner pith layer of short woody fibers called hurds, and an outer phloem or parenchyma layer, where the bast fibers are primarily found (Kraenzel et al, 1998). Both the hurd and bast fibers can be processed for use. *Cannabis sativa* is an annual plant, which means that it must be grown each year from seed, and is normally dioecious, with the species divided into male and female plants, the females producing the seeds. Monoecious (unisex) varieties have been developed through breeding and selection in a number of countries (Ehrensing, 1998; Dempsey, 1975).

Cultivation

Cultivation techniques depend on the desired output, since not only do specific varieties exist for seed and fiber production, but a tradeoff exists between the production and quality of the two. Most fiber hemp varieties reach 10 to 12 feet in height in 3 or 4 months, with minimal foliage. The optimal harvest time for fiber comes before the seeds are fully mature, generally 70 to 90 days after seeding. If left beyond this time the fiber becomes too course for textile applications. When grown for fiber, industrial hemp is planted in narrow rows to reduce branching, increase stalk height, and increase the percentage of the bast fibers that are the very long primary fibers (the bast fiber component also includes many shorter secondary fibers) (Meijer, 1996). Row spacing estimates in the literature range from 3 to 8 inches (Ehrensing, 1998; Kraenzel et al., 1998). Seeding rates cited in the literature vary considerably. These include historical rates of 40-140 kg/ha (Dempsey, 1975), 55-70 kg/ha for Canada (giving plant densities of 200-450 plants/m^2) (BCMAF, 1999), 50-70 kg/ha in Western Europe (Ehrensing, 1998), 150 to 400 seeds per square yard in a North Dakota study (Kraenzel et al., 1998), and 150 or less seeds per square yard in a Kentucky study (Vantreese, 1997).[1]

Harvesting for seed usually occurs 4 to 6 weeks later than that for fiber (BCMAF, 1999: Kraenzel et al., 1998; Vantreese, 1997). When grown for seed, hemp is planted farther apart to encourage branching and therefore greater seed development. Row spacing for seed production

[1] 1 kg/ha = 0.89 lbs/acre.

generally ranges from 8 to 16 inches. One estimate calculates that seeding rates should be one-fifth of those for fiber production (Kraenzel et al, 1998; Vantreese, 1997).

Industrial hemp is well adapted to the temperate zone and can grow in a wide range of environmental conditions. However, higher yields require a rich supply of nutrients and abundant moisture throughout the growing season, so fertilizer use is generally required. It grows best on loose, well-drained loam soils that have abundant organic matter. Optimal mean daily temperature for cultivation ranges between 60° and 80° F (13°-22° C), though hemp will endure both colder and warmer conditions, and both seedlings and mature plants are resistant to light frosts of short duration (Ehrensing, 1998; Kraenzel et al, 1998). Hemp needs ample moisture, especially during its first six weeks for optimum yield. European studies indicate that 10 to 14 inches of rainfall are required during this time, with 20 to 28 inches needed overall (Bocsa and Karus, 1998). Once hemp becomes well rooted, it can endure drier conditions, but severe drought has been shown to hasten maturity and produce dwarfed plants (Ehrensing, 1998; USDA, 2000).

In general, minimal biocide use is needed for hemp cultivation. Significant insect damage and major disease outbreaks are generally rare, though they do occur (Ehrensing, 1998; USDA, 2000). A serious problem can be the many bird species that voraciously feed on the *Cannabis* seed (McPartland, 1996). This was found to be a significant problem in experimental crops grown in Hawaii (West, 2001). Cochran et al. (2000) point out, however, that if hemp were to be intensively cultivated, increased incidence of pest problems should be anticipated. When grown for fiber, hemp is very competitive with weeds, and requires little if any herbicides. Ehrensing (1998) argues that weed suppression with minimal pesticide use is potentially one of the greatest agronomic and environmental benefits of hemp, making it a good rotational crop. Low (1995) describes recent commercial experiences in the UK indicating that weeds can be almost completely suppressed during the growing season with properly timed planting. Wright (1918) documents a hemp crop grown in 1911 at Waupun, Wisconsin, that virtually wiped out a bad infestation of quack grass. However, when hemp is grown for seed, or as a dual seed and fiber crop, the crop does not form a sufficiently dense canopy to suppress weed growth, and herbicide use generally becomes necessary (Baxter and Scheifele, 1999).

Harvesting and Processing

The harvesting of industrial hemp generally involves six basic steps: chemical defoliation (removal of unnecessary leaf mass with chemical use), cutting, retting, baling, loading and transport (Kraeznel et al., 1998). The harvesting of hemp in Europe is usually done with tractor drawn harvester-spreaders cutting hemp stems and laying them in windrows for field retting. Later, using a second machine, hemp is gathered and tied in field-dried stem bundles for pickup and delivery to the processor. These systems are designed to maintain the parallel alignment of hemp stems throughout harvest and processing in order to maximize recovery of the long primary bast fibers. As a result, harvesting equipment has limited capacity per day, and additional innovations would be needed to further reduce harvesting costs (Ehrensing, 1998).

Retting is the microbial process that breaks the chemical bonds holding the bast fiber bundles together, and allows for efficient processing of textile-quality fiber. The two traditional types of retting are water retting, in which plant stems are immersed in water, and dew or field retting, in which the crop is spread in the field to rot and dry for 2-3 weeks. Water retting produces fiber of superior quality and uniformity, but is very labor and capital intensive, and requires large volumes of high quality water (Ehrensing, 1998). Most hemp fiber used for textiles is water retted in China or Hungary, where labor costs are lower and environmental regulations less stringent since the process produces significant volumes of waste water (USDA, 2000). Current research in Europe is focused on developing a less labor and resource intensive chemical retting process, but technological breakthroughs have yet to occur (Cochran et al., 2000; Ehrensing, 1998; Kessler, 1996).

Once retted, dried and bailed, stalks are brought to a processing mill for scrutching (breaking the woody core of the stems into short pieces) and decortication (the separation of bast fiber from the hurds). Some processes convert all of the bast fiber into tow (tow refers to the short broken fibers used for yarn, twine and stuffing), which results in higher throughput and lower skilled labor requirements. European researchers are currently trying to increase throughput capacity and reduce labor costs by bypassing traditional retting and scrutching techniques using steam explosion and ultrasound (USDA, 2000; Ehrensing, 1998). Processing hemp seed involves hulling or pressing and crushing, depending upon the desired output.

IV. Markets for Hemp Fiber and Seed

The market potential for industrial hemp is a critical consideration in accessing the long-term feasibility of developing a domestic industry. Numerous sources in the literature have cited hemp's current and potential uses, a variety of which are summarized in Table 1 below relative to their processing requirements (Gardner Pinfold and White, 1998; Thompson et al., 1998). The USDA (2000), however, points out that for the many potential uses of hemp to translate into concrete market opportunities, it needs to be competitive with current well-established sources of bast fiber, hurds and seeds, in terms of characteristics, quality and price. Since industrial hemp has not been commercially produced in the US since the late 1950s, any forecasts of potential marketability are speculative.

Table 1: Hemp Products Flowchart

Harvest							
Hemp Seeds				**Hemp Stalks**			
Intermediate Processing							
Hulling		**Pressing/Crushing**		**Decorticating**			
Meat	Shell	Oil	Cake	Fiber			Hurds
Further Processing							
				Hackling		**Scrutching**	
				Primary (line) Fiber	Secondary Fiber	Tow	Hurds
Uses							
• Food	• Flour	• Food • Fuel • Paint • Personal-care products	• Food • Beer • Feed	• Fabric • Insulation • Carpeting • Paneling	• Cordage • Pulp • Recycling Additive	• Cordage bagging • Fiber board	• Fiber board • Compost • Paper filler • Absorbent • Animal bedding • Chemical feedstocks for plastics, paint and sealants

Source: Adapted from Kraenzel et al., p. 10

The next two sections summarize the key findings of studies conducted by various entities regarding prospects for commercial hemp production. The first focuses on the overall market prospects for hemp, and the following section summarizes various estimates of short-term farm-gate profitability for North American production.

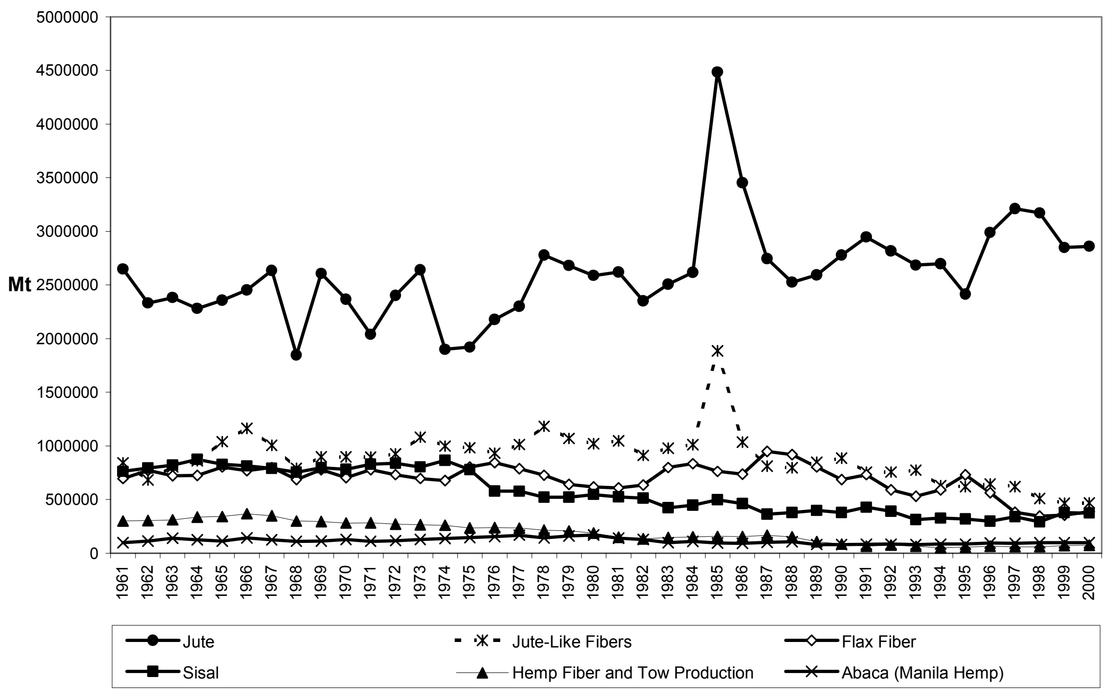
A. Fiber Markets

Current markets for bast fibers include specialty textiles, paper, and composites. As a rough look at available supply, Figures 1 and 2 document world production of various bast fiber plants and industrial hemp, respectively, from 1961 to 2000. As can be seen, hemp has made up a very small share of world bast fiber plant production, averaging only 8% of the level of jute production, and 27% of flax production. Flax has been described as similar to hemp in terms of fiber quality and processing requirements (FAO, FAOSTAT; USDA, 2000). Overall, world production of bast plant fibers has changed little over time. Jute, abaca and jute-like fibers have all had positive average annual growth rates, with jute having the highest rate at 1.6% per annum. Hemp fiber and tow production, flax fiber and sisal have all had negative average annual growth rates, ranging from –0.7% per annum for flax fiber, to –2.9% per annum for hemp fiber and tow. Jute production in 2000 was, in fact, only about 8% more than that of 1961. As can be seen in Figure 2, hemp fiber and tow production has steadily decreased over the past three decades, from about 300 thousand metric tons in 1961 to 74 thousand metric tons in 2000.

Textiles

As documented in Table 2 (reproduced from USDA 2000), the levels of recent imports of hemp fiber to the US have been small. Using hemp fiber and linen imports as lower and upper bounds, respectively, on the short-term market potential for domestically cultivated hemp, USDA (2000) estimates a potential 2,000 – 250,000-acre production-equivalent range for hemp in the US.[2] However, they argue that near-term market potential is likely to be at the low end of this range (which could be supplied by only a few farms in the US, given the average farm size of about 500 acres) since hemp fiber imports have generally been 0.5 percent or less of linen imports, and since no textile flax is produced in the US despite a lack of restrictions on its cultivation. This provides some evidence that domestic production of crops similar to flax, such as hemp, are unprofitable.[3] Demand for domestic hemp fiber textile is likely to be constrained by the need to further develop technology for spinning hemp into fine yarns, since its variable fiber quality it can damage current high-speed processing machinery (Gardner Pinfold and White, 1998). In addition, both hemp and linen are specialty fibers, and accounted for less than 3 percent of world textile fiber production since 1980 (USDA, 2000). Some authors point out that demand exists for apparel specifically made from hemp. However, the USDA (2000) concludes this is likely to remain a very small and somewhat cyclical niche market, dependent on trends in fashion and taste.

Figure 1: World Production of Selected Bast Plant Fibers (Mt), 1961 - 2000



Source: FAO, FAOSTAT

[2] According to the study, linen, produced from fiber flax, is hemp's closest competing fiber for textile use in terms of production, processing and characteristics (USDA, 2000).

[3] Thompson et al. (1998) notes that the flax straw byproduct of domestic flaxseed production is sold for specialty papers, but at low price of roughly US$40/ton.

Figure 2: World Hemp Fiber and Tow Production (Mt), 1961 - 2000

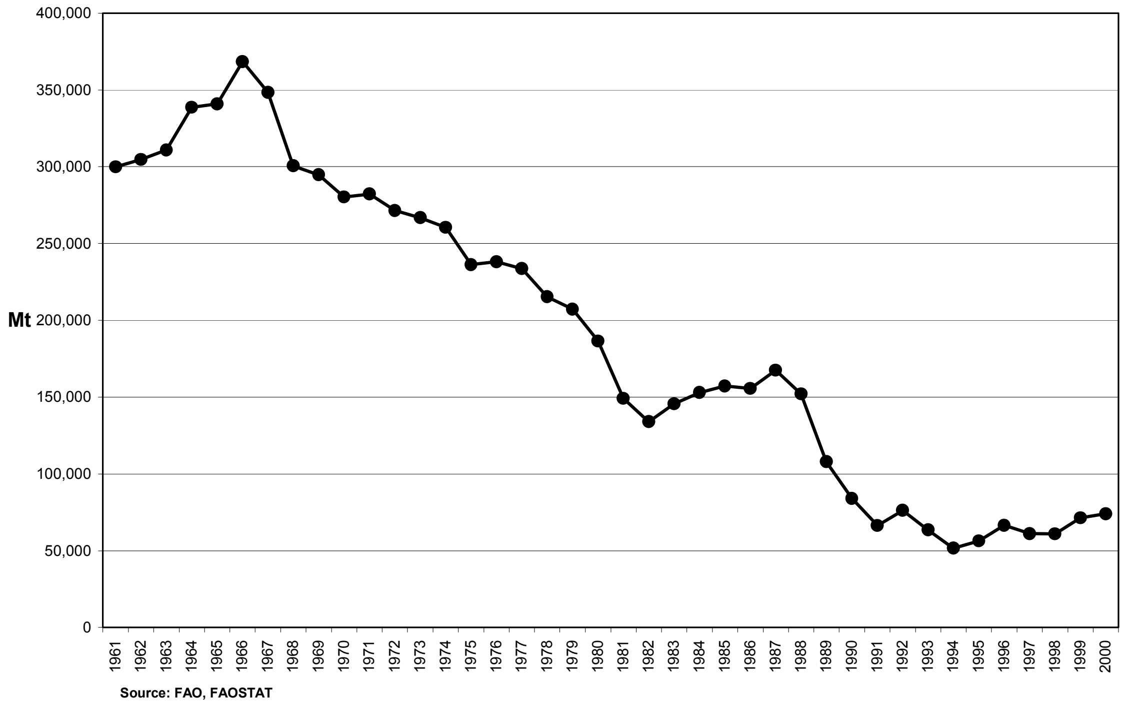


Table 2: U.S. Hemp Imports, by Category, 1989-99

Reproduced from USDA (2000)

Year	Raw fiber	Tow and yarn waste	Yarn	Total fiber, tow/waste and yarn	Fabric	Total[1]
			Pounds			
1989	0	166,200	0	166,200	na	166,200
1990	0	74,697	542	75,239	na	75,239
1991	1,900	127,429	132	129,462	na	129,462
1992	904	15,410	88	16,402	na	16,402
1993	0	121	16,848	16,969	na	16,969
1994	463	6,089	11,570	18,122	na	18,122
1995	14,844	7,754	8,181	30,779	222,495	253,274
1996	72,991	43,568	12,899	129,458	291,517	420975
1997	193,535	13,340	624,682	831,557	451,174	1,282,731
1998	708,918	73,471	149,447	931,836	522,789	1,454,625
1999 [2]	1,587,674	35,170	65,927	1,688,771	201,650	1,890,421

na = Not available. A separate import code for hemp fabrics was added in 1995.

[1] Includes fabric for 1995-99.

[2] January to September.

Source: U.S. Department of Commerce, Bureau of Census.

Paper

Various sources have noted that rising wood prices make plant fibers such as hemp increasingly attractive to the paper industry as a source of fiber and pulp. However, in the short-term, hemp is not price competitive with wood and non-wood fibers such as cotton, flax, kenaf and abaca in standard and specialty paper markets. This is due to its high processing costs and unresolved technical issues involved with pulping (Gardner Pinfold and White, 1998; Johnson, 1999; USDA, 2000; Thompson et al., 1998). Dutch and German research suggests that hemp may be used as a fiber supplement to recycled paper pulp (USDA, 2000), and Thompson et al. (1998) estimate that industrial hemp fiber can capture up to 20 percent of the 75,000 tones of flax fiber used for specialty papers. They estimate this would translate into 12,500 acres of industrial hemp. These estimates are based on the experience of French hemp producers, who supply industrial hemp fiber to specialty paper mills in a number of European countries. Van der Werf (1994) reports that the vast majority of the 12,000 acres of industrial hemp grown and processed in France in the early 1990s was utilized to manufacture paper pulp, and industrial hemp fiber from other European countries such as the UK or Spain is also used in specialty paper production. However, Vantreese (1997) points out that hemp production has been subsidized in most of Europe, thereby obscuring the degree to which such production is profitable. In the long term, hemp's profitability as a source of paper fiber and pulp will depend on innovations in processing and pulping technology, as well as the world market for wood and other non-wood fibers.

Animal Bedding and Cat Litter

Thompson et al. (1998) conclude that hemp hurds appear price-competitive with other sources of animal bedding such as wood chips, fine wheat straw and other types of bedding used for valuable thoroughbred or breeding horses, and by pet owners willing to spend more on their pets. These materials are favored for their water absorbency, which reduces illnesses. Companies in England, France and the Netherlands make horse bedding from hurds, and some members of the racehorse industry have expressed interest in using hemp hurds (Patton, 1999). Hemp hurd-based cat litter is being sold in England, France and Germany (Gardner Pinfold and White, 1998). Studies point out that since hurds are a joint product with bast fiber in hemp, finding markets for hurds could mean the difference between profitability and loss for industrial hemp cultivation (USDA, 2000; Gardner Pinfold and White, 1998).

Other Applications

Other potential markets for hemp fiber include molded car parts, fiberglass substitutes and composites. Domier (1998) reports that in recent years several car companies have investigated the use of non-wood fibers, such as hemp and kenaf, in the manufacture of molded car parts because they are lighter and easier to recycle than current raw materials. Several BMW models have trunk liners and press-molded airbag parts that use hemp fibers. Kenex Ltd. has developed prototype molded car parts, and transit buses are being retrofitted in Florida with molded hemp parts for use in Orlando (Thompson et al., 1998). However, to gain in these markets hemp would have to compete with other sources of non-wood fiber, and would have to be supplied in sufficient quantities throughout the year. According to the USDA (2000), use of non-wood fibers such as hemp in composites is still largely in research and development stages, or in the early stages of commercialization in North America.

Wheat straw, flax, kenaf, jute and hemp, in combination with various resins, can be used to make composite board, with wheat straw being the dominant non-wood fiber in these applications (Glaser and Van Dyne, 1997). Hemp fiber could be desirable in this market because of its length and strength. Gardner Pinfold and White (1998) report that a number of factories using non-wood fibers have opened in Manitoba and Alberta. They produce non-structural fiberboard and strawboard, and hemp could be a potential feedstock in their production process given sufficiently low price.

Thompson et al. (1998) reports that hemp and other non-wood fibers could also replace fiberglass in some applications. Their use would be limited, however, to replacing chopped fiberglass and in applications where moisture is not a problem.

B. Seed Markets

Hempseed can be used as a food ingredient, or crushed for oil and meal. As a food ingredient, hempseed has been shown to be highly nutritious, containing 20 percent high-quality digestible protein. The seed is approximately 29 to 34 percent oil by weight, and the oil can be used for both human consumption and industrial applications (USDA, 2000). The oil contains roughly the same ratio of linoleic and linolenic acids that would be found in a nutritionally balanced diet (Marshall, 1998). However, hemp oil is fairly unstable and becomes rancid quickly due to its fairly high proportion of polyunsaturated oils. Hemp meal contains 25 to 30 percent protein and can be used in food or animal feed (Vantreese, 1998). Various food products containing hempseed include nutrition bars, tortilla chips, pretzels and beer. At least two breweries in the US, as well as some in Canada, Germany and Switzerland, make hemp beer (*The Economist*, Aug 1, 1998; Gardner Pinfold and White, 1998; Louie, 1998). The USDA (2000), however, concludes that the market for hempseed as a food ingredient will likely remain small, on par with other specialty seeds such as sesame and poppy seed.

Hempseed oil has been sold as a nutritional supplement in health food stores, as well as an ingredient for body-care products including lotions, moisturizers, shampoos and lip balms (Marshall, 1998: Rorie, 1999). The market for hempseed oil has been limited by a number of factors. These include the need for mechanical crushing combined with solvent extraction to produce higher oil yields. Hemp oil does not undergo degumming and bleaching as do many other vegetable oils, thereby limiting appeal to consumers due to taste and appearance, as well as the fact that some consumers prefer oil that has not been produced with chemical processes. The oil easily oxides, and so must be kept in dark-colored bottles, has a limited shelf life, and cannot be used for frying (USDA, 2000).

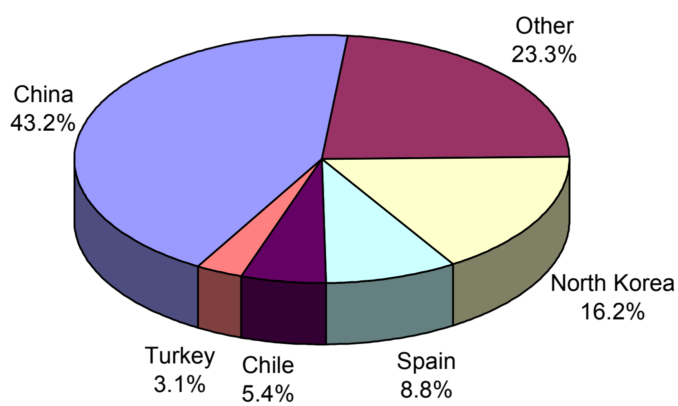
As a drying oil, hemp would have to compete with current well-established sources of manmade chemicals and plant-based oils, such as linseed and tung oils, in industrial applications. USDA (2000) notes that use of linseed and tung oils, consistent with industrial uses of all plant and animal oils and fats, has fluctuated in the last two decades, with no apparent trend.

Thompson et al. (1998) estimate the demand for hempseed in the US and Canada at about 1,300 tons per year. Using German yields of 1,000 pounds per acre, domestic demand could be satisfied with 2,600 acres of production. Kraeznel et al. (1998) identified four potential processing facilities in North Dakota, but the general manager of AgGrow, Dr. John Gardner, considered production and processing of industrial hemp in 1993 and concluded that it was not worthwhile due to the costs of externalities and administrative burdens.

C. World Market Considerations

Figure 3 displays the composition of world hemp fiber and tow production for 2000. A few major producers dominate world production, with China being the world's largest producer of hemp fiber and seed for many years. China contributed on average 34% and 76% of the world's total annual industrial hemp fiber and seed production, respectively, from 1980 to 2000. Its production share of hemp fiber ranged from about 20% to 45%, and for hempseed from 64% to 85% over the last 20 years (FAO, FAOSTAT).

Figure 3: Composition of World Hemp Fiber and Tow Production, 2000
Source: FAO, FAOSTAT



Wang and Shi (1999) analyzed the sensitivity of China's hemp fiber production to world export prices as a means to gauge future prospects for the market. They found that while China's domestic price for cotton closely follows trends in its world export price, the domestic price for hemp fiber has generally diverged from its world price. Despite a steady increase in the world export price since 1986, China's domestic hemp fiber price has decreased or stagnated.[4] This is

[4] They also point out that some of the world price increase could be due to increased processing before export.

troubling for world market prospects since they also find that acreage sown to hemp indeed appears to be positively correlated by the previous year's prices, as would be expected, and that the inelasticity of price transmission observed appears to be related to institutional constraints that could be reduced as a result of China's accession to the WTO. This suggests that as China's domestic prices more closely reflect world prices, domestic production could increase, potentially depressing world prices since the total world market is relatively small.

Along the same vein, USDA (2000) and Vantreese (1997) point out that the thinness of current hemp markets could translate into the potential for significant price volatility. Vantreese (1997) notes that when China began dumping hempseed on the market between 1986 and 1991, increasing world export volume 3 to 5 times previous levels, world prices dropped by nearly half from around \$0.26/lb during 1981-1985 to \$0.15/lb from 1986-1991. After China stopped exporting hempseed in 1991, prices nearly doubled in 1992 and increased further after that. Such price fluctuations, she adds, would be difficult for many farmers to weather, and is an important factor to consider when examining the possibilities of reviving industrial hemp cultivation in the US.[5]

Canada's experience with industrial hemp production suggests market participants will face significant market uncertainty. Canada produced its first hemp crop in 1994, after 50 years of prohibition. In 1995, seven groups were granted production licenses, including joint efforts between academia, government and private industry (Vantreese, 1997). By 1998, Health Canada permitted 259 farmers to grow hemp on 6,180 acres, primarily in Ontario and Manitoba. In June 1999, 674 hemp production licenses were issued for cultivation on about 35,000 acres. More than half of this acreage was in Manitoba, followed by Saskatchewan and Ontario. Actual acreage under cultivation was less than allowed because of planting delays associated with a wet spring in western Canada, however (Health Canada, 1998; Health Canada, 1999; Hansen-Trip, 1999; Hanks, 1999). The number of commercial licenses issued dropped in 2000 to 213 as a result of fewer applications. These allowed for cultivation on about 13,560 acres, more than half of which was again in Manitoba. One of the major reasons cited for the drop in license

[5] It should be noted, however, that significant price variability existed for most domestically cultivated crops through the decade of the 1990s.

applications was that the major contractor buying industrial hemp in Manitoba closed its doors, leaving contracting farmers uncertain as to existing and future demands (Hansen-Trip, 2000). In fact, the general manager of Kenex Ltd., a company that specializes in industrial hemp research, production and processing in Southwestern Ontario, indicated that the 1999 supply of Canadian hemp fiber and seed oversupplied the North American hemp market (von Sternberg, 1999). Canada's experience highlights the economic challenges facing the development of an industrial hemp industry in North America.

V. Viability of US Cultivation and Processing

Yields

Yield is a key parameter to consider in assessing the viability of any crop. The literature on industrial hemp documents a wide range of yield estimates, the comparison of which is complicated by the range of varieties cultivated, the scale of cultivation, the different growing locations and climatic conditions present, and the different standards of reporting used. Many European authors, for example, generally report all above-ground dry matter for fiber hemp, which also includes leaves and seed, instead of the dry-stem yields reported by other authors (Ehrensing, 1998). To put this into perspective, both Dempsey (1975) and Wright (1918) estimate that 1 lb of dry retted stems contains 0.2 lbs of fiber (which is comprised of the long, "line" fiber and the tow), whereas 1 lb of dry retted *stems and leaves* contains about 0.13 lbs of fiber. Ehrensing (1998) reports that research trials for fiber hemp in Europe over the last four decades showed dry-matter yields ranging from 2.6 to 8.7 tons per acre. Research trials in the Netherlands during the late 1980s reported dry-stem yields of 4.2 to 6.1 tons per acre. Yields in France have typically ranged from 3.6 to 4.5 tons per acre. Recent commercial experience in England from cultivation on several thousand acres over several years, a larger scale of cultivation than has generally been conducted in mainland Europe, produced average dry-matter yields of 2.2 to 3 tons per acre (Ehrensing, 1998).

Regarding the US and Canada, Dewey (1913) reports dry-stem yields for US fiber hemp in the early 1900s ranging from 2 to 12.5 tons per acre, averaging 5 tons per acre under good conditions. Wright (1918) documents average dry-stem yields for fiber hemp grown in

Wisconsin, Indiana, Ohio and Michigan in 1917 of 3 tons per acre, as compared to 6.7 tons per acre for California and 5 tons per acre for Kentucky. In Canada, Baxter and Sheifele (1999) report recent air-dried stem yields in Ontario ranging from 1.1 to 6.1 tons per acre.

Reported yields for hempseed also vary widely. Vantreese (1998) reports dramatic increases in hempseed yields in recent years. In 1997, world average yields were 876 pounds per acre, with a high of 1,606 pounds per acre for China, where seed is consumed, and 595 pounds per acre for France, where much of the production is certified planting seed. In Germany, current seed yields are about 1,000 lbs per acre, while in Eastern Europe yields range from 350 to 450 lbs per acre (Thompson et al., 1998; Mackie, 1998). In Canada, seed yields in 1999 averaged 800 pounds per acre (Hanks, Fall 1999).

Processing Costs

The current state of harvesting and processing technology for fiber hemp, likely due in part to US restrictions on hemp cultivation, makes its production significantly labor- and resource-intensive. This partially explains why countries with lower labor costs such as China, Hungary, Poland and Romania, remain major suppliers (USDA, 2000; Ehrensing, 1998). Vantreese (1997 & 1998) points out that since raw hemp is a bulky commodity entailing significant transportation costs, the simultaneous development of local processing facilities with hemp production capacity will be necessary to insure the long-term prospects of a US hemp industry. Halbrendt et al. (1996) concludes that lack of local processing capacity makes estimates of profitability from hemp production in the US extremely speculative. While there is research in Europe focused on increasing throughput capacity of fiber processing techniques, and reducing labor costs by bypassing traditional retting and scrutching techniques using steam explosion and ultrasound, technological breakthroughs resulting in significant cost savings have yet to occur (USDA, 2000; Ehrensing, 1998; Kessler, 1996).

The USDA (2000) reports that specialty oilseed crushing facilities capable of accommodating hemp seed do exist in the US. They cite the *Soya & Oilseed Bluebook*, which documents companies in North Dakota, Minnesota, Georgia and North Carolina that mechanically crush flaxseed, borage, safflower, canola, sunflower seed, crambe, peanuts and cottonseed (Soyatech, 1999; USDA, 2000). These same facilities could likely crush hemp seed as well.

Estimates of Farm Gate Profitability

Tables 3 and 4 summarize various estimates of profitability for hemp fiber and seed production extant in the literature. Since industrial hemp has not been grown commercially in the US for almost half a century, these studies have relied on cost estimates for comparable crops, as well as on the Canadian and European experience. Also, it should be noted that these estimates do not include costs associated with licensing, monitoring and verification. Moes (1998) estimates licensing, sampling and analytical fees for Manitoba to be around $14 per acre. Baxter and Scheifele (1999) cite total costs for Global Positioning, sampling and THC testing to be around $27 per acre for Ontario.[6] All seed production estimates assume that the residual hemp stalks are processed for fiber or pulp. As mentioned in Section III above, fiber from dual production is of a lower quality than that from fiber-only cultivation, and these authors have given lower price estimates for fiber produced in the dual production scenarios. Given the various issues discussed in Section IV regarding overall market prospects for industrial hemp, the prices for seed stock, and seed and fiber output are clearly the most speculative parts of these estimates, and will be most affected by future developments in technology, market access and domestic sources of certified seed. Regarding seed stock, for example, since China and France are currently the two major world producers of certified seed, the development of North American supplies of certified seed stock could significantly reduce the transportation component in seed costs. Furthermore, all of these studies assume the existence of local processing facilities, and so transportation costs are relatively low.

Thompson et al. (1998) estimates seed and fiber prices based on the price of hemp imports into the US in 1998. They use cost estimates developed for Kentucky by Dave Spalding of the University of Kentucky College of Agriculture, and updated to 1997 values based on the increases in costs from growing corn and the results of research in Canada. Their yield estimates come from German agricultural data (Nova Institute, 1996). Ehrensing (1998) bases his estimates

[6] Their estimates were in 1998 and 1999 Canadian dollars. The values presented above are calculated using a recent exchange rate of 0.665 US$ / Canadian $.

on typical costs associated with irrigated field corn in the Pacific Northwest, and comes up with the hemp fiber price of $75/dry-weight ton based on discussions with an Oregon hemp composite manufacturer and on current trends in the price for wood chip.[7] Moes (1998) uses cost estimates derived from 1994-1997 research trials in Manitoba, Canada, and does not include estimates of market price for fiber and seed. Baxter and Sheifele (1999) and BCMAF (1999) do not explicitly indicate the source for their estimates, but it is to be assumed that these come from the combined results of research from trial crops and commercial experience in Canada.

Overall, issues of location and time period aside, profitability estimates from these studies range from -$241.30 to $605.91 per acre. Estimated hemp fiber prices used range from $75 - $200 per ton for fiber only crops, to $90.50 - $200 per ton for fiber produced from dual production crops. Produced seed prices range from $0.30 to $1.2 per pound, depending on whether it is for grain or certified seed, whereas the input price of seed stock in these estimates ranges from $0.81 to $3.32 per pound. Generally, fiber yields are in the same ballpark, ranging from 3.4 to 5 tons per acre for fiber-only production, and 0.5 to 2.5 tons per acre for dual production crops. Seed yields range from 300 to 1,069 pounds per acre. Estimates for variable costs range from $121.45 to $378.39, and where given, fixed cost estimates ranged from $36.44 to $245.

In addition to estimating the profitability of industrial hemp itself, some authors have also compared it with other cash crops, since relative profitability is an important consideration. Table 5 is a compilation of various estimates of profitability for other crops used as a basis of comparison to hemp from these various studies. Thompson et al. (1998) concludes that estimated returns to hemp compare well with other field crops in Kentucky, though falls below estimates for tobacco. Vantreese (1997) estimates a range of returns to hemp of $5.33 to $141.65 per acre, with an average of $73.49 per acre, and concludes that hemp is generally comparable to other cash crops in Kentucky, though not as competitive as tomatoes for processing or tobacco. Kraeznel et al. (1998) uses hemp profit estimates from both Vantreese (1997) and Thompson et al. (1998), and finds that only irrigated potatoes compare favorably with industrial hemp.

[7] Wood chips, like hemp, are a common raw material for animal bedding.

Table 3: Profit Estimates for Fiber Hemp Production

STUDY	Thompson et al. (1998)	Ehrensing (1998)	Baxter & Scheifele (1999)	BCMAF, Canada (1999)
State / Region	**Kentucky**	**Pacific Northwest (Oregon)**	**Ontario, Canada***	**British Columbia, Canada***
Variable Costs / Acre				
Seed (lbs.)	$125.00 (50)	$34.00 (25)	$109.73 (50)	$50.30 (62)
Total Fertilizer Cost	$45.01	$85.00	$46.55	$18.62
Application / Acre		*600 lbs, 16-16-16*	*135 MAP 11-52-0, 70 Muriate of Potash 0-0-60, 250 U.A.N. 28-0-0*	
Price		*$250 / ton*		
Herbicides	$0.00	$0.00		$0.00
Lime	$12.12			
Fuel, Oil	$18.43			
Repair	$16.14			
Interest / Operating Capital Interest	$8.38	$29.78	$15.30	
Pickup		$7.68		
Farm Truck		$6.34		
General Overhead		$20.00		
Storage	$5.00		$46.55	$2.66
Transport to Processor (loading and trucking)	$27.20	$15.00	$49.88	
Operator Labor / Acre				
Tillage and Planting		*$40.00*	*$33.92*	*$13.96*
Irrigation		*$62.00*		
Forage Chopper		*$15.00*		
Raking		*$7.50*		
Cutting & Swathing			*$16.63*	
Retting			*$16.63*	
Bailing		*$49.00*	*$43.23*	
Harvest and Haul				*$35.91*
Total Labor Cost / Acre	$56.00	$173.50	$110.39	$49.87
Total Variable Costs	**$313.28**	**$371.30**	**$378.39**	**$121.45**
Fixed Costs / Acre				
Land Rent		$150.00		
Insurance -- Machinery & Equipment		$3.00		
Irrigation System -- Depreciation & Interest		$44.00		
Machinery and Equipment --		$48.00		
Total Fixed Costs	**$50.27**	**$245.00**	**--**	**--**
Total Enterprise Costs	$363.55	$616.30		
Yield (Tons/Acre)	3.4	5.0	3.86	3.6
Price (/ Ton)	$200.00	$75.00	$119.70	
Total Revenue / Acre	$680.00	$375.00	$462.04	
Profit / Acre	**$316.45**	**-$241.30**	**$40.57 ****	**--**

Note: *Assumptions and definitions of cost vary considerably across estimates, and should thus be viewed with caution*

* All values have been converted to US$ from Canadian dollars by the current rate, as of Jan 30, 2001, of 0.665 US$ to (

** Does not include fixed costs.

Table 4: Profit Estimates for Dual Hempseed & Hemp Fiber Production

STUDY	Thompson et al. (1998)	Moes, 1998.	Baxter & Scheifele, 1999.	BCMAC, 1999.
STATE / REGION	**Kentucky**	**Manitoba, Canada**	**Ontario, Canada***	**British Columbia, Canada**
Variable Costs / Acre				
	Grain / Certified Seed / Grain & Straw	Dual Production	Grain & Straw	Seed for Oil
Seed (lbs.)	$25 (10) / $25 (10) / $125 (50)	$32.92 (15) - $66.50 (20)	$87.78 (40)	$17.04 (21)
Fertilizer Cost	$45.01	$25.36	$46.55	$16.62
Application /Acre		*100 lbs N & 45 lbs* P_2O_5	*135 MAP 11-52-0, 70 Muriate of Potash 0-0-60, 250 U.A.N. 28-0-0*	
Herbicides	$10.95 / $10.95 / $0.00	$6.65		$0.00
Lime	$12.12			
Fuel, Oil	$14.06 / $14.06 / $22.25	$9.97		
Repair	$30.38 / $30.38 / $23.12			
Interest / Operating Capital Interest	$5.24 / $5.24 / $8.94	$4.45 - $5.69	$14.63	
Pickup				
Farm Truck				
General Overhead				
Storage	$5.00	$2.85	$29.93 **	$3.32
Other Costs		$4.99		
Crop / Hail Insurance		$3.99		
Land Taxes		$3.66		
Transport to Processor (loading and trucking)	$8.00 / $5.60 / $24.00		$35.24	
Operator Labor / Acre				
Tillage and Planting			*$33.92*	*$13.96*
Machinery Operating		*$13.96*		
Combining			*$46.55*	
Cutting and Swathing			*$16.63*	
Retting			*$16.63*	
Baling			*$26.60*	
Seed Drying for Storage		*$1.42 - $2.37*		
Grain Cleaning		*$1.99 - $3.33*		*$13.30*
General Labor	*$56.00 / $70.00 / $63.00*	*$19.95*		
Harvest and Haul				*$75.14*
Total Labor Cost / Acre	$56.00 / $70.00 / $63.00	$37.32 - $39.61		$102.40
Total Variable Costs	**$211.76 / $223.36/ $328.44**	**$132.16 - $169.27**	**$354.46**	**$139.40**
Fixed Costs / Acre				
Land Investment Costs		$11.84		
Machinery Depreciation & Investment		$24.60		
Total Fixed Costs	**$45.00 / $70.73 / $75.05**	**$36.44**	**--**	**--**
Total Enterprise Costs	$256.76 / $294.09 / $403.49	$168.60 - $205.71		
Residual Stalk Yield (Tons/Acre)	0.5 / 0.5 / 2.25	1.5 - 2.5	2.2	1.8
Stalk Price (/ Ton)	$120 / $120 / $200		$90.50	
Seed Yield (Lbs/Acre)	1069 / 700 / 700	300 - 500	300 - 1500	800
Seed Price (/ lb)	$0.39 / $1.20 / $0.39		$0.30	
Total Revenue / Acre	$536.91 / $900 / $723		$289.10 - $649.10	
Profit / Acre	**$220.15 / $605.91 / $319.51**	--	**-$65.36 - $294.64** ***	--

Note: *Assumptions and definitions of cost vary considerably across estimates, and should thus be viewed with caution.*

* All values have been converted to US$ from Canadian dollars by the current rate, as of Jan 30, 2001, of 0.665 US$ to Canadian $.

** Does not include grain storage.

*** Does not include fixed costs.

Table 5: Estimated Returns to Selected Cash Crops, Various Sources

Crop	Estimated Profitability (US$ / Acre)
Thompson et al. (1998), Kentucky	
Alfalfa Hay	$141.34
Continuous Corn	$75.71
No-Till Corn, Rotation Following Soybeans	$106.48
Popcorn, Reduced Tillage	$78.25
White Corn, Rotation Following Soybeans, Reduced Tillage	$135.84
Grass Legume Hay, Round Bales	$161.56
Grain Sorghum, Conventional Tillage	$10.51
Soybeans, No-Till, Rotation Following Corn	$102.20
Barley- No-Till Soybeans, Double Crop, Following Corn	$158.09
Wheat- No-Till Soybeans, Double Crop, Following Corn	$158.43
Burley Tobacco, Bailed, Non-Irrigated	$1,563.48
Dark Air-Cured Tobacco	$182.48
Dark Fire-Cured Tobacco	$1,104.87
Wheat, Reduced Tillage	$14.24
Vantreese (1997), Kentucky	
Grain Corn	$136 - $56
Soft Red Winter Wheat	$60 - $39
Tobacco	$1,050.00
Tomatoes for Processing	$775.00
Wheat (+ Def Payment) and Soybeans, Double Crop	$175.00
Soybeans	$100.00
Hay and Silage	$100.00
Kraeznel et al. (1998), North Dakota	
Spring Wheat	-$2.31
Malting Barley	$5.48
Grain Corn	-$38.50
Conf. Sunflowers	$0.86
Irrigated Potatoes	$444.91

VI. Political Issues

In addition to estimates of industrial hemp's market potential and profitability, the Drug Enforcement Agency's (DEA) strong opposition to industrial hemp cultivation in the US is an important consideration regarding its commercial viability. Industrial hemp remains classified as a Schedule I Controlled Substance under the Controlled Substances Act in the US, and the DEA remains adamantly opposed to cultivation of industrial hemp for the following reasons (Vantreese, 1998):

- It is very difficult to distinguish between industrial hemp, which has low THC content, and marijuana.

- It has been suggested that industrial hemp advocates have a hidden agenda of supporting the legalization of marijuana.

In the past, DEA has granted no registrations for the cultivation of hemp for industrial purposes, and under the Controlled Substances Act determination needs to be made that such production is in the public interest (Industrial Hemp Taskforce, 2000). Consequently, any lifting of restrictions on cultivation of industrial hemp will most certainly be accompanied by strict regulations governing licensing and certification, cultivation, testing and monitoring of hemp cultivation (this is currently the case in Canada). Compliance will likely be primarily born by individual producers. Given the potential political and regulatory costs, combined with the broader tasks of stimulating the levels of investment in research, market development and domestic processing capacity needed to make hemp a viable US crop, an important consideration in determining its long-term feasibility is the level of collective state government interest in the crop. The broader the degree of interest, the less the burden will be on individual state efforts. Though an in-depth discussion of this is beyond the scope of this paper, the current situation regarding state efforts to legalize production is documented in Appendix I for reference.

VII. Conclusion

Although research on cultivation and the development of varieties of fiber and seed hemp better suited to North American climatic and soil conditions would be a necessary part of developing industrial hemp production in the US, the literature generally concludes that agronomic considerations are of relatively minor concern. Lack of innovation in both harvesting and processing technology – reducing labor and resource costs and improving fiber quality and yield – is continually cited as a major barrier to the economic feasibility of industrial hemp in the US, and its competitiveness with other comparable raw materials worldwide. This observation is highlighted by the fact that today's major world suppliers are generally those countries with low labor and resource costs, as well as European producers that have benefited from government subsidies. Such innovations would not only improve farm gate profitability, but would also improve the prospects for the profitable development of local processing facilities for hemp fiber and seed, which is a key requirement, cited by numerous authors, for making industrial hemp cultivation feasible in North America.

Previous studies have generally concluded that hemp production would be marginally profitable for US producers given assumptions relative to compliance costs and the development of local processing capacity. In general, hemp is found to be slightly more profitable than traditional row crops, but less profitable than other specialty crops. Importantly, these studies do not generally account for the potential price impact associated with a significant increase in the market supply of hemp. Based on the Canadian experience, current demand could be quickly satiated with only a small amount of commercial production. Before hemp can become a major US crop offering profit opportunities to most US producers, significant cost saving innovations need to occur in harvesting, processing, and transport technologies. Until this happens, economic opportunities will be limited to the few producers who are able to contract directly with processors serving small niche markets (including food and beverage manufacturers, as well as makers of hemp fabrics). Such market opportunities will tend to be limited to producers in close proximity to end-users.

A strong argument in favor of hemp's commercialization is its relatively low environmental impact. Recent research on hemp has indeed confirmed its reputation as a potentially excellent rotational crop that needs minimal to negligible pesticide and herbicide use, and which is well-suited to a wide range of growing conditions. However, the degree to which such characteristics make it a desirable industrial crop greatly depend on the overall costs – both environmental and otherwise – of its harvesting and processing as a raw material. As noted above, the level of current technology does not appear to warrant the adoption of hemp cultivation on any significant scale. Industrial hemp generally needs to be grown on prime agricultural land with ample fertilizer use and moisture for good yields, and current processing techniques for its fiber and pulp remain relatively resource and labor-intensive and may be as environmentally damaging as competitive sources of raw materials (Johnson, 1999). Furthermore, Cochran et al. (2000) point out that if hemp were to be intensively cultivated, increased incidence of pest problems should be anticipated, which could compromise the longer-term impacts of its environmental benefits.

Rawson (1992) points out that many of the alternative crops closest to commercialization – guayule, jojoba, kenaf and winter rapeseed – have similar uses to those possible for hemp, yet progress in bringing these crops to full commercial use has been slow and has required a continuing flow of Federal funds to overcome barriers. Hemp would likely face the same barriers to commercialization, and would definitely face fierce competition from many other well-established crops with many of the same potential (including industrial) uses. Potential competitors include corn, soybeans, sorghum and cotton, not to mention other bast fiber crops such as abaca, kenaf, flax and jute. Vantreese (1998) notes that although no barriers exist for US multinationals to invest in hemp research and production elsewhere, such investment has been minimal. This seems to indicate low long-term estimates of profitability on the part of private industry.

The greatest research need for the commercialization of hemp appears to be in the development of harvesting and processing technology. The marginal profitability currently estimated combined with several substitute inputs in most industrial uses suggests that a significant increase in the supply of hemp would adversely impact market prices to the point that US hemp production would not be viable. Cost saving innovations would be necessary to overcome the price impact of increased supply if hemp were to be a viable crop for US producers over the longer term.

Bibliography

Adams, Richard A. "The US Hemp Market: An Economic Examination of the Hemp Industry." Baker College Center for Graduate Studies. http://www.druglibrary.org/schaffer/hemp/indust/ECNPAPER.html.

Alden, Dave M., John L. R. Proops and Phillip W. Gay. 1996. "Industrial Hemp's Double Dividend: A Study for the USA." Research Paper No. 528, Department of Economics, The University of Melbourne.

Baxter, W. J. (Bill) and Gordon Scheifele. 1999. *Growing Industrial Hemp*. Ontario, Canada: Ontario Ministry of Agriculture, Food and Rural Affairs, Guelph. http://www.gov.on.ca/OMAFRA/english/crops/hort/hemp/hempinfosheet-apr-99.htm.

Blade, Stanford F. 1998. "Industrial Hemp in Alberta." *Alberta Hemp Symposium Proceedings*. Edmonton, Alberta, Canada: Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/crops/special/hemp/symposia2.html.

Blanch, Morley, Val Blanch and John Toogood. 1998. "Review of Three Years of Hemp Trials on the Blanch Farm, " in *Alberta Hemp Symposia Proceedings*. Alberta Agriculture, Food and Rural Development.

Boulder Hemp Initiative Project. 1994. *Industrial Hemp as a Cash Crop for Colorado Farmers. http://www.welcomehome.org/cohip/PAGES/IND_HEMP/CASHCROP.HTM.*

Bosca, Ivan and Michael Karus. 1998. *The Cultivation of Hemp: Botany, Varieties, Cultivation and Harvesting.* Sebastopol, CA: Hemptech.

Briskin, Don. 2000. "Industrial Hemp Shows Promise for Illinois Farmers." *ACES News, University of Illinois*, March 6. http://www.ag.uiuc.edu/news/articles/952373633.html.

Charest, Nicole. 1998. "Industrial Hemp: Markets, The Next Challenge." *Alberta Hemp Symposium Proceedings*. Edmonton, Alberta, Canada: Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/crops/special/hemp/symposia5.html.

Cochran, Mark J., Tony E. Windham and Billy Moore. 2000. *Feasibility of Industrial Hemp Production in Arkansas.* University of Arkansas, Division of Agriculture

Correia, F., D. N. Roy and K. Goel. 1998. "Pulping of Canadian Industrial Hemp (Cannabis sativa L.)." *Pulp Paper Canada* 99 (9): 39-41.

Dempsey, James M. 1975. "Hemp," in *Fiber Crops*. University of Florida, Gainsesville: 46-89.

Dewey, L. H. and J. L. Merrill. 1916. "Hemp Hurds a Paper-making Material", USDA Bulletin No. 404, US Government Printing Office, Washington.

Domier, Kenneth W. 1998. "The Potential for Agricultural Fibres." *Alberta Hemp Symposium Proceedings.* Edmonton, Alberta, Canada: Alberta Agriculture, Food, and Rural Development. http://www.agric.gov.ab.ca/crops/special/hemp/symposia6.html.

Dragla, Peter. 1997. *Growing Hemp for the 21st Century.* Ridgetown College and the University of Guelph, Ontario. Canada.

Dyer, H. ed. 1996. *1997 Lockwood-Post's Directory of the Pulp, Paper and Allied Trades.* Miller Freeman, NY, NY.

*The Economist.*1998. "Hemp's Good Habits." Aug. 1.
Ehrensing, Daryl T. 1998. *Feasibility of Industrial Hemp Production in the United States Pacific Northwest*. Station Bulletin 681, Oregon State University, Corvallis. http://eesc.orst.edu/AgComWebFile/EdMat/SB681/body.html.
Gardner Pinfold Consulting Economists Ltd. and Jim White of InfoResults Ltd. 1998. *A Maritime Industrial Hemp Product Marketing Study*. Prepared for the Nova Scotia Department of Agriculture and Marketing and the New Brunswick Department of Agriculture and Rural Development, Canada. http://agri.gov.ns.ca/pt/agron/hemp/hempms.htm.
Glaser, Lewrene and and Donald Van Dyne. 1997. "Straw and Kenaf Make Inroads in Building Materials and Paper." *Industrial Uses of Agricultural Materials Situation and Outlook Report,* IUS-7. USDA, ERS: 17-25.
Halbrendt, Catherine, Quingbin Wang Chan and Matthew C. Mole. 1996. *Alternative Agricultural Strategies in Vermont: The Case of Industrial Hemp.* Department of Community Development and Applied Economics. College of Agricultural and Life Sciences, University of Vermont. Paper presented at the Vermont Agricultural Economic Development Conference. http://www.uvm.edu/%7Ermelamed/UVM_Hemp_Report_1997.html.
Hanks, Arthur. 1999. "The Great Canadian Hemp Experiment: Year II." *The Carbohydrate Economy* 2(3), Institute for Local Self-Reliance, Minneapolis, MN: 1, 4-6
Hanson-Trip, Niels. 2000. *Industrial Hemp Licensing and Authorization Statistical Summary, June 2000.* Health Canada.
Hanson-Trip, Niels. 1999. *Industrial Hemp Licensing and Authorization Statistical Summary, June 1999.* Health Canada. http://www.hc-sc.gc.ca/hpb-dgps/therapeut/zfiles/english/hemp/revrep99_e.html.
Health Canada. 1999. *Therapeutic Products Report on Industrial Hemp Licences, Jung 1999, Questions and Answers.* http://www.hc-sc.gc.ca/hpb-dgps/therapeut/zfiles/english/hemp/revrep_e.html.
Health Canada. 1998. *Therapeutic Products Programme Report on Industrial Hemp Licences, June 1998.* http://www.hc-sc.gc.ca/hpb-dgps/therapeut/zfiles/english/hemp/statsq-a_e.html.
Hill, Kasea, Nathan Boshard-Blackey and Jim Simson (eds.). 2000. *Viability of Industrial Hemp*. Vermont Legislative Research Shop, University of Vermont. http://www.uvm.edu/~vlrs/doc/hemp.htm.
Industrial Hemp Investigative and Advisory Task Force Report. 2000. Submitted to the Illinois House of Representatives, January 26, 2000.
Johnson, Patricia. 1999. "Industrial Hemp: A Critical Review of Claimed Potentials For Cannabis Sativa." *Tappi Journal* 82(7): 113-123.
Kessler, R. W. and R. Kohler. 1996. "New Strategies for Exploiting Flax and Hemp." *Chemtech*, December: 34-42.
Kraenzel, David G., Tim Petry, Bill Nelson, Marshall J. Anderson, Dustin Mathern and Robert Todd. 1998. "Industrial Hemp as an Alternative Crop in North Dakota: A White Paper Study of the Markets, Profitability, Processing, Agronomics and History." *Agricultural Economics Report* no. 402. North Dakota State University. Institute of Natural Resources and Economic Development.

Letniak, Ron. 1999. "Low THC Hemp (Cannabis sativa L.) Research Report 99-10028-R11999 – Hemaruka, Alberta." Edmonton, Alberta, Canada: Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/crops/special/hemp/hemplowthc.html.

Louie, Elaine. 1998. "Cannabis Beer? Not What You Think." *New York Times*, Sept. 15.

Low, I. 1995. "UK Hemp Production," in *1995 Bioresource Hemp Symposium Proceedings*. Frankfurt: Germany: 106-108.

Mackie, Gordon. 1998. "Hemp: The Acceptable Face of Cannabis." *Textile Month*, October: 49-50.

Marcus, David. 1996. *Commercial Hemp Cultivation in Canada: An Economic Justification.* Ivey Business School, University of Western Ontario. http://naihc.org/hemp_information/content/dmarcustx.html.

Marshall, Tony. 1998. "Is There a Market for Hemp Oil?" *Alberta Hemp Symposium Proceedings*. Edmonton, Alberta, Canada: Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/crops/special/hemp/symposia14.html.

McIntosh, DJ, Richard Barge and Thomas Brown, eds. 1998. *The 5 Minute Guide to Industrial Hemp in New Zealand.* Auckland, New Zealand: New Zealand Hemp Industries, Inc.

McNulty, Sara (editor). 1995. *Report to the Governor's Hemp and Related Fiber Crops Task Force*. Commonwealth of Kentucky. http://www.globalhemp.com/Archives/Government_Research/USDA/report_to_governor_of_ky.shtml.

McPartland, J. M. 1996a. "A Review of *Cannabis* Diseases." *Journal of the International Hemp Association* 3(1): 19-23.

McPartland, J. M. 1996b. "*Cannabis* Pests." Journal of the International Hemp Association 3(2): 52-55.

Meijer, W. J. M., H. M. G. van der Werf, G. J. van Roekel, E. P. M. de Meyer and W. Huisman. 1996. "Fibre Hemp: Potentials and Constraints." Alberta Agriculture, Food and Rural Development. http://www.agric.gov.ab.ca/crops/special/conf/meijer.html.

Miller, Richard Lawrence. 1991. *Hemp as a Crop for Missouri Farmers*. Report to Agriculture Task Force, Missouri House of Representatives, Jefferson City, Missouri. http://naihc.org/hemp_information/content/rlmiller.html.

Ministry of Agriculture and Food, British Columbia, Canada (BCMAF). 1999. *Specialty Crops Factsheet: Industrial Hemp.* http://www.agf.gov.bc.ca/croplive/plant/horticult/specialty/hemp/hempinfo.pdf.

Moes, Jack. 1998. "Hemp Research in Manitoba –- 1995-1997." In *Alberta Hemp Symposia Proceedings.*

Nelson, Peter A. 1999. *State Hemp Legislation Updates: Individual State Action in Relation to the Development of a United States Industrial Hemp Industry*. Memphis, TN: Agro-Tech Communications.

Nelson, Peter A. 1998. "The Future of Farming: Industrial Hemp." *AgVentures* 2(3): 43-44.

Nova Institute. 1996. *The Hemp Produce Line Project.* Koln, Germany: The Nova Institute.

Oliver, Al and Howard Joynt. 1999. *Industrial Hemp Fact Sheet*. Kamploops, British Columbia, Canada: British Columbia Ministry of Agriculture and Food.
Orgel, Stephen and Michael Ravnitzky. 1994. “Hemp: The First Industrial Textile.” *Industrial Fabrics Review* 71(6): 26-27.
Parsad, B., J. Gratzl, A. Kirkman, H. Jameel, T. Rost, and V. Magnotta. 1994. "High-Kappa Pulping and Extended Oxygen Delignification Decreases Recovery Cycle Load." *TAPPI Journal* 77(11): 135-147.
Rawson, Jean M. 1992. *Growing Marijuana (Hemp) for Fiber: Pros and Cons.* Report 92-510, Congressional Research Service, Washington, DC.
Reichert, Gordon. 1994. “Government of Canada: Report on Hemp.” *Bi-Weekly Bulletin* 7(23).
Rorie, Somlyn. 1999. “The Rediscovery of Hemp.” *Organic & Natural News*, Aug: 17-19.
Roulac, John W. and Hemptech. 1997. “Hemp Horizons: The Comeback of the World’s Most Promising Plant.” White River Junction, VT: Chelsea Green Publishing Company.
Schafer, E. R. and F. A. Simmonds. 1926. "A Comparison of the Physical and Chemical Characteristics of Hemp Stalks and Seed Flax Straw." Publication No. R868, USDA Forest Products Laboratory, Madison, WI.
Scheifele, Gordon. 1999. *Determining the Feasibility and Potential of Field Production of Low THC Industrial Hemp (Cannabis sativa) for Fibre and Seed Grain in Northern Ontario*. Thunder Bay, Ontario, Canada: Ontario Ministry of Agriculture, Food and Rural Affairs. Final Report. http://www.gov.on.ca:80/OMAFRA/english/crops/hort/hemp/info_final_report.htm.
________________. 1999. *1999 Agronomic Field Studies to Determine Factors Effecting Hemp Stalk Production in Northern Ontario.*
Selkirk, S. W. and R. D. Spencer. 1999. “Economics of fibre production from industrial hemp and blue gum plantations.” *Australian Forestry* 62(2): 193 201.
Soyatech, Inc. 1999. *Soya & Oilseed Bluebook*. ME: Bar Harbor.
The Economist. 1998. “Hemp’s Good Habits.” Aug. 1, 1998: 55.
Thompson, Eric C, Mark C. Berger and Steven Allen. 1998. *Economic Impact of Industrial Hemp in Kentucky.* Lexington, Kentucky. University of Kentucky, Center for Business and Economics Research. http://www.kltprc.net/Foresight/Chpt_20.htm.
USDA. 1999. “Industrial Hemp in the United States: Status and Market Potential.” USDA Report AGES001E.
USDA Economic Research Service and Economic Research Service. 1995. “Industrial Hemp and Other Alternative Crops for Small-Scale Tobacco Producers.” http://www.globalhemp.com/Archives/Government_Research/USDA/usda_1995.shtml.
van der Warf, H. M. G. 1994. “Hemp Facts and Fiction.” *Journal of the International Hemp Association,* volume 1.
Vantreese, Valerie L. 1997. *Industrial Hemp: Global Markets and Prices*. Lexington, Kentucky. University of Kentucky, Department of Agricultural Economics.
Vantreese, Valerie L. 1998. *Industrial Hemp: Global Operations, Local Implications.* Lexington, Kentucky. University of Kentucky, Department of Agricultural Economics.

Vavilov, N. I. 1992. *Origin and Geography of Cultivated Plants.* English Edition, Cambridge University.
von Sternberg, Bob. 1999. "In Canada, Hemp Hasn't Lived Up to the Hype." *Minneapolis Star Tribune,* Minneapolis, MN, Oct. 16, 1999.
Wang, Qingbin and Guanming Shi. 1999. "Industrial Hemp: China's Experience and Global Implications." *Review of Agricultural Economics* 21(2): 344 357.
Welna, David. 1999. "Reintroducting Hemp." *Morning Edition*, National Public Radio, December 14, 1999.
West, David P. 2001. *Second Annual Report to the Hawaii State Legislature*. Hawaii Industrial Hemp Research Project. January 7, 2001.
West, David P. 2000. *Annual Report to the Hawaii State Legislature.* Hawaii Industrial Hemp Research Project. January 15, 2000.
West, David P. 1998. "Hemp and Marijuana: Myths & Realities." North American Industrial Hemp Council, Inc.
Wilsie, C. P., C. A. Black and A. R. Aandahl. 1944. "Hemp Production Experiments: Cultural Practices and Soil Requirements." Publication P63, Agricultural Experiment Station, Agricultural Extension Service, Ames, Iowa.
Wisconsin Department of Justice, Division of Narcotics Enforcement, Special Operations Bureau, Strategic Intelligence Section. 1999. *Industrial Marijuana (Hemp) Information Paper.* http://www.sarnia.com/groups/antidrug/experts/wallluks.html.
Wright, Albert Hazen. 1918. *Wisconsin's Hemp Industry*. Agricultural Experiment Station Bulletin no. 293, University of Wisconsin – Madison.

Appendix I: State Legislative Action for the Development of a Hemp Industry in the U.S.

Reproduced with the permission of Hawaii Representative Cynthia Henry Thielen.

STATE	LEGISLATION PASSED	RESOLUTIONS ADOPTED	MEASURES PENDING
(AL) Alabama	--	--	--
(AK) Alaska	--	--	
(AZ) Arizona	--	--	--
(AR) Arkansas	--	**SR13 (adopted 1999):** Requires the University of Arkansas to conduct studies to determine the feasibility of growing hemp as an alternative and profitable crop. Report due by December 31, 2000.	--
(CA) California	--	**HR32 (adopted 1999):** Finds that industrial hemp has many uses in many products; that it will contribute to the state economy; that the legislature should revise the legal status of industrial hemp; and that the University of California and other agencies should prepare studies in conjunction with private industry on the cultivation, processing, and marketing of industrial hemp.	--
(CO) Colorado	--	--	--
(CT) Connecticut	--	--	--
(DE) Delaware	--	--	--
(FL) Florida	--	--	--
(GA) Georgia	--	--	--
(HI) Hawaii	**HB32 (Act 305 SLH 1999):** Authorizes the State to allow privately-funded industrial hemp research in Hawaii when state and federal agencies (DEA) issue controlled substance registrations; authorizes state and federal agencies to monitor all phases of the research; requires status reports. *NOTE: First plot sown in December 1999. Nation's first legal hemp patch in nearly 50 years.*	**HR109 (adopted 1999):** Requests the U.S. Dept. of Agriculture to recommend the use of hemp fiber soil erosion control blankets whenever feasible. **HR110 (adopted 1999):** Requests the Hawaii Dept. of Business, Economic Development, and Tourism to examine the feasibility of growing industrial hemp in Hawaii for biomass energy production.	--
(ID) Idaho	--	--	--

STATE	LEGISLATION PASSED	RESOLUTIONS ADOPTED	MEASURES PENDING
(IL) Illinois	**SB1397 (Passed Both Houses 1/9/01):** Requires the University of Illinois and Southern Illinois University to study the feasibility and desirability of industrial hemp production; requires report of findings/recommendations by January 1, 2002; excludes industrial hemp from the definition of "cannabis" under the Cannabis Control Act.	**SR49 (adopted 1999):** Creates the Industrial Hemp Investigative and Advisory Task Force; requires the task force to report on the economic viability of industrial hemp production; requests the University of Illinois to work with the task force. **HR168 (adopted 1999):** Companion measure to SR49. **HR553 (adopted 2000):** Urges Congress to acknowledge the difference between marijuana and industrial hemp, and to clearly authorize the commercial production of industrial hemp.	
(IN) Indiana	--	--	--
(IA) Iowa	--	--	--
(KS) Kansas	--	--	--

STATE	LEGISLATION PASSED	RESOLUTIONS ADOPTED	MEASURES PENDING
(KY) Kentucky	--	--	**HB100:** Calls for creation of industrial hemp research program to be administered by Dept. of Agriculture in conjunction with a university; creation of the Industrial Hemp Commission to monitor the research program; directs the adoption of federal rules and regulations; establishes an "industrial hemp program fund" to offset costs. **City of Midway Resolution:** in support of the reintroduction of historic production of industrial hemp; encourages legislation; directed to legislators and House/Senate Agricultural committees.
(LA) Louisiana	--	--	--
(ME) Maine	--	--	--
(MD) Maryland	**HB1250 (2000 Maryland Laws Ch. 681):** Establishes a pilot program to study the growth and marketing of industrial hemp; requires the Secretary of Agriculture to administer the pilot program in consultation with State and federal agencies; provides for monitoring and access rights; requires an individual to be licensed by the Dept. of Agriculture prior to participation in the pilot program.	--	**--**
(MA) Massachusetts	--	--	**--**

STATE	LEGISLATION PASSED	RESOLUTIONS ADOPTED	MEASURES PENDING
(MI) Michigan	--	--	--
(MN) Minnesota	**HF1238 (1999 Minnesota Session Laws):** Authorizes the commissioner of agriculture to permit experimental and demonstration plots to investigate the potential for industrial hemp as a commercial agricultural crop; requires material from industrial hemp plants grown on the plots to be used only for commercial uses; requires registration of applicants for participation; requires reporting.	--	--
(MS) Mississippi	--	--	--
(MO) Missouri	--	--	--
(MT) Montana	--	**HR2 (adopted 1999):** Requests that the federal government repeal restrictions on the production of industrial hemp as an agricultural and industrial product.	--
(NE) Nebraska	--	--	**LB273:** Provides for cultivation of industrial hemp.
(NV) Nevada	--	--	--
(NH) New Hampshire	--	--	**HB239 (Interim Study Subcommittee Work Session Status 2000):** Permits the production of industrial hemp; requires licensing for a person or business entity wishing to grow and produce industrial hemp.
(NJ) New Jersey	--	--	--

STATE	LEGISLATION PASSED	RESOLUTIONS ADOPTED	MEASURES PENDING
(NM) New Mexico	**HB104 (Appropriation incorporated into General Budget Bill 1999):** Appropriates $50,000 to New Mexico State University for the purpose of conducting a study of the feasibility of growing industrial hemp as a commercial crop; requires reporting.	--	--
(NY) New York	--	--	--
(NC) North Carolina	--	--	--
(ND) North Dakota	**HB1428 (Ch. 4-41-01, 02 NDCC; 4-09-01 NDCC 1999):** Authorizes the production of industrial hemp; recognizes industrial hemp as an oilseed; requires any person desiring to grow industrial hemp to apply for a license; allows for the supervision of the industrial hemp during its growth and harvest. **SB2328 (Ch. 4-05.1-05 NDCC 1999):** Authorizes the North Dakota State University main research center to conduct baseline research, including production and processing, regarding industrial hemp and other alternative industrial use crops.	**HCR3038 (adopted 1999):** Urges the U.S. Congress to acknowledge the difference between marijuana and industrial hemp, and to clearly authorize the commercial production of industrial hemp.	--
(OH) Ohio	--	--	--

STATE	LEGISLATION PASSED	RESOLUTIONS ADOPTED	MEASURES PENDING
(OK) Oklahoma	--	--	--
(OR) Oregon	--	--	**SB89:** Permits production and possession of industrial hemp and trade in industrial hemp commodities and products; authorizes State Dept. of Agr. To administer licensing and inspection program for growers and handlers of industrial hemp; authorizes civil penalty not exceeding $2,500.
(PA) Pennsylvania	--	--	--
(RI) Rhode Island	--	--	--
(SC) South Carolina	--	--	--
(SD) South Dakota	--	--	--
(TN) Tennessee	--	--	--
(TX) Texas	--	--	--
(UT) Utah	--	--	--
(VT) Vermont	--	**JRS98 (adopted 2000):** Urges the U.S. DEA, the U.S. Dept. of Agriculture, and the U.S. Congress to reconsider federal policies that restrict the cultivation and marketing of industrial hemp and related products.	--
(VA) Virginia	--	**HJR94 (adopted 1999):** Urges the U.S. Secretary of Agriculture, the Director of the DEA, and the Director of the Office of National Drug Control Policy to permit the controlled, experimental cultivation of industrial hemp in Virginia.	--
(WA) Washington	--	--	--
(WV) West Virginia	--	--	--
(WI) Wisconsin	--	--	--
(WY) Wyoming	--	--	--

Sources:

1. Westlaw Database Search; October 31, 2000
2. North American Industrial Hemp Council, Inc.; http://www.naihc.org
3. Hemp Industries Association; http://www.thehia.org
4. Legislative Reference Bureau State Legislatures Gateway; http://www.state.hi.us/lrb/card
5. Legislative Websites—all 50 states; various URLs