Industrial Hemp in the United States: Status and Market Potential

Abstract

Industrial hemp has been the focus of official interest in several States. However, hemp and marijuana are different varieties of *Cannabis sativa*, which is classified as a controlled substance in the United States. With Canada now allowing hemp production, questions have been raised about the demand for hemp products. U.S. markets for hemp fiber (specialty textiles, paper, and composites) and seed (in food or crushed for oil) are, and will likely remain, small, thin markets. Uncertainty about longrun demand for hemp products and the potential for oversupply discounts the prospects for hemp as an economically viable alternative crop for American farmers.

Keywords: industrial hemp, markets, bast fiber, hurds, seed, oil.

Washington, DC January 2000

Contents

Executive Summary

Industrial hemp and marijuana are different varieties of the same species, *Cannabis sativa* L. Marijuana typically contains 3 to 15 percent of the psychoactive ingredient delta-9-tetrahydrocannabinol (THC) on a dry-weight basis, while industrial hemp contains less than 1 percent. However, the two varieties are indistinguishable by appearance. In the United States, *Cannabis sativa* is classified as a Schedule I controlled substance, regardless of its narcotic content, under the Controlled Substances Act as amended. Since 1990, varieties containing less than 0.3 percent THC have been legalized in Great Britain, Germany, Austria, and Switzerland. Canada and Australia legalized hemp production in 1998. In other countries, such as China, Russia, and Hungary, hemp production was never outlawed.

With Canada now allowing production of industrial hemp, questions have been raised about the potential commercial market demand for industrial hemp products in the United States. Hemp cultivation has been the focus of official interest in several States. The Governor of Kentucky established a Hemp and Related Fiber Crops Task Force in 1994. Legislation passed in Vermont, Hawaii, and North Dakota in 1996 and 1997 authorized agronomic and economic feasibility studies. In 1999, nine States (Arkansas, California, Hawaii, Illinois, Minnesota, Montana, New Mexico, North Dakota, and Virginia) passed legislation concerning the research, study, or production of industrial hemp as a crop. The first test plots of industrial hemp in the United States were planted in Hawaii in December 1999.

Previous experience in the United States and other countries indicates that industrial hemp grows well in areas where corn produces high yields. Plants require plentiful moisture throughout the growing season and need substantial amounts of available nutrients to produce high yields. Hemp can be grown as a fiber, seed, or dual-purpose crop. It is a bast fiber plant similar to flax, kenaf, and jute. The interior of the stalk contains short woody fibers called hurds, while the outer portion contains the long bast fibers. Hemp seeds are smooth and about one-eighth to one-fourth of an inch long.

No data are available on imports of hemp seed and oil into the United States, but data do exist on hemp fiber, yarn, and fabrics. Imports of raw hemp fiber have increased dramatically in the last few years, rising from less than 500 pounds in 1994 to over 1.5 million pounds for the first 9 months of 1999. Yarn imports also have risen substantially, peaking at slightly less than 625,000 pounds in 1997. The switch from yarn to raw fiber in the last 2 years probably reflects the development of U.S. spinning capacity. At least two companies are now spinning hemp yarn from imported fibers. Imports of hemp fabric have more than doubled from over 222,000 pounds in 1995 to about 523,000 pounds in 1998.

Current markets for bast fibers like industrial hemp include specialty textiles, paper, and composites. Hemp hurds are used in various applications such as animal bedding, composites, and low-quality papers. As joint products, finding viable markets for both hemp bast fiber and hurds may increase the chances of a successful business venture. Hemp industry sources and some academic studies cite many potential uses for hemp fiber and hurds. However, for these applications to develop or expand, hemp will have to compete with current raw materials and manufacturing practices. The U.S. market for hemp fibers is, and will likely remain, a small, thin market. Changes in price or quantity could be more disruptive and have a greater adverse impact on market participants than would be the case in a larger market.

Since there is no commercial production of industrial fiber hemp in the United States, the "size" of the market can only be gauged from hemp fiber and product imports. The near-term, low-end size of the U.S. market for hemp as a textile fiber might be defined by considering the domestic production and acreage required to replace imports of hemp fiber, yarn, and fabric in 1999. Assuming a potential U.S. yield of 1,550 pounds of fiber per acre and using linen yarn and fabric conversion factors, the estimated import quantity of hemp fiber, yarn, and fabric in 1999 could have been produced on less than 2,000 acres of land. Given the average size of farms in the United States (near 500 acres), just a few farms could have supplied the hemp fiber equivalent of 1999 import levels.

As a specialty bast fiber, hemp's closest competing textile fiber is linen. A longer term, high-end size of the potential U.S. market for hemp fiber could be defined as domestic production and acreage required to replace hemp and linen imports. The hemp fiber required to replace the equivalent level of hemp and linen fiber, yarn, and fabric imports in 1999 could have been produced on 250,000 acres—roughly 40 percent of 1999 tobacco acreage, 5 percent of U.S. oat acreage, or 0.4 percent of wheat acreage.

Despite the similarities between hemp and linen, there is no industry consensus as to how closely the markets for the two fibers are allied. But since hemp fiber imports were just 0.5 percent of linen imports during the first 9 months of 1999, the near-term market potential for hemp in the United States for domestic textile production is closer to the low end of the 2,000- to 250,000-acre production-equivalent range. Moreover, the absence of a thriving textile flax (linen) production sector in this country (despite no legal barriers) suggests that hemp, flax's close cousin in fiber uses and in production techniques, will be unable to sustain adequate profit margins for a large production sector to develop.

In 1998, imports of hemp seed into North America were estimated at 1,300 tons. Given yields in Germany of about 1,000 pounds per acre, it would take 2,600 acres to satisfy the demand for hemp seed. As with fiber imports, it would take only a few average-sized farms to meet this demand. Hemp seeds can be used directly as a food ingredient or crushed for oil and meal. Hemp seeds and flour are being used in nutrition bars, tortilla chips, pretzels, beer, salad dressings, cheese, and ice cream. The market potential for hemp seed as a food ingredient is unknown. However, it probably will remain a small market, like the markets for sesame and poppy seeds. Some consumers may be willing to pay a higher price for hemp-seed-containing products because of the novelty, but otherwise hemp seed will have to compete on taste and functionality with more common food ingredients.

Hemp oil is being used as an ingredient in body-care products, such as lotions, moisturizers, and shampoos, and sold in health food stores as a nutritional supplement. The market for hemp oil is limited by a number of factors. First, mechanical crushing produces a lower oil yield than crushing combined with solvent extraction. Nor does hemp oil undergo degumming and bleaching as do many other vegetable oils. Some consumers prefer an oil that has been processed without chemicals, but others may dislike hemp oil's color or taste. Second, the oil is high in unsaturated fatty acids, which can easily oxidize, so it is not used for frying and must be kept in dark-colored bottles and has a limited shelf life. Third, to be used as a salad oil, it will have to be tested by the U.S. Food and Drug Administration and found "generally recognized as safe." Last, as a drying oil, hemp would have to compete on functionality and price with current raw materials, such as linseed and tung oils, in established industrial markets.

Several States have published reports or authorized agronomic and economic feasibility studies of hemp production. The four reports summarized here have focused on different aspects of supply and/or demand. Their estimates of hemp costs and returns reflect these various focuses, as well as different assumed production practices and costs. However, the widest range of estimates exhibited among the reports is for stalk and seed yields and prices—not surprising given the uncertainty about hemp production and current and potential hemp markets. Overall, hemp production was profitable only at the higher end of estimated yields and prices. It seems questionable that U.S. producers could remain profitable at the low end of the estimated net returns, particularly given the thinness of current U.S. hemp markets.

The market for hemp products might easily be oversupplied, as in Canada where the 35,000 acres of hemp produced in 1999 was seemingly more than the market could handle. The *Minneapolis Star Tribune* quotes the general manager of Kenex Ltd., Canada's biggest hemp processor, as saying "It's given us one hell of a glut of grain and fiber. There's been a major overestimation of the market that's out there" (von Sternberg, 1999).

Industrial Hemp in the United States

Status and Market Potential

Introduction

Industrial hemp and marijuana are different varieties of the same species, *Cannabis sativa* L. In the United States, *Cannabis sativa* is classified as a Schedule I controlled substance, regardless of its narcotic content, under the Controlled Substances Act as amended. Regulatory authority is vested in the Office of the Attorney General and is carried out by the Drug Enforcement Administration (DEA). Since 1990, varieties containing very low levels of the psychoactive ingredient delta-9-tetrahydrocannabinol (THC) have been legalized in Great Britain, Germany, Austria, and Switzerland. Canada and Australia legalized hemp production in 1998. In other countries, such as China, Russia, and Hungary, hemp production was never outlawed.

With Canada now allowing production of industrial hemp, questions have been raised about the potential commercial market demand for industrial hemp products in the United States. Several companies import hemp fabrics and garments into the United States. Other firms import hemp fiber or sterile hemp seed for further processing and manufacturing into products, such as paper, nutrition bars, and beer.

Hemp cultivation has been the focus of official interest in several States. The Governor of Kentucky established a Hemp and Related Fiber Crops Task Force in 1994. Legislation passed in Vermont, Hawaii, and North Dakota in 1996 and 1997 authorized agronomic and economic feasibility studies. Published study results are available from Kentucky, Oregon, and North Dakota (McNulty, 1995; Thompson et al., 1998; Ehrensing, 1998; Kraenzel et al., 1998).

Since 1995, a total of 19 States (Arkansas, California, Colorado, Hawaii, Illinois, Iowa, Kansas, Maryland, Minnesota, Missouri, Montana, New Hampshire, New Mexico, North Dakota, Oregon, Tennessee, Vermont, Virginia, and Wisconsin) have introduced hemp legislation. In 1999, nine States (Arkansas, California, Hawaii, Illinois, Minnesota, Montana, New Mexico, North Dakota, and Virginia) passed legislation concerning the research, study, or production of industrial hemp as a crop (Nelson, 1999). The legislation in Minnesota and North Dakota permits the production of industrial hemp, provided farmers obtain licenses from DEA. Farmers are looking for alternative crops, particularly for tobacco, but also for rotation crops to break pest and disease cycles.

The first test plots of industrial hemp in the United States were planted in Hawaii in December 1999. To gain DEA approval of the project, scientists were required to enclose the plot inside a 12-foot-high fence with infrared surveillance (Welna, 1999; Associated Press, 2000). The project received $200,000 in funding from a hair-care company that uses hemp oil in its products (Hanks, July 1999).

This report examines the similarities and differences between industrial hemp and marijuana. It then reviews hemp's history as a crop; its plant characteristics and growing requirements; and harvesting, retting, and fiber separation. This is followed by a brief review of Canadian hemp production and a discussion of U.S. hemp fiber and fabric imports. The next two sections assess hemp fiber and seed markets. The following two sections discuss some of the issues involved in potential U.S. hemp production and processing and review estimated costs and returns for hemp production from four State-sponsored studies.

Identification: Industrial Hemp or Marijuana?

Marijuana and industrial hemp are different varieties of the same plant species, *Cannabis sativa* L. Marijuana typically contains 3 to 15 percent THC on a dry-weight basis, while industrial hemp contains less than 1 percent (Blade, 1998; Vantreese, 1998). Most developed countries that permit hemp cultivation require use of varieties with less than 0.3 percent THC. However, the two varieties are indistinguishable by appearance. DeMeijer et al. (1992), in a study of 97 Cannabis strains, concluded that short of chemical analysis of the THC content, there was no way to distinguish between marijuana and hemp varieties.

Industrial hemp can be grown as a fiber and/or seed crop. Grown for fiber, it is planted in dense stands to maximize stalk production. Grown for seed or for seed and fiber, plants are spaced farther apart to encourage branching and seed production. Marijuana varieties are grown for their leaves and flower buds, and therefore are grown under low-density conditions to maximize branching. Thus, planting density and other production characteristics do not offer a reliable way to distinguish varieties for law enforcement purposes.

Health Canada announced regulations on March 12, 1998, that control activities relating to the production, import, export, transport, and sale of industrial hemp (see Appendix I for the fact sheet from Health Canada). Production is highly regulated, with farmers required to obtain annual government permits. Farmers cannot have had a drug offense in the past 10 years and need to have a criminal background check done at their own expense. Federal agronomists and police will check fields and test plants to make sure that no narcotic plants are grown along with the industrial hemp.

The European Union (EU) issued rules governing hemp production in 1989, which include registration of the area to be planted in advance, the use of seed from certified low-THC varieties, and testing of fields to determine THC content.

History

The first records of hemp cultivation and use are from China, where the species most likely originated (Ehrensing). Migrating peoples likely brought hemp to Europe where, by the 16th century, it was widely distributed, cultivated for fiber, and the seed cooked with barley or other grains and eaten (Dempsey, 1975).

Hemp reportedly was first grown in the New World in Chile in 1545 (Blade). The Puritans brought hemp to New England in 1645 as a fiber source for household spinning and weaving, but it never rivaled flax in importance. Cultivation spread to Virginia and, in 1775, to Kentucky, where the crop grew so well a commercial cordage industry developed. The hemp industry flourished in Kentucky, Missouri, and Illinois between 1840 and 1860 because of strong demand for sailcloth and cordage by the U.S. Navy. However, increased production of cotton in the South, due to the development of the cotton gin, and imports of cheaper jute and abaca eventually displaced most domestic hemp production (Dempsey, Ehrensing).

In 1937, Congress passed the Marijuana Tax Act, which placed all *Cannabis* culture under the regulatory control of the U.S. Treasury Department. The Act required the registration and licensing of all hemp growers with the Federal Government in an effort to restrict production of marijuana in the United States (Dempsey; Rawson, 1992; Ehrensing).

During World War II, when imports of abaca and jute were unavailable, the Government instituted an emergency program to produce hemp as a domestic substitute. USDA's Commodity Credit Corporation contracted with War Hemp Industries, Inc., a quasi-official organization, to produce planting seed and fiber. Production peaked in 1943 and 1944. After the war, production rapidly declined as imports resumed and legal restrictions were reimposed. A small hemp fiber industry continued in Wisconsin until 1958 (Dempsey, Ehrensing).

Industrial Hemp in Canada

In 1998, Health Canada permitted 259 farmers to grow hemp on 6,180 acres, mostly in Ontario and Manitoba (Health Canada, June 1998; Health Canada, June 1999). As of June 1999, Health Canada had issued 674 hemp production licenses, allowing cultivation on 35,000 acres. Manitoba accounted for over half of the acreage, followed by Saskatchewan and Ontario (Hansen-Trip, 1999). Actual acreage under cultivation was lower because of a wet spring in western Canada, lack of certified seed, and license delays (Hanks, Fall 1999). Most of the production was for seed, especially in western Canada.

Gardner and White (1998) and Hanks (Fall 1999) profile the leading Canadian companies involved in hemp production and processing. Most process seed or oil using existing facilities. Two Manitoba companies, Hemp Oil Canada and Fresh Hemp Foods, have their own presses. Only two companies, Ontario-based Hempline, Inc. and Kenex Ltd., operate fiber processing facilities.

Plant Characteristics and Growing Requirements

Cannabis sativa L. is often referred to as true hemp to distinguish it from other fiber crops. These include *Musa textilis* (abaca or manila hemp), *Agave sisalina* (sisal hemp), and *Crotalaria juncea* (sunn hemp).

Cannabis sativa is normally dioecious, meaning the species has separate male and female plants. Monoecious varieties, with the male and female flower parts on the same plant, have been developed in a number of countries through breeding and selection (Dempsey, Ehrensing). Several countries, such as France, the Netherlands, Hungary, Romania, and China, have ongoing breeding programs. The industry is seeking high-yielding strains that are low in THC and meet various end-use needs. For example, breeders are looking for fiber lines that are high in primary fiber yields (for pulping), extra-fine fibers (for textiles), and cellulose content (for biomass fuel) and for seed lines with various seed sizes (for easier hulling and assorted food uses), special amino acid profiles (for human and animal feeds), and specific components in the oil for industrial uses (such as industrial lubricants) (Vantreese, 1998).

Hemp is sensitive to day length; the plant matures (sets seed) as days get shorter in the fall. Since production has historically been concentrated in northern temperate regions, industrial hemp varieties have been selected to mature in early fall (Blade; Reichert, 1994).

Industrial hemp can be grown as a fiber, seed, or dual-purpose crop. Hemp is a bast fiber plant similar to flax, kenaf, and jute. The interior of the stalk is hollow, surrounded by a pith layer of woody fibers called hurds (fig. 1). Outside the cambium layer, where cells grow and differentiate, is the phloem or parenchyma layer, which contains the long cells known as bast fiber. Hemp seeds are smooth and about one-eighth to one-fourth of an inch long. The seeds usually contain from 29 to 34 percent oil. The oil is similar in composition to drying oils such as linseed and tung and consists primarily of three fatty acids: linoleic (54-60 percent), linolenic (15-20 percent), and oleic (11-13 percent) (Ehrensing). Both the fiber and seed can be used in a wide range of applications (fig. 2).

Industrial hemp grows well in areas where corn produces high yields (Ehrensing). It can be grown on a variety of soils, but it does best on loose, well-drained loam soils with high fertility and abundant organic matter. Plants require plentiful moisture throughout the growing season, especially during the first 6 weeks (Dempsey; Blade; Baxter and Scheifele, 1999). Hemp also needs substantial amounts of available nutrients to produce high yields. Both Dempsey (1975) and Ehrensing (1998) review numerous fertilization studies and conclude that hemp requires liberal fertilization for high fiber yields.

Hemp diseases are not widespread and occur sporadically. They are usually caused by seed- and soil-borne fungi, which can be controlled by seed treatment before planting or by rotation (Dempsey). Under favorable conditions, hemp is very competitive with weeds so herbicides are generally unnecessary in hemp fiber production (Ehrensing). Due to lower planting densities, weed suppression may be less complete when hemp is grown for seed (Baxter and Scheifele).

Harvesting, Retting, and Fiber Separation

Harvesting and fiber processing differ depending on whether the crop is grown for high-quality textile fiber, for seed, or for fiber and seed. The Oregon study, *Feasibility of Industrial Hemp Production in the United States Pacific Northwest*, summarizes current information and research on hemp harvesting, retting, and fiber separation when the crop is grown for fiber (Ehrensing).

Harvesting

When grown for textile fiber, the crop is harvested when the fiber is at its highest quality. During World War II, tractor-drawn harvester-spreaders were used to cut hemp stems and lay them in windrows for field retting. After retting, a second machine was used to gather and tie the stems into bundles for pickup and delivery to the mill. A similar harvest system is still used in Europe, but with more modern, specialized equipment. Because these systems are designed to maintain the parallel alignment of hemp stems throughout harvest and processing in order to maximize the recovery of long textile fibers, the equipment has limited throughput capacity.

For seed, hemp is harvested when the seed is mature and ready for combining. When produced as a dual-purpose crop in countries such as France and Hungary, the seed is harvested near maturity with combines modified to cut high off the ground, and then the stems are harvested. The fiber from a dual-purpose crop is usually of lower quality and is often used in low-value applications such as pulp and paper. The 1998 crop in Canada was for dual production, and farmers found that the length and strength of hemp fibers were very rough on equipment during harvest (Gardner and White; Vantreese, 1998; Scheifele, 1999). In 1999, some Canadian farmers planted early flowering cultivars, which are shorter than traditional varieties and easier to combine (Baxter and Scheifele). The first Canadian-bred seed strain, which will be available next year in limited quantities, is also short (Hanks, Fall 1999).

Retting

If hemp or flax (linen) fibers are to be used in textiles and other high-quality applications, the bast fibers must be separated from the rest of the stalk. Retting is a microbial process that breaks the chemical bonds that hold the stem together and allows separation of the bast fibers from the woody core. The two traditional types of retting are field and water retting.

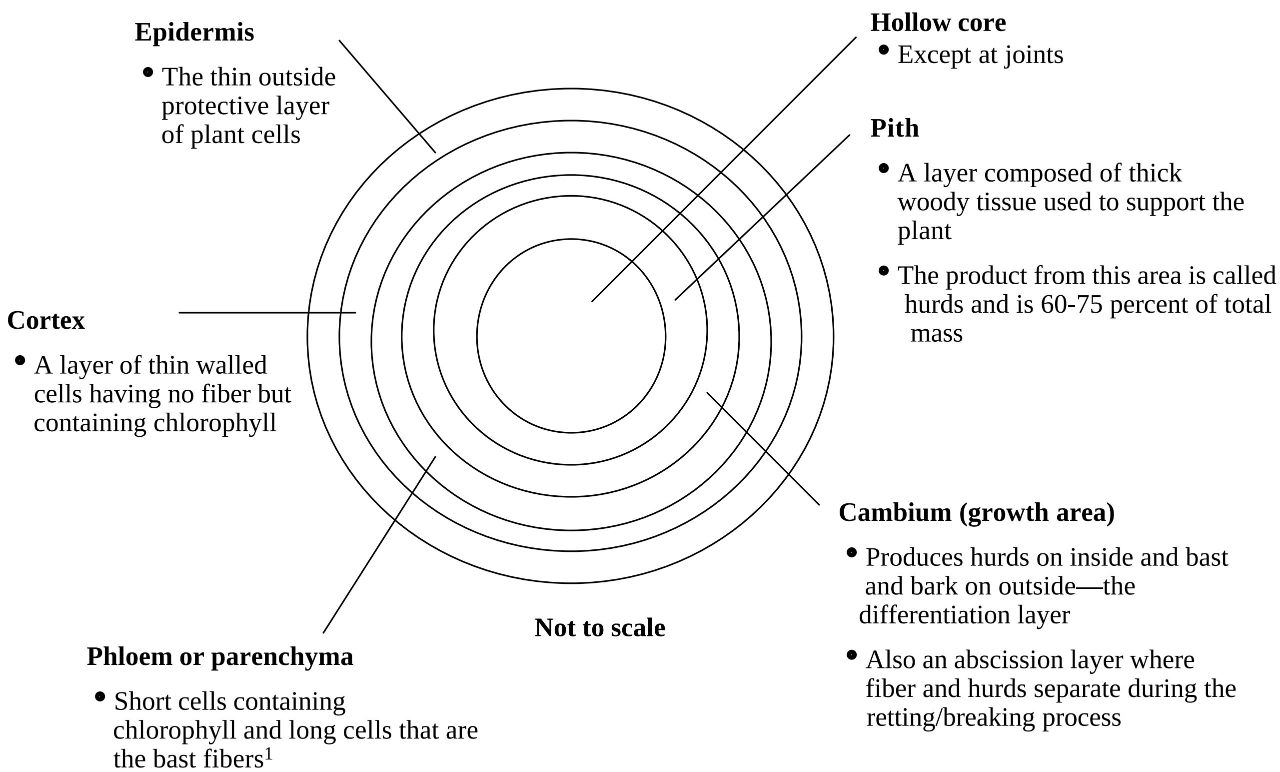
With field or dew retting, plant stems are cut or pulled up and left in the field to rot. Farmers monitor the process closely to ensure that the bast fibers separate from the inner core without much deterioration in quality. Moisture is needed for the microbial breakdown to occur, but then the weather must be dry enough for the stalks to dry for bailing. Although varying weather conditions affect the quality of fiber, field retting has been used extensively for hemp because it is inexpensive, mechanized, and does not use water.

Water retting produces more uniform and high-quality fiber, but the process is very labor- and capital-intensive. Stems are immersed in water (rivers, ponds, or tanks) and monitored frequently. Not only is this labor-intensive, farmers and/or workers must be knowledgeable about fiber quality. Also, the process uses large volumes of clean water that must be treated before being discharged. Water retting has been largely abandoned in countries where labor is expensive or environmental regulations exist. Most hemp fiber currently used in textiles is water retted in China or Hungary. Scientists speculate that improved microorganisms or direct use of enzymes may allow countries in Europe and North America to produce textile-quality bast fibers.

Fiber Separation

Once the stalks are retted, dried, and baled, they are brought to a central location for processing. With mechanical separation, in a process called breaking, stalks are passed between fluted rollers to crush and break the woody core into short pieces (called hurds), separating some of it from the bast fiber. The remaining hurds and fiber are separated in a process called scutching. Fiber bundles are gripped between rubber belts or chains and carried past revolving drums with projecting bars that beat the fiber bundles, separating the hurds and broken or short fibers (called tow) from the remaining long fiber (called line fiber). Fiber and hurds also can be separated with one machine called a decorticator (Kerr, 1998). Figure 3 presents a generalized schematic of plant and fiber yields, when grown

Figure 1. Cross section of a hemp stem



[1] Bast fibers are composed of primary bast fibers, which are long and low in lignin, and secondary bast fibers, which are intermediate in length and higher in lignin.

Source: Oliver and Joynt, p. 3.

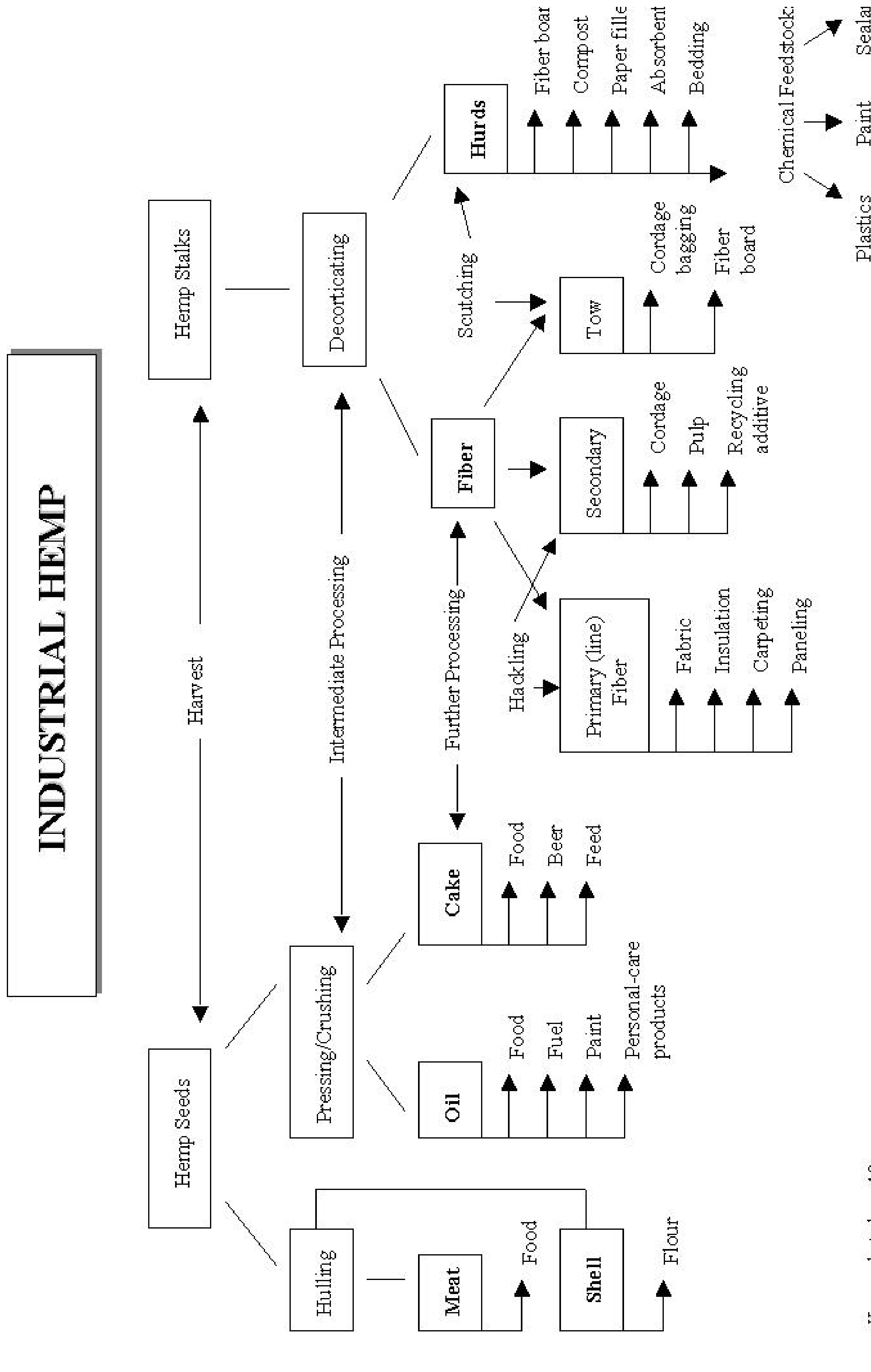
for high-quality textile fiber, from harvest through to fiber separation.

Although partially mechanized, these procedures are functionally identical to traditional hand methods of preparing hemp line fiber and tow for twisting into twine or rope or for spinning into yarn. Not only are these methods time consuming, they require skilled workers and considerable investment in capital equipment.

It is also possible to mechanically convert virtually all of the bast fiber directly into tow using flax breaking and tow processing machinery. This eliminates traditional scutching and allows processing of randomly oriented baled straw. Compared with scutching machinery, tow-processing equipment usually has higher throughput, requires fewer and less skilled workers, and costs less. However, a tow processing system cuts all of the bast fiber into short lengths, making it appropriate only for lower value uses, such as pulp and paper, instead of textiles.

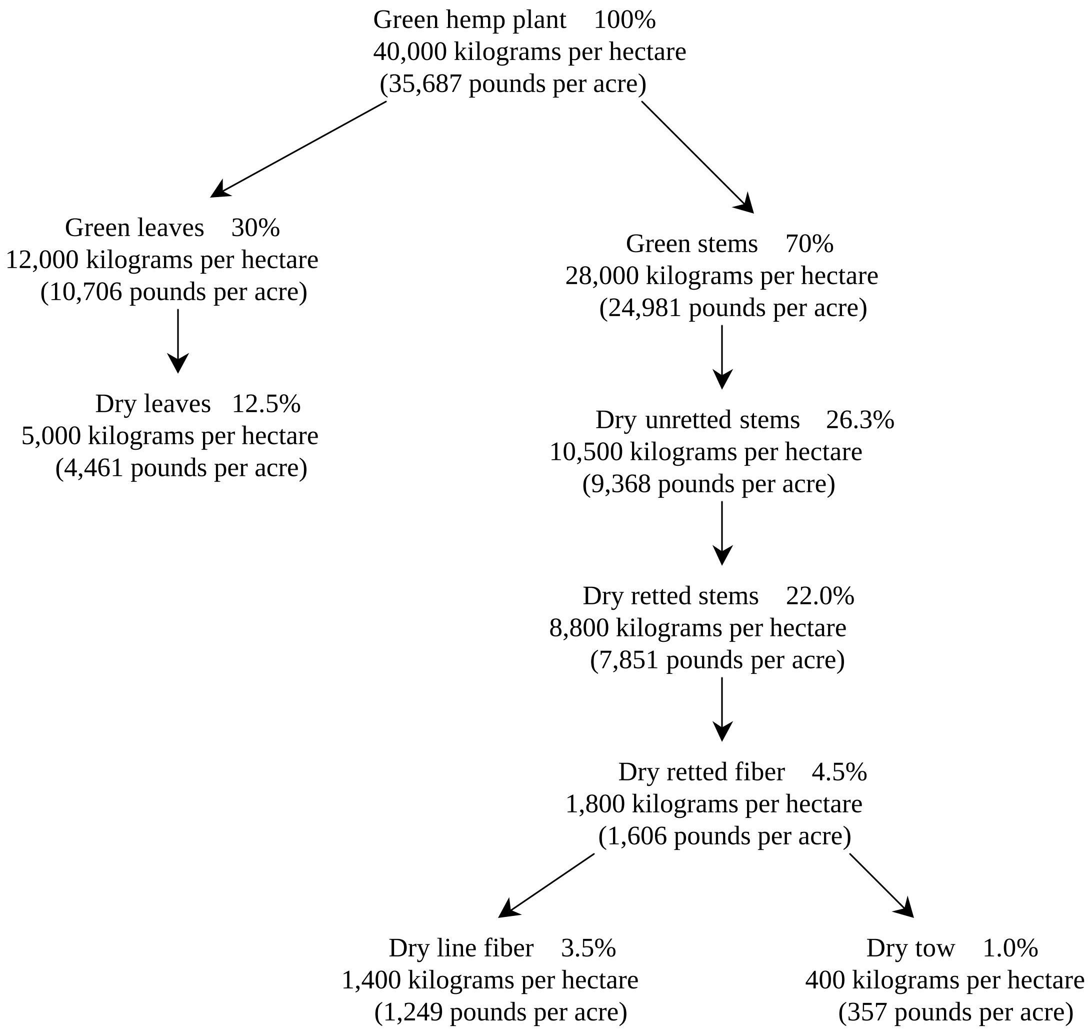
Research in Europe has sought methods for separating the bast fiber that bypass traditional retting and scutching. Steam explosion and ultrasound are under investigation in Germany, but the processes produce only short fiber. Neither technology has moved beyond laboratory or pilot scale trials. For hemp to be a viable fiber crop in the United States, modern hemp harvesting and processing methods would need to be developed.

Figure 2. Hemp products flowchart



Source: Kraenzel et al., p. 10.

Figure 3. A typical breakdown of the green- and dry-plant components of hemp grown for fiber



Note: Although these stem and fiber yields are from 1970, they illustrate how bast fibers are only a small portion of total crop yields.

Source: Dempsey, p. 82.

U.S. Hemp Fiber and Fabric Imports

No data are available on imports or exports of hemp seed and oil into the United States, but data do exist on hemp fiber, yarn, and fabrics.

Imports of raw hemp fiber have increased dramatically in the last few years, rising from less than 500 pounds in 1994 to over 1.5 million pounds for the first 9 months of 1999 (table 1). Yarn imports also have risen substantially, peaking at slightly less than 625,000 pounds in 1997. The switch from yarn to raw fiber in the last 2 years probably reflects the development of U.S. spinning capacity. At least two companies are now spinning hemp yarn from imported fibers (Gross, 1997). According to industry sources, domestic spinning capacity for hemp was not available earlier in the decade. No direct information is available on the uses of the yarn, but it is likely used to manufacture apparel, household furnishings, and/or floor coverings.

A separate import code for hemp fabrics was added to the Harmonized Tariff Schedule in 1995, so only a few years of data are available. Imports more than doubled from over 222,000 pounds in 1995 to about 523,000 pounds in 1998. The volume dropped for the first 9 months of 1999, again probably reflecting domestic production of hemp-containing fabrics. China is the largest supplier of hemp fabric to the United States, followed by Hungary, Poland, and Romania. Data are not available on how much hemp clothing and household furnishings are imported into the United States.

Imports of tow and yarn waste have declined since the late 1980's and early 1990's and have varied from year to year (table 1). No direct information is available on the uses of hemp tow and yarn waste. However, both hemp and flax are bast fibers and flax tow and yarn wastes are byproducts of linen processing and spinning. Since the main use of flax tow and waste is in specialty papers, hemp tow and waste may be used for the same purpose.

The United States also exports hemp raw fiber, tow and yarn waste, and yarn. During 1997-99, hemp exports were around 10 percent of imports. The data for earlier years, however, are suspect as exports of raw fiber are unexplainably larger than imports.

A full discussion of world production and trade of hemp fiber and seed can be found in Charest (1998) and Vantreese (1998). Wang and Shi (1999) also review the decade-long decrease in world hemp fiber production and highlight China's critical role in declining world production and exports. Dempsey (1975) and Ehrensing (1998) provide historic information on world fiber production.

Table 1—U.S. hemp imports, by category, 1989-99

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	420,975
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.

Fiber Markets

Currently, the markets for bast fibers like industrial hemp include specialty textiles, paper, and composites. Cordage markets have long disappeared, as natural fibers have largely been replaced by plastic and steel (Miller, 1991; Orgel and Ravnitzky, 1994). In recent years, Canada, Australia, and a few European countries, including the Netherlands and Germany, have researched industrial hemp as a possible fiber for textile and paper production. Hungary and China currently are the major producers of high-quality, water-retted hemp textile fibers (Ehrensing). Small specialty pulp and paper mills in Britain, Spain, and Eastern Europe process flax, hemp, and other specialty fibers. Other potential uses of hemp bast fiber include molded automobile parts and as a replacement for fiberglass. In addition, hurds are utilized in various applications such as animal bedding.

Industry sources and some academic studies, such as Thompson et al. (1998) and Gardner and White (1998), cite numerous current and potential uses for hemp bast fiber and hurds. For these applications to develop or expand, hemp will have to compete with current raw materials and manufacturing practices. In the market for nonwood fibers, hemp would have to compete with cotton, flax, abaca, sisal, and other nonwood fibers in terms of fiber characteristics, fiber quality, and price. The U.S. market for hemp fibers is, and will likely remain, a small, thin market. Changes in price or quantity could be more disruptive and have a greater adverse impact on market participants than would be the case in a larger market. For example, small increases in world hemp fiber and tow production caused export prices to fall by half to a world average of 35 cents per pound in 1996 (Vantreese, 1998). See Appendix II for a discussion and some examples of oversupply in small, thin markets.

Specialty Textiles

According to Ehrensing (1998), hemp textile production is based primarily in Asia and central Europe. Most hemp fiber used in textiles is water-retted in China or Hungary. However, water retting has been largely abandoned in countries where labor is expensive or environmental regulations are enforced. Several companies in Poland also make hemp yarn and fabrics (Gardner and White). A small market based on hemp textiles imported from China, Poland, and Hungary has developed in North America and western Europe during the 1990's. In the last few years, a couple of U.S. companies have begun producing hemp yarns and/or fabrics (Gross, Gardner and White).

The current, low-end size of the U.S. market for hemp raw materials may be defined as the equivalent domestic production and acreage required to replace imports of hemp fiber, yarn, and fabric in 1999.[1] Reichert (1994) reports hemp fiber yields of 800 to 2,320 pounds of fiber per acre. Assuming a potential U.S. yield of 1,550 pounds of fiber per acre (midpoint of the range) and using linen yarn and fabric conversion factors (1.0989 and 1.1447, respectively), the total import quantity of hemp fiber, yarn, and fabric in 1999 could have been produced on less than 2,000 acres of land. Given the average size of farms in the United States (near 500 acres), just a few farms could have supplied the hemp fiber equivalent of 1999 import levels. Detailed data are not available on the amount of hemp seed or oil or the levels of hemp-containing clothing and household furnishings imported into the United States. Thus, this calculation understates the production capacity needed to replace all hemp product imports. Nevertheless, the calculation does demonstrate the small, thin nature of the market for industrial hemp and its products in the United States.

Hemp's closest competing fiber for textile uses—in terms of fiber production, processing, and characteristics—is linen, which is derived from textile flax. Textile flax is not grown in the United States, with demand met wholly by imports. While U.S. imports of hemp fiber, yarn, and fabric have increased dramatically in recent years, 1999 hemp imports (January-September) represented just 0.5 percent of U.S. linen yarn, thread, and fabric imports. However, the U.S. market for linen may indicate the longer term potential demand for hemp fiber and products. During 1989-99, imports of linen yarn, thread, and fabrics accounted for 62 percent of total linen imports (table 2). Linen apparel accounted for another 33 percent, with household furnishing and floor coverings taking up the remainder. The United States also exports a small amount of linen products (table 3).

A long-term, high-end size of the potential U.S. market for hemp fiber could be defined by considering the equivalent domestic production and acreage required

[1] Nine months of import data were extrapolated to estimate a full year of imports.

Table 2—U.S. linen imports, by category, 1989-99[1]

Year	Yarn, thread, and fabric	Apparel	Household furnishings	Floor covering	Total[2]
			1,000 pounds		
1989	388,036	178,957	1,799	9,555	578,347
1990	408,078	170,367	1,512	9,611	589,568
1991	368,383	177,722	3,137	10,812	560,054
1992	320,325	192,787	1,611	22,877	537,600
1993	321,186	193,040	914	22,286	537,426
1994	339,604	196,292	1,797	34,089	571,782
1995	368,778	163,492	3,171	35,736	571,177
1996	246,191	144,194	1,990	32,559	424,934
1997	329,590	154,634	1,835	36,846	522,905
1998	253,270	183,602	1,954	44,995	483,821
1999[3]	186,301	148,106	3,142	41,707	379,256

[1] Estimated raw-fiber equivalent quantity contained in the products.
[2] Does not include imports of raw fiber and tow/yarn waste.
[3] January to September.

Source: Meyer.

Table 3—U.S. linen exports, by category, 1989-99[1]

Year	Yarn, thread, and fabric	Apparel	Household furnishings	Floor covering	Total[2]
			1,000 pounds		
1989	24,256	12,160	2,471	8,154	47,041
1990	32,727	15,794	4,267	12,011	64,799
1991	28,005	16,072	4,300	15,440	63,817
1992	30,755	14,878	3,274	15,431	64,338
1993	30,178	19,629	2,610	17,455	69,872
1994	35,511	23,038	2,457	14,569	75,575
1995	35,106	24,397	3,011	13,733	76,247
1996	39,681	27,745	2,729	14,844	84,999
1997	54,604	19,803	3,980	26,784	105,171
1998	56,282	19,976	3,738	22,906	102,902
1999[3]	48,045	16,598	1,733	14,093	80,469

[1] Estimated raw-fiber equivalent quantity contained in the products.
[2] Does not include exports of raw fiber and tow/yarn waste.
[3] January to September.

Source: Meyer.

to replace both hemp and linen imports. The hemp fiber required to replace the equivalent level of hemp and linen fiber, yarn, and fabric imports in 1999 could have been produced on 250,000 acres—roughly 40 percent of 1997 tobacco acreage, 5 percent of U.S. oat acreage, or 0.4 percent of wheat acreage.

Hemp and linen are specialty textile fibers. Since 1980, linen and hemp together have accounted for less than 3 percent of world textile fiber production (table 4). Cotton and noncellulosic fibers are the dominant components. Worldwide production of hemp fibers decreased from a high of 569 million pounds in 1980 to 222 million pounds in 1995, a decline of 61 percent. A new data series was started in 1996, which does not

Table 4—World textile fiber production, 1980-98

Year	Rayon and acetate	Non-cellulosic fibers	Cotton	Wool (clean)	Silk	Flax	Hemp (soft)[1]	Total fibers
				Million pounds				
1980	7,147	23,095	31,427	3,675	123	1,389	569	67,425
1981	7,064	23,869	30,474	3,719	126	1,347	492	66,969
1982	6,493	22,368	31,993	3,656	121	1,437	459	66,603
1983	6,457	24,418	31,560	3,759	121	1,733	406	69,779
1984	6,605	26,023	42,552	3,831	123	1,512	443	71,669
1985	6,462	27,533	38,541	3,816	150	1,642	481	77,011
1986	6,304	28,499	33,880	3,924	139	1,605	485	80,688
1987	6,229	30,293	38,891	4,079	139	2,108	474	82,213
1988	6,385	31,784	40,514	4,202	141	2,039	465	85,530
1989	6,488	32,512	38,280	4,431	146	1,799	397	84,053
1990	6,079	32,838	41,808	4,359	146	1,570	364	87,164
1991	5,365	33,678	45,636	3,929	148	1,541	439	90,736
1992	5,130	35,629	39,650	3,794	148	1,484	432	86,267
1993	5,171	36,566	37,234	3,695	150	1,369	260	84,445
1994	5,087	39,549	41,229	3,437	152	1,261	209	90,924
1995	5,342	40,514	44,868	3,283	203	1,537	223	95,970
1996	5,004	43,887	43,219	3,289	194	1,448	139	97,180
1997	5,102	48,837	44,132	3,181	192	1,400	148	102,992
1998	4,817	50,135	40,629	3,120	192	1,424	152	100,469

[1] *Cannabis sativa*. Figures prior to 1996 include rough estimates for the former Soviet Union and Eastern Europe. A new data series was started in 1996 that does not include estimates from these regions.

Source: Meyer.

include production estimates from the former Soviet Union and Eastern Europe. During 1996-98, production averaged 146 million pounds, with China as the dominant producer.

According to industry sources, the fineness and quality of flax and hemp overlap depending upon growing conditions, variety, and how the crop is handled after harvesting. There is no industry consensus as to how closely the markets for the two fibers are allied (Gross). Nonetheless, with hemp fiber imports just 0.5 percent of linen imports, the near-term market potential for hemp in the United States (for domestic textile production) is closer to the low end of the 2,000- to 250,000-acre production-equivalent range. The general manager of Kenex Ltd. indicated that the 1999 supply of hemp fiber and seed from 35,000 Canadian acres has oversupplied the North American hemp market (von Sternberg, 1999).

Some people will buy hemp apparel and related items simply because they are made from hemp. This is probably a small but stable component of demand. A more volatile component is based on fashion trends and whether designers use hemp- or linen-containing fabrics in their designs. In the last few years, some famous designers, including Calvin Klein, Giorgio Armani, and Ralph Lauren, have included hemp fabrics in their clothing lines (Gross; *The Economist*, 1998; Copeland, 1999). Because of changing fashion trends, markets for specialty textile fibers tend to be cyclical. Cyclical markets would be more disruptive to fibers with small markets than to fibers with large market shares, such as cotton.

Hemp also is being used in the manufacture of household furnishings and floor coverings, particularly carpets (Gross; von Hahn, 1999). Competition with linen for traditional upholstery, drapery, and floor covering markets would depend on the fiber's quality and price.

A comparison of the import values for hemp and linen yarns reveals that hemp may be able to compete on price (table 5). From 1994 to 1998, the import value

Table 5—U.S. import value of linen and hemp yarns, 1989-99

Year	Linen yarn, single	Linen yarn, multiple	Hemp yarn
		Dollars/pound	
1989	2.47	6.76	na
1990	2.50	6.34	12.92
1991	2.38	5.33	21.19
1992	2.14	5.67	18.26
1993	2.38	4.61	1.34
1994	3.49	2.26	1.34
1995	3.73	2.24	2.89
1996	2.39	1.86	1.93
1997	3.14	2.62	1.01
1998	2.86	3.34	2.47
1999[1]	2.79	3.09	3.31

na = Not available.
[1] January-September.

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

of hemp yarn averaged $1.93 per pound, while the value for single- and multiple-strand linen yarn averaged $2.97 per pound. Information on yarn quality is not available, which may account for linen's higher value. Nevertheless, the value of hemp imports per pound, calculated by dividing the value of hemp yarn imports by the volume, has fluctuated widely since the early 1990's. During 1990-92, the value of hemp yarn ranged from $12.92 to $21.19 per pound. Between 1993 and 1999, the value ranged from $1.01 in 1997 to $3.31 for the first 9 months of 1999. The lower values in recent years may be to due to the increased volume of imports, enabling companies to spread their costs over more tonnage. Similar variations occurred in the import values of raw hemp fiber, which settled at around 40 cents per pound in 1997 and 1998.

Paper and Composites

The specialty and recycled paper markets are also possibilities for industrial hemp bast fibers. Specialty paper markets include currency, cigarette papers, filter papers, and tea bags. A number of companies in U.S. and European markets are selling paper that contains small amounts of hemp fiber, usually blended with less expensive nonwood fibers. These papers have gained some market acceptance as ecologically friendly or tree-free, but at present are considerably more expensive than wood-based paper (Ehrensing, Gardner and White). Within the mainstream pulp and paper market, fibers compete on quality characteristics, with cotton predominant among nonwood fibers, then flax, and then kenaf and other specialty fibers. Manufacturers are willing to pay more for specialty fibers if quality dictates. For example, abaca fibers retain their strength and form when wet, commanding a high price.

Rising wood prices and regulatory practices have promoted the growth of recycled pulp and paper. Therefore, a potential market may exist for agricultural fibers as an additive to strengthen paper made from recycled materials. Recent Dutch and German research suggests that industrial hemp may not be competitive in the specialty paper market, but may be used as a fiber supplement to recycled paper pulp.

In North America, use of nonwood fibers, such as hemp, in composites is still largely in research and development or the early stages of commercialization. Flax, kenaf, jute, hemp, and wheat straw—in combination with various resins—can be used to make composite board. Wheat straw is the dominant nonwood fiber in these applications (Glaser and Van Dyne, 1997). Hemp fibers could be desirable in this market because of their length and strength. Composites made using agricultural fibers are being developed in companies and research institutes in Europe, Canada, and the United States. The USDA Forest Service's Forest Products Laboratory is a leader in the research of nonwood fibers in composites. The percentage of the composites market captured by nonwood fibers in coming years will depend on economics and availability of raw materials.

Other Potential Uses

The *Economic Impact of Industrial Hemp in Kentucky* cites molded automobile parts and fiberglass replacement as potential uses for hemp bast fiber. Hemp fibers have been used in the manufacture of trunk liners and press-molded airbag parts for several BMW models. Kenex Ltd. has developed prototype molded car parts. Transit buses are being retrofitted in Florida with molded hemp parts for use in Orlando (Thompson et al.). In recent years, several automobile companies have investigated using nonwood fibers, such as hemp and kenaf, in the manufacture of molded car parts because they are lighter and more recyclable than current raw materials (Domier, 1998; Copeland). For nonwood fibers to gain a part of this market, they will have to be supplied in adequate quantities throughout the year at prices competitive with current raw materials.

The Kentucky report also suggests that hemp and other nonwood fibers could replace fiberglass in certain applications. The short fiber length and absorbent properties of these fibers would limit their use to replacing chopped fiberglass and in applications where moisture is not a problem. Given current market conditions, it can be assumed that synthetic fibers are the raw material of choice because of their properties (e.g., moisture resistance), their price, or both.

Hemp Hurds

In countries currently producing industrial hemp, hurds are sold for a variety of uses, including animal bedding, composites, and low-quality papers. According to Thompson et al. (1998), industrial hemp hurds appear to be price-competitive with wood chips, fine wheat straw, and other types of bedding used for high-value racehorses. Hemp hurds are favored over cheaper alternatives since they are more absorbent, and thus, reduce illness. Companies in England, France, and the Netherlands are making horse bedding from hurds. Some members of the racehorse industry in Kentucky have expressed interest in using hemp hurds (Patton, 1999). In addition, hurd-based cat litter is being sold in England, France, and Germany (Gardner and White). Since hurds are a joint product with the bast fiber, finding markets for hemp hurds may make the difference between a profitable and unprofitable industrial hemp enterprise.

Seed Markets

Thompson et al. (1998) estimated the demand for hemp seed by asking seed processing firms in the United States and Canada how many tons they purchased per month. They estimated North American demand at 1,300 tons at an average price of 39 cents per pound. Given yields in Germany of 1,000 pounds per acre, it would take 2,600 acres to satisfy the estimated demand for hemp seed. Ehrensing (1998) found bulk hemp seed prices at about 45 cents per pound, with strong demand. Hanks (Fall 1999) reports an average Canadian seed price of 41 cents per pound (60 cents Canadian) in 1999, but states that many observers fear overproduction of hemp in western Canada may bring crop prices down. In comparison, during the 1994/95-1998/99 marketing years, soybean, canola, and flaxseed prices averaged 10, 11, and 10 cents per pound, respectively (Ash, 1999).

According to Vantreese (1998), export prices of hemp seed have been extremely volatile in the last 20 years, mainly due to the variability of Chinese exports. China began producing and exporting hemp seed in large quantities in 1986, causing world prices to fall from 25 cents in 1985 to 15 cents per pound in 1986. In 1991, China stopped exporting hemp seed and prices nearly doubled in 1992. Prices peaked in 1995 at 41 cents a pound. During the 1990's, increased EU production of hemp also increased the demand for seed stock for planting, thereby raising export values.

Hemp seeds can be used as a food ingredient or crushed for oil and meal. The seed contains 20 percent high-quality, digestible protein, which can be consumed by humans, animals, and birds (Vantreese, 1998). The seed is approximately 29 to 34 percent oil by weight. The oil can be used both for human consumption and industrial applications (fig. 2). Due to the high content of polyunsaturated oils, it is fairly unstable and becomes rancid quickly unless preserved. The meal (seed cake) contains 25 to 30 percent protein and can be used in food and animal feed (Vantreese, 1998; Hinz, 1999).

Companies are using hemp seed in their products. Natural-product magazines, such as the *Natural Food Merchandiser* and *Organic & Natural News*, have advertised products containing hemp ingredients such as roasted hulled seed, nutrition bars, tortilla chips, pretzels, and beer. At least two breweries in the United States, as well as breweries in Canada, Germany, and Switzerland, make hemp beer (*The Economist*; Gardner and White; Louie, 1998). One article touts hulled hemp seeds as more shelf-stable than flax and more digestible than soybeans and finds the seed in snacks, spreads, salad dressings, cheese, and ice cream (Rorie, 1999). The market potential for hemp seed as a food ingredient is unknown. However, it probably will remain a small market, like those for sesame and poppy seeds. Some consumers may be willing to pay a higher price for hemp-seed-containing products because of the novelty, but otherwise hemp seed will have to compete on taste and functionality with more common food ingredients.

Currently, a trendy use of hemp oil is for body-care products, such as lotions, moisturizers, shampoos, and lip balms (Marshall, 1998; Rorie). For example, The Body Shop, a British-based international skin products company, began selling hemp-oil-containing products about 2 years ago in the United States. In June 1999, the company reported that those seven or eight products now account for 10 percent of total sales. However, to meet this demand, The Body Shops imports only 12 tons of organic hemp seed oil a year into the United States (Patton).

Hemp oil is also sold in health food stores as a nutritional supplement. The oil is mechanically (cold) pressed from the seed to maintain its quality and integrity. According to one industry participant, cold-pressed hemp oil has a dark green color and nutty flavor (Hemp-Agro). It contains roughly the same ratio of linoleic and linolenic acids that would be found in a nutritionally balanced diet (Marshall, Hinz). In addition to these two essential fatty acids, hemp oil contains 1 to 4 percent gamma-linolenic acid (GLA). GLA is also available from evening primrose and borage oils that, because of their unpleasant taste, are sold only in capsule form (Marshall, Hemp-Agro).

The market for hemp oil is limited by a number of factors. First, mechanical crushing produces a lower oil yield than crushing combined with solvent extraction. Nor does hemp oil undergo degumming and bleaching as do many other vegetable oils. Some consumers prefer an oil that has been processed without chemicals, but others may dislike hemp oil's color or taste. Second, the oil is high in unsaturated fatty acids, which can easily oxidize, so it must be kept in dark-colored bottles and has a limited shelf life. Like flax and safflower oils, which also are highly unsaturated,

Table 6—U.S. use of selected vegetable oils in industrial applications, 1978/79-1998[1]

Year[2]	All fats and oils[3]	Linseed oil	Tung oil	Linseed and tung oils
		Million pounds		
1978/79	4,443.9	207.5	13.5	221.0
1979/80	4,216.1	160.0	15.7	175.7
1980/81	4,163.2	127.6	16.6	144.2
1981/82	3,721.0	92.7	14.6	107.3
1982/83	3,649.6	97.6	12.2	109.8
1983/84	3,982.1	121.2	19.7	140.9
1984/85	3,665.0	166.0	12.4	178.4
1985/86	3,571.3	176.9	11.6	188.5
1986/87	5,990.6	280.8	12.2	293.0
1987/88	4,098.1	159.3	14.8	174.1
1988/89	3,805.4	154.9	7.7	162.6
1989/90	3,509.8	110.5	8.9	119.4
1991	3,745.1	95.8	6.4	102.2
1992	3,727.9	154.4	7.3	161.7
1993	3,646.2	125.8	11.2	137.0
1994	4,307.5	124.3	9.3	133.6
1995	3,760.2	112.8	20.2	133.0
1996	3,588.7	98.6	21.3	119.9
1997	3,889.8	83.0	19.4	102.4
1998	3,695.4	79.4	14.3	93.7

[1] Includes soaps, paints, varnishes, resins, plastics, lubricants, fatty acids, and other products.
[2] Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991.
[3] Includes castor oil, coconut oil, tallow (beef fat), lard (pork fat), linseed oil, rapeseed oil, soybean oil, tall oil, and tung oil.

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

hemp oil should not be used for frying. Third, to be used as a salad oil, it will have to be tested by the U.S. Food and Drug Administration and found "generally recognized as safe." In Canada, hemp foods are now regulated as novel foods, a legislative category developed primarily for products containing genetically modified organisms (Hanks, Fall 1999).

As a drying oil, hemp oil would have to compete with manmade chemicals and plant-based oils, such as linseed and tung oils, in industrial applications. As with industrial uses of all plant and animal oils and fats, use of linseed and tung oils has fluctuated in the last two decades, with no apparent upward or downward trend (table 6). Hemp oil would have to compete on functionality and price with current raw materials in these established industrial markets.

Potential U.S. Production and Processing

Potential yields and processing methods, along with farmer costs and returns, are important considerations when evaluating industrial hemp as a potential U.S. crop. Revenue is dependent on yields and market prices. Generally, the lower the market price, the greater the yield must be for producers to break even or make a profit. In addition, U.S. experience with kenaf and flax may lend insights into the processing hurdles hemp may face in the United States.

Possible Yields

The Oregon study summarizes hemp yields reported by researchers from various countries since the 1900's (Ehrensing). Early in this century, U.S. dry-stem yields ranged from 2 to 12.5 tons per acre, but averaged 5 tons per acre under good conditions. Research trials in Europe during the last four decades had dry-matter yields that ranged from 3.6 to 8.7 tons per acre. In the Netherlands, research trials during the late 1980's reported dry-stem yields of 4.2 to 6.1 tons per acre. Recent commercial production in England produced average dry-matter yields of 2.2 to 3 tons per acre on several thousand acres over several years. Experimental production in Canada during 1995 and 1996 yielded 2.5 to 3 tons of dry stems per acre. According to the study, some of the variation in yield can be attributed to different measurement practices. For example, European authors generally report total above-ground dry matter, including stems, leaves, and seed, versus the dry-stem yields reported by other researchers.

Vantreese (1998) reports that hemp seed yields have increased dramatically in recent years. In 1997, world average yields reached 876 pounds per acre. Yields ranged significantly, from a high of 1,606 pounds per acre in China, where the seed is consumed, to 595 pounds per acre in France, where much of the production is certified planting seed. In Germany, current seed yields are about 1,000 pounds per acre (Thompson et al.), while those in Eastern Europe range from 350 to 450 pounds per acre (Mackie, 1998). In Canada, seed yields in 1999 averaged 800 pounds per acre (Hanks, Fall 1999).

Processing

In addition to the uncertainty about yields, there is some question as to whether hemp fibers can be profitably processed in the United States. As was outlined earlier, the technologies used to process hemp fiber have not changed much and they require capital investment and knowledgeable workers. Research is under way to streamline harvesting, retting, and fiber separation, but those technological breakthroughs have yet to occur. Traditional retting and fiber-separation

Table 7—Estimated enterprise costs for hemp production in Kentucky, 1994

Costs	Fiber[1]	Seed	Certified seed
		Dollars/acre	
Variable costs:			
Seed (pounds)	(40) 80.00	(10) 20.00	(10) 20.00
Fertilizer	33.58	33.58	33.58
Lime (tons)	(1) 10.82	(1) 10.82	(1) 10.82
Fuel, oil (hours)	(4.5) 16.02	(2.2) 12.22	(2.2) 12.22
Repairs	9.35	17.60	17.60
Interest	7.93	4.24	4.24
Total	184.12	98.46	98.46
Fixed costs[2]	46.08	41.25	64.84
Operator labor[3] (hours)	(8) 56.00	(8) 56.00	(10) 70.00
Total enterprise costs	286.20	195.71	233.30

1 Harvested and sold as raw stalks.
2 Depreciation, taxes, insurance.
3 At $7 per hour.

Source: McNulty.

processes—both labor and resource intensive—could limit the ability of U.S. hemp producers to compete against major suppliers such as China, Hungary, Poland, and Romania.

Specialty oilseed crushing mills that could accommodate hemp seed do exist in the United States. According to the *Soya & Oilseed Bluebook*, companies in North Dakota, Minnesota, Georgia, and North Carolina mechanically crush flaxseed, borage, safflower, canola, sunflowerseed, crambe, peanuts, and cottonseed (Soyatech, 1999).

Estimated Costs and Returns

Both the 1995 Kentucky Task Force report (McNulty) and the 1998 Kentucky impact analysis (Thompson et al.), as well as the Oregon and North Dakota studies (Ehrensing, Kraenzel et al.), present estimated costs and returns for hemp production. All include estimates for fiber (stalk) production. The 1995 Kentucky, 1998 Kentucky, and North Dakota reports also present estimates on seed production. In addition, most of the studies compare the estimated hemp costs and returns to those for other crops.

The Kentucky Task Force estimated total costs—which include variable costs, fixed costs, and operator labor—to be $286 per acre for hemp fiber, $196 for seed, and $233 for certified seed (table 7). These costs were comparable to 1993 estimated expenses for producing corn and double-crop wheat/soybeans in Kentucky (table 8). The analysis assumed that hemp grown for fiber would be harvested and sold as raw stalks on a dry-weight basis. Various sources priced raw, dry defoliated stalks at $60 to $125 per metric ton. Yields were assumed to range from 7 to 15 metric tons per hectare (2.8-6.1 metric tons per acre), based largely on European studies. Thus, potential returns for hemp fiber ranged from a low price/low yield estimate of $170 per acre to a high price/high yield return of $759 per acre (table 8). With estimated production expenses of $286, net returns for hemp for fiber ranged from -$116 to $473 per acre. Returns for hemp seed were estimated to range from $60 to $800 per acre. Given costs of production at $196 per acre, net returns ranged from -$136 to $604 per acre (McNulty).

The Oregon report also estimated costs and returns for hemp grown for fiber, using typical costs associated with irrigated field corn in the Pacific Northwest (table 9). Variable and fixed costs for hemp were estimated at $371 and $245 per acre, respectively. The dry-matter yield was assumed to be 5 tons per acre, which is consistent with the higher average yields reported in Western Europe using well-adapted cultivars. A price of $75 per dry ton was based on the price of wood chips in the Pacific Northwest, as it was anticipated that the fiber could be used by local composite and paper companies. Given this yield and price, gross

Table 8—Estimated costs of production and returns for various crops in Kentucky, 1993 or 1994

Crop[1]	Yield per acre	Return per acre	Estimated cost per acre: Variable	Fixed	Labor	Total	Net return per acre
			Dollars				
Fiber hemp[2]	2.8-6.1 metric tons	170-759	184	46	56	286	-116 to 473
Hemp seed[3]	na	60-800	98	41	56	196	-136 to 604
Corn grain	110 bushels	231	155	46	32	233	-2
Wheat/soybeans (double crop)	45/28 bushels	300	149	44	37	230	70
Tomatoes (for processing)	27 tons	2,430	1,278	154	231	1,663	767
Burley tobacco	2,500 pounds	4,375	1,905	626	700	3,231	1,144

na = Not available.
[1] For all crops except hemp, source is University of Kentucky, Department of Agricultural Economics crop budgets for 1993.
[2] Various sources priced dry, defoliated stalks at $60 to $125 per metric ton.
[3] One source estimated returns at $60 to $171 per acre for seed (for oil and feed), while another estimated seed returns at $800 per acre (2,000 pounds per acre at 40 cents per pound).
Source: McNulty.

Table 9—Estimated production budget for hemp in the Pacific Northwest[1]

Item	Dollars/acre	Dollars/ton (dry weight)
Variable costs:		
Cultural		
Tillage and planting	40.00	8.00
Hemp seed	34.00	6.80
Fertilizer and application[3]	85.00	17.00
Irrigation	62.00	12.40
Total	221.00	44.20
Harvest[4]		
Forage chopper ($3/ton)	15.00	3.00
Raking ($1.50/ton)	7.50	1.50
Baling, large square bales ($9.80/ton)	49.00	9.80
Loading and trucking ($3.00/ton)	15.00	3.00
Total	86.50	12.80
Miscellaneous		
Operating capital interest	29.78	5.96
Pickup	7.68	1.54
Farm truck	6.34	1.27
General overhead	20.00	4.00
Total	63.80	12.76
Total variable costs	371.30	69.76
Fixed costs:		
Land rent	150.00	30.00
Insurance, machinery and equipment	3.00	0.60
Irrigation system, depreciation and interest	44.00	8.80
Machinery and equipment, depreciation and interest	48.00	9.60
Total	245.00	49.00
Total production costs	616.30	118.76
Gross income (yield = 5 tons/acre)[5]	375.00	75.00
Net projected returns	-241.30	-43.76

[1] Budget was developed using typical costs associated with irrigated field corn in the Pacific Northwest. Production practices were chosen to maximize stem dry-weight yield for possible production of composite wood products or paper. [2] 25 pounds/acre at $1.36/pound. The assumed cost of hemp seed is the average of prices reported for commercially available European hemp varieties. Cost of shipping from Europe was not included. [3] 600 pounds/acre 16-16-16 at $250/ton. [4] Based on cost of operating silage corn harvesters and local cost of raking and baling hay and grass seed straw. No costs associated with retting, such as additional irrigation, are included. [5] The dry matter yield is assumed to be 5 tons/acre, which is consistent with the higher average yields reported in Western Europe using well-adapted hemp cultivars. An assumed price of $75 per dry ton was used in the analysis since prices for wood chips in the Pacific Northwest have risen over the past decade and this trend is expected to continue.

Source: Ehrensing.

revenue would be $375 per acre and net returns would be -$241 per acre (Ehrensing).

The Oregon report presents a sensitivity analysis of net returns based on various yields and potential market prices (table 10). Most of the net returns remain negative except under the highest yield/price combinations. The analysis was further refined to see if dual production was any more profitable. The cost of combine seed harvest, $20 per acre, was added to variable costs, and stalk yields were lowered to 2.5 tons per acre with a price of $75 per ton. Again, most of the net returns are negative except for the highest yield/price combinations (table 11) (Ehrensing).

The 1998 Kentucky report estimates costs and returns for hemp grown for fiber (straw), seed (grain), certified seed, and both fiber and seed (table 12). The cost esti-

Table 10—Estimated net return per acre from hemp production in the Pacific Northwest at various price and yield levels

Yield (tons per acre)	Price (dollars/ton) 50	75	100	125
	Dollars/acre			
3	-431.70	-356.70	-281.70	-206.70
4	-399.00	-299.00	-199.00	-99.00
5	-366.30	-241.30	-116.30	8.70
6	-333.60	-183.60	-33.60	116.40
7	-300.90	-125.90	49.10	224.10

Source: Ehrensing.

Table 11—Estimated net return per acre from dual-purpose hemp production in the Pacific Northwest at various seed prices and yield levels[1]

Seed price (dollars/pound)	Seed yield (pounds/acre) 500	750	1000
	Dollars/acre		
0.30	-255	-181	-106
0.35	-231	-143	-56
0.40	-206	-106	-6
0.45	-181	-68	45
0.50	-156	-31	94
0.55	-131	7	144

[1]The cost of combine seed harvest, $20 per acre, was added to variable costs. Hemp stem yield was assumed to be 2.5 tons per acre with a price of $75 per ton. Other assumptions are the same as those used for table 9.

Source: Ehrensing.

Table 12—Estimated growing costs and returns for industrial hemp in Kentucky using 1997 technology, yields, and, prices[1]

Item	Fiber[2]	Seed[2]	Certified seed	Fiber and seed[2]
		Dollars/acre		
Variable costs:				
Seed (pounds)	(50) 125.00	(10) 25.00	(10) 25.00	(50) 125.00
Fertilizer	45.01	45.01	45.01	45.01
Herbicides	0.00	10.95	10.95	0.00
Lime (tons)	(1) 12.12	(1) 12.12	(1) 12.12	(1) 12.12
Fuel, oil (hours)	(4.5) 18.43	(2.2) 14.06	(2.2) 14.06	(2.2) 22.25
Repair	16.14	30.38	30.38	23.12
Interest	8.38	5.24	5.24	8.94
Storage	5.00	5.00	5.00	5.00
Transport to processor	27.20	8.00	5.60	24.00
Total	257.28	155.76	153.36	265.44
Fixed costs[3]	50.27	45.00	70.73	75.05
Operator labor[4] (hours)	(8) 56.00	(8) 56.00	(10) 70.00	(9) 63.00
Total enterprise costs	363.55	256.76	294.09	403.49
Stalk revenue	680.00	60.00	60.00	450.00
Stalk yield	3.4 tons/acre	0.5 tons/acre	0.5 tons/acre	2.25 tons/acre
Price per ton	200/ton	120/ton	120/ton	200/ton
Seed revenue	na	416.91	840.00	273.00
Seed yield	na	1,069 lbs/acre	700 lbs/acre	700 lbs/acre
Price per pound	na	0.39/pound	1.20/pound	0.39/pound
Total revenue	680.00	476.91	900.00	723.00
Profit	316.45	220.15	605.91	319.51

na = Not applicable.
[1] Figures are based on estimates in McNulty (1995) and updated to 1997 based on the increased costs of growing corn. Also, herbicide, storage, and transport-to-processor costs were added; estimates for repair were increased by 50 percent; 50 pounds of hemp seed per acre were assumed for cultivating hemp for fiber rather than 40 pounds.
[2] Referred to in the report as straw and grain.
[3] Fixed costs include depreciation, taxes, and insurance.
[4] At $7 per hour.

Source: Thompson et al.

mates are based on the 1995 Kentucky report and updated to 1997 with some modifications. The yields used in the analysis are from Germany. The prices, based on import prices and/or prices paid in Canada, were estimated to be 39 cents per pound for seed, $1.20 per pound for certified seed for planting, and $200 per ton for hemp stalks. The residual stalks from seed production were estimated to fetch $120 per ton. Total costs ranged from $257 to $403 per acre. According to the report, these cost estimates are consistent with those made by Reichert (1994), by Kenex Ltd., and from German cultivation data (Thompson et al.).

Estimated revenue ranges from $477 per acre for seed to $900 per acre for certified seed. Thompson et al. admit that the very high returns calculated in these estimates cannot be sustained. While most of their discussion focuses on why the price of certified seed will decrease, little attention is given to stalk prices. The price they used for stalks is the first-year (1998) price offered by Kenex Ltd., the Ontario firm contracting for hemp acreage, which is not representative of long-term stalk prices. With new crops, firms often have to offer farmers an initial premium to induce them to experiment with a new crop and to compensate them for lower initial yields and the forgone returns of a conventional crop. Thus, many of the revenue estimates likely overstate average annual returns. Given the high estimates, it is not surprising that when compared with conventional field crops, hemp net

Table 13—Estimated returns to land, capital, and management per acre for industrial hemp and common Kentucky crops, 1997

Crop	Estimated return to land, capital, and management
	Dollars/acre
Hemp, seed only	220.15
Hemp, fiber only	316.45
Hemp, seed and fiber	319.51
Hemp, certified seed only	605.91
Grain sorghum, conventional tillage	10.51
Wheat, reduced tillage	14.24
Continuous corn	75.71
Popcorn, reduced tillage	78.25
Soybeans, no-till, rotation following crop	102.20
No-till corn, rotation following soybeans	106.48
White corn, rotation following soybeans, reduced tillage	135.84
Alfalfa hay	141.34
Barley/no-till soybeans, double-crop following corn	158.09
Wheat/no-till soybeans, double-crop following corn	158.43
Grass legume hay, round bales	161.56
Dark air-cured tobacco	182.48
Dark fire-cured tobacco	1,104.87
Burley tobacco, baled, nonirrigated	1,563.48

Source: Thompson et al.

returns were higher than those for all the selected crops except tobacco (table 13).

The costs and returns in the North Dakota report are based on a dual-purpose crop in Ontario, Canada. Information from Vantreese (1997) was used as the basis for the three price/yield scenarios. Prices ranged from $5.51 to $6.80 per bushel for seed and from $40.44 to $51.45 per ton for fiber (table 14). Yield estimates ranged from 14.3 to 23.8 bushels of seed per acre and 2.5 to 3 tons of fiber per acre. Total costs were estimated at $175 per acre, while potential revenue ranged from $180 to $316 per acre, resulting in net returns of $5 to $142 per acre. The return for the low-price/low-yield hemp scenario was comparable to those for most of the comparison crops in the study. Only irrigated potatoes had higher net returns than any of the three hemp scenarios (Kraenzel et al.).

Among the studies, total costs ranged from $175 for North Dakota to $616 in Oregon (table 15). A lot of the variation can be attributed to differences in fixed costs. For example, fixed costs in the Kentucky studies, which do not include land rent, are estimated at $75 per acre or below. In the Oregon report, fixed costs are $245 per acre, including land rent and irrigation-system depreciation. When land and irrigation costs are removed, fixed costs drop to $51. Also, when land rents, estimated at $65 to $75 (Vantreese, personal communication), are added to the Kentucky estimates, fixed costs range from $106 to $150. The estimates also may differ due to varying assumptions about production practices and may reflect different cost structures among the States. The Oregon study did cite high land costs as one reason hemp production may not be viable in the Pacific Northwest (Ehrensing).

Table 14—Estimated costs and returns for hemp and other crops in North Dakota, 1998

Crop	Average yield	Average price	Total revenue	Total costs	Net returns
	Per acre	*Dollars/unit*	*Dollars/acre*		
Low-price/low-yield hemp[1]	14.3 bushels; 2.5 tons	$5.51/bushel; $40.44/ton	179.96	174.63	5.33
Average hemp[1]	19 bushels; 2.75 tons	$6.16/bushel; $45.96/ton	248.13	174.63	73.49
High-price/high-yield hemp[1]	23.8 bushels; 3 tons	$6.80/bushel; $51.47/ton	316.29	174.63	141.65
Corn grain[2]	54 bushels	2.25	121.50	159.70	-38.20
Spring wheat[2]	31 bushels	3.71	115.01	117.32	-2.31
Confectionery sunflowers[2]	1,080 pounds	0.131	141.48	140.62	0.86
Malting barley[2]	50 bushels	2.41	120.50	115.02	5.48
Irrigated potatoes[2]	32,500 pounds	0.045	1,462.50	1,017.59	444.91

[1] Estimates are for a dual-purpose crop in Ontario, Canada.
[2] From projected 1998 crop budgets for Northeast North Dakota.

Source: Kraenzel et al.

Table 15—Comparison of estimated costs and returns for hemp from the various State studies

Report	Variable costs	Fixed costs[1]	Operator labor	Total costs	Revenue	Net returns
			Dollars/acre			
1995 Kentucky:						
Fiber	184	46	56	286	170 to 759	-116 to 473
Seed	98	41	56	196	60 to 800	-136 to 604
Certified seed	98	65	70	233	na	na
Oregon:						
Fiber	371	245	na	616	375	-241
1998 Kentucky:						
Fiber	257	50	56	364	680	316
Seed	156	45	56	257	477	220
Certified seed	153	71	70	294	900	606
Fiber and seed	265	75	63	403	723	320
North Dakota:						
Fiber and seed	na	na	na	175	180 to 316	5 to 142

na = not available.
[1] In the two Kentucky studies, fixed costs include depreciation, taxes, and insurance. In the Oregon study, fixed costs include land rent ($150), irrigation-system depreciation and interest ($44), machinery depreciation and interest, and insurance.

None of the cost estimates include costs for monitoring, licensing, or regulating hemp production. These external expenses would be part of the cost of producing industrial hemp and could be borne by taxpayers or passed on to growers and/or processors. According to Thompson et al. (1998), Kenex Ltd. estimates that Canadian farmers will pay US$50 annually for a background check and to obtain the satellite coordinates for their hemp fields (fields are monitored via satellite as part of the Canadian program).

The studies also present a range of revenue estimates, which is not surprising given the uncertainty about demand and expected market prices. Overall, it seems questionable that U.S. producers could remain profitable at the low end of the estimated net returns. In addition, given the thinness of the current U.S. hemp fiber market, any overproduction could lead to lower prices and lost profitability.

U.S. Experience With Kenaf and Flax

Both kenaf and flax can be legally grown in the United States. Their recent production history may lend additional insights into the potential for hemp in the United States.

Kenaf is a relatively new crop. It can be grown in many parts of the United States, but it generally needs a long growing season to produce the necessary yield to make it a profitable crop. With a long growing season, like that found in the southern United States, kenaf can reach a height of 12 to 18 feet and produce 5 to 10 tons of dry fiber per acre annually. An estimated 8,000 acres of kenaf was grown in the United States in 1997, up from 4,000 acres in 1992 and 1993. Primary production areas are Texas, Mississippi, Georgia, Delaware, and Louisiana (Glaser and Van Dyne). Processing and product technology for kenaf-based pulp and for about six other markets have been developed, but markets must be established in each geographic area since the core fraction is very low density and expensive to ship.

Flax is grown in the United States in small quantities. Production is almost totally oilseed varieties (for linseed oil). Textile or linen flax has not been grown commercially in North America for 40 years (Domier). The United States does not produce textile flax for several reasons. First, the market for linen is very small compared with other natural fibers like cotton, which accounts for nearly one-third of U.S. fiber mill use. Linen textile imports have accounted for an annual average of 2 to 3 percent of the quantity of all fibers consumed in the United States (mill use plus net textile trade). Additionally, since 1989, linen textile imports as a percentage of total textile imports have consistently fallen from 12 percent to 4 percent in 1998 and 1999. The market remains small because the economics of producing textile flax is not very price/cost competitive. As noted earlier, many inefficiencies continue to exist in this industry, particularly the methods of harvesting and processing. Because of the length of the fiber and the variation in quality, U.S. mills are reluctant to use textile flax. Some recent developments, however, have allowed the use of textile flax waste on cotton-spinning systems. Also, a flax fiber mill reopened in Quebec in December 1997, and research and development activities are occurring in Alberta, Connecticut, Maine, Oregon, and Saskatchewan (Domier; Hanks, Fall 1999).

State Study Findings

Each of the three 1998 studies focused on different aspects of supply and/or demand. Since Kentucky was a major producer of certified hemp seed in the past, it is one of the main markets mentioned in the 1998 study. Also, the horse racing industry in the State could be a significant buyer of hemp hurds for animal bedding. North Dakota has an oilseed crushing industry. Thus, the North Dakota study concluded that the largest market opportunity for the State may be hemp seed oil. The Oregon report concentrated on fiber production because of the pulp and paper industry in the Pacific Northwest. (Summaries from each of the reports are in Appendix III.)

All three of the studies do mention hemp's benefits as a rotation crop. As stated in the Oregon report, industrial hemp may provide an excellent rotation crop for traditional crops to avoid outbreaks of insect and disease problems or to suppress weeds (Ehrensing). The North Dakota report further states that hemp rebuilds and conditions soils by replacing organic matter and providing aeration through its extensive root system (Kraenzel et al.).

The Kentucky Task Force had a broad mandate to examine legal, agronomic, and economic aspects of hemp production. In 1995, the majority of the Kentucky Task Force concluded that legal prohibition of *Cannabis* cultivation was the overriding obstacle to reintroduction of fiber hemp production in Kentucky. Significant progress on agronomics, marketing, or infrastructure development is unlikely, and of relatively little importance, unless legal issues are resolved (McNulty).

The North Dakota report takes a different position. Since industrial hemp may have potential as an alternative rotation crop, the report recommends that the North Dakota Legislature consider action that would allow controlled experimental production and processing. This would allow collection and analysis of necessary baseline production, processing, and marketing data. At the same time, the concerns and costs of law enforcement agencies could be addressed (Kraenzel et al.).

Conclusions

Current markets for bast fibers like industrial hemp include specialty textiles, paper, and composites. Hemp hurds, the inner woody portion of the plant stem, are used in various applications such as animal bedding, composites, and low-quality papers. As joint products, finding viable markets for both hemp bast fiber and hurds may increase the chances of a successful business venture. Hemp industry sources and some academic studies cite many potential uses for hemp fiber and hurds. However, for these applications to develop or expand, hemp will have to compete with current raw materials and manufacturing practices. The U.S. market for hemp fibers is, and will likely remain, a small, thin market. Changes in price or quantity could be more disruptive and have a greater adverse impact on market participants than would be the case in a larger market.

Since there is no commercial production of industrial fiber hemp in the United States, the "size" of the market can only be gauged from hemp fiber and product imports. The near-term, low-end size of the U.S. market for hemp as a textile fiber might be defined by considering the domestic production and acreage required to replace imports of hemp fiber, yarn, and fabric in 1999. Assuming a potential U.S. yield of 1,550 pounds of fiber per acre and using linen yarn and fabric conversion factors, the estimated import quantity of hemp fiber, yarn, and fabric in 1999 could have been produced on less than 2,000 acres of land. Given the average size of farms in the United States (near 500 acres), just a few farms could have supplied the hemp fiber equivalent of 1999 import levels.

As a specialty bast fiber, hemp's closest competing textile fiber is linen. A longer term, high-end size of the potential U.S. market for hemp fiber could be defined as domestic production and acreage required to replace hemp and linen imports. The hemp fiber required to replace the equivalent level of hemp and linen fiber, yarn, and fabric imports in 1999 could have been produced on 250,000 acres—roughly 40 percent of 1999 tobacco acreage, 5 percent of U.S. oat acreage, or 0.4 percent of wheat acreage.

Despite the similarities between hemp and linen, there is no industry consensus as to how closely the markets for the two fibers are allied. But since hemp fiber imports were just 0.5 percent of linen imports during the first 9 months of 1999, the near-term market potential for hemp in the United States for domestic textile production is closer to the low end of the 2,000- to 250,000-acre production-equivalent range. Moreover, the absence of a thriving textile flax (linen) production sector in this country (despite no legal barriers) suggests that hemp, flax's close cousin in fiber uses and in production techniques, will be unable to sustain adequate profit margins for a large production sector to develop.

Thompson et al. (1998) estimate imports of hemp seed into North America at 1,300 tons. Given yields in Germany of about 1,000 pounds per acre, it would take 2,600 acres to satisfy the demand for hemp seed. As with fiber imports, it would take only a few average-sized farms to meet this demand. Hemp seeds can be used directly as a food ingredient or crushed for oil and meal. Hemp seeds and flour are being used in nutrition bars, tortilla chips, pretzels, beer, salad dressings, cheese, and ice cream. The market potential for hemp seed as a food ingredient is unknown. However, it probably will remain a small market, like the markets for sesame and poppy seeds. Some consumers may be willing to pay a higher price for hemp-seed-containing products because of the novelty, but otherwise hemp seed will have to compete on taste and functionality with more common food ingredients.

Hemp oil is being used as an ingredient in body-care products, such as lotions, moisturizers, and shampoos, and sold in health food stores as a nutritional supplement. The market for hemp oil is limited by a number of factors. First, mechanical crushing produces a lower oil yield than crushing combined with solvent extraction. Nor does hemp oil undergo degumming and bleaching as do many other vegetable oils. Some consumers prefer an oil that has been processed without chemicals, but others may dislike hemp oil's color or taste. Second, the oil is high in unsaturated fatty acids, which can easily oxidize, so it is not used for frying, must be kept in dark-colored bottles, and has a limited shelf life. Third, to be used as a salad oil, it will have to be tested by the U.S. Food and Drug Administration and found "generally recognized as safe." Last, as a drying oil, hemp would have to compete on functionality and price with current raw materials, such as linseed and tung oils, in established industrial markets.

Several States have published reports or authorized agronomic and economic feasibility studies of hemp production. The four reports summarized here have focused on different aspects of supply and/or demand. Their estimates of hemp costs and returns reflect these various focuses, as well as different assumed production practices and costs. However, the widest range of estimates exhibited among the reports is for stalk and seed yields and prices—not surprising given the uncertainty about hemp production and current and potential hemp markets. Overall, hemp production was profitable only at the higher end of estimated yields and prices. It seems questionable that U.S. producers could remain profitable at the low end of the estimated net returns, particularly given the thinness of current U.S. hemp markets.

The market for hemp products might easily be oversupplied, as in Canada where the 35,000 acres of hemp produced in 1999 was seemingly more than the market could handle. The *Minneapolis Star Tribune* quotes the general manager of Kenex Ltd., Canada's biggest hemp processor, as saying "It's given us one hell of a glut of grain and fiber. There's been a major overestimation of the market that's out there" (von Sternberg).

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INFORMATION March 1998

COMMERCIAL PRODUCTION OF INDUSTRIAL HEMP

Effective March 12 , 1998, the commercial production (including cultivation) of industrial hemp is now permitted in Canada, under licences and authorizations, issued by Health Canada.

Industrial Hemp usually refers to varieties of the *Cannabis* plant that have a low content of THC (delta-9 tetrahydrocannabinol) and that are generally cultivated for fibre. Industrial hemp should not be confused with varieties of *Cannabis* with a high content of THC which are referred to as marijuana. The psychoactive ingredient in marijuana is THC.

Internationally, *Cannabis* is regulated by the United Nation's ***Single Convention on Narcotic Drugs***. Canada has signed and ratified this Convention. The ***Controlled Drug and Substance Act (CDSA)*** came into force effective May 14, 1997. The ***Industrial Hemp Regulations*** to the CDSA will permit the commercial cultivation of industrial hemp in Canada.

The Regulations control the activities relating to importation, exportation, possession, production, sale, provision, transport, sending, delivering and offering for sale of industrial hemp.

The Regulations define industrial hemp as the plants and plant parts of the *Cannabis* plant, whose leaves and flowering heads do not contain more than 0.3 percent THC. It includes derivatives of the seeds such as oil and seedcake. It does not include non-viable *Cannabis* seed, but it includes its derivatives.

It also does not include the mature stalks or the fibres derived from those stalks. This means that such fibres or the products made from the mature cannabis stalk may be imported, treated and sold in Canada.

The Regulations consist of the following components:

- Importers and exporters of industrial hemp, in the form of seed or viable grain, will be licensed. In addition to holding a licence they will also be required to obtain a permit for each shipment.

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- The importer must ensure that shipments of viable grain are accompanied by foreign certification. A list will be published by Health Canada indicating which countries are designated as having equivalent controls on the production of viable grain. Viable grain may only be imported from listed countries. This will ensure that viable grain imported will not produce a plant containing more than 0.3% THC.

- Seed growers will be restricted to a 0.4 hectare minimum plot size and will be required to demonstrate current membership in the Canadian Seed Growers Association as part of their licence application. Seed growers will be required to provide the number of hectares grown in the previous two years as part of their licence application.

- Plant breeders will not be restricted to minimum plot sizes. Persons applying for a licence as a plant breeder must be registered with the Canadian Seed Growers Association and may only cultivate industrial hemp under this regulatory framework. The pedigreed seed restriction which applies to growers in the year 2000 does not apply to plant breeders nor does the limitation to the *List of Approved Cultivars*.

- Growers for fibre or viable grain will require a licence before they can purchase seeds from a distributor or cultivate industrial hemp. Growers will be required to provide the number of hectares grown in the previous two years as part of their licence application.

- Only approved varieties of industrial hemp seeds, as listed on Health Canada's *List of Approved Cultivars* may be planted. Commencing January 1, 2000, only pedigreed seeds of approved varieties may be planted. Growers will be required to identify their fields, and maintain records of production and distribution.

- Licences and audit trails will also be required for processing activities such as pressing seeds into oil. All parties licensed or authorized will be required to identify a person resident in Canada who will be responsible for the licensed activities.

- To obtain a licence for the importation, exportation, production or sale of industrial hemp, applicants will be required to produce a police security check.

- Derivatives of seed or viable grain, such as oil and seed cake, will be exempted from the Regulations if there is evidence that the derivatives contain no more than 10 micrograms of delta-9-tetrahydrocannabinol per gram and carry appropriate labelling statements. Products made from derivatives of seed or viable grain will be exempted if there is evidence that each lot or batch contains no more than 10 micrograms of delta-9-tetrahydrocannabinol per gram.

- Importers and exporters of derivatives will be required to provide proof with each shipment that the shipment contains no more than 10 micrograms of delta-9-tetrahydrocannabinol per gram for each lot to ensure that the product is within the limit. Similarly products made from the derivatives of seed or viable grain must be accompanied with evidence that each shipment contains no more than 10 micrograms of delta-9-tetrahydrocannabinol per gram.

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- No person will be permitted to import or export a derivative or a product produced from a derivative that contains more than 10 micrograms of delta-9-tetrahydrocannabinol per gram.

- No person will be permitted to import or sell whole plants, including sprouts or the leaves, flowers or bracts of industrial hemp; or import, sell, or produce any derivative or any product made from a derivative of the above.

- Authorizations will be required for transportation, when products are transported outside the direction or control of a licence holder, or for possession for the purpose of testing for viability.

- No person shall advertise to imply that a derivative or product is psychoactive.

- Testing for the level of THC in leaves or in derivatives must be done by a competent laboratory according to standards defined by Health Canada.

Health Canada will continue to issue licenses for approved research studies related to the cultivation of hemp for industrial purposes.

Application Forms and relevant Guidance Documents, aimed at expediting the review of licences and authorizations for the commercial cultivation of industrial hemp and also for research licences, are available.

The documents are available from:

Internet: www.hc-sc.gc.ca/hpb-dgps/therapeut
Section: Hemp

or

Jean Peart, Manager, Hemp Project
Bureau of Drug Surveillance
Therapeutic Products Directorate
Address Locator 4103A, 122 Bank Street, 3rd Floor
Ottawa, Ontario, Canada, K1A 1B9
Phone: (613) 954-6524 FAX: (613) 952-7738
Internet: jean_peart@hc-sc.gc.ca

Copies of the *Controlled Drugs and Substances Act* are available from:

Internet: canada.justice.gc.ca/FTP/EN/Laws/

or

Canada Communications Group
Ottawa, Ontario
KlA 0S9
Telephone - (613) 956-4802

Appendix II

Oversupply of Small, Thin Markets

This appendix presents the general economic theory behind the operations of small, thin commodity markets and provides three case studies to illustrate the consequences of oversupply.

General Economic Theory

Agricultural commodities are generally homogeneous and undifferentiated. Small, thin (niche-like) markets may develop due to changes in demand, such as a shift in consumer tastes, or changes in supply, such as a new production technology, a new product, or a new use for a traditional product. Oversupply in small, thin markets can result from supply-side phenomena, demand-side phenomena, or both.

When the stimulus comes from the supply side, innovators may actually have to cultivate a market for their product. Provided that expectations about production efficiencies hold true, early firms that discover and serve the market are able to realize a significant return. However, the early firms may not be able to deter new entries. When new firms enter, they are not aware of the number of other new entrances or the extent to which original firms are expanding production. Total supply may increase by more than what firms expect, driving prices down. For less efficient firms, price may be below average cost and they will exit the market. As the market matures, information is exchanged among buyers and sellers and parties develop more accurate expectations of market behavior.

On the demand side, changes in consumer preferences may stimulate a new or added demand for a product. With expectations for continued growth in demand, producers respond to initial price incentives by entering the market. If demand does not expand as expected, the market finds itself oversupplied and prices decline.

In some cases, expectations about production efficiencies and future growth in demand combine to define a potential niche market. When one or both of the expectations fall short, the market becomes oversupplied and prices fall.

The extent of any price decline in small, thin markets that are oversupplied depends on secondary markets. The availability of a secondary market limits the price decline in the primary market; its absence sharpens the price decline and may force out all but the most efficient producers.

Losses incurred by producers/growers in an oversupplied niche market are a function not only of net returns to the production process, but of the size and specialized nature of the initial investment. Investment losses of the firms who exited the market will depend on the firms' sunk costs and the degree of specialization. If the initial investment was high, the losses may be greater. The degree of specialization is also important. If the plant and equipment can be used for another economic activity, some of the losses may be recouped or offset. However, if the equipment is specialized, the salvage value may be low.

Case Studies

A review of particular niche markets—poinsettias, emus, and mesclun—may serve to illustrate the issues involved in oversupply.

Poinsettias. *Large numbers of entrants led to oversupply. No secondary markets were available, so prices declined. Investment in specialized resources was minimal, so that many producers were able to shift resources to other horticultural products.*

U.S. growers produce more than $900 million of potted flowering plants annually, with poinsettias the most important. Only small quantities are imported from and exported to Canada. Poinsettias are a perishable product, demand is highly seasonal (November-December), and no secondary markets exist. Therefore, with imperfect knowledge about market supply and prices, growers can easily overproduce and prices can fall quickly, particularly since no secondary markets exist. Grower numbers probably peaked in 1992 and have since trended downward due to declining profit margins. Similar cases are found with other potted flowering plants, such as Easter lilies. Because production processes are similar, growers will typically switch to producing other flowering plants, foliage plants, or bedding and garden plants if profit margins decline.

Emus. *Significant investment in specialized resources (breeding stock), unexpectedly high production costs, and limited demand created substantial losses to growers.*

Production of ratites—ostriches, emus, and rhea—has occurred on a small scale in the United States for about 100 years. Starting about 1985, a few studies indicated that ratites might be efficient converters of feed. At the time, there was a known, albeit small, market for meat, hides, emu oil, eggs, and feathers, but it was expected to expand as production increased. This raised the price of breeding stock. U.S. ratite production entered into what is called the breeder phase. As more producers became convinced that ratites would be profitable, the demand for birds grew and the price of breeding stock skyrocketed. As long as producers were convinced that more breeding stock (and eventually products) could be marketed, the price remained very high. When the demand for products did not develop as growers had hoped, the demand for breeding stock declined and the price of breeding stock plummeted. Investment in the production of ratites, particularly in breeding stock, expanded much more rapidly than demand for products. Emus have received the most attention, as producers have let them run wild or killed the birds to avoid having to feed and care for them. In many cases, growers incurred significant losses when prices fell. There will probably continue to be a small market for some products and market size may even expand over time, but investment and production increased too fast, too soon.

Organic Mesclun. *Increased consumer demand for a popular new product led to high prices. Production costs and efficiencies for organic mesclun were not distinctly different from alternative (nonorganic) production practices. Nonorganic mesclun producers entered the market, supplies increased, and prices declined. Requirements for highly specialized investments were minimal. Firms with land certified for organic production could switch to other organic products with more profitable returns, which limited losses from oversupply of this market.*

For several years, USDA's Agricultural Marketing Service (AMS) has collected data on prices for organic mesclun mix (salad mix of baby lettuces, herbs, and greens) in the Boston wholesale market. Organic mesclun prices are higher than regular (nonorganic) mesclun, but the price premiums have declined in recent years. In 1996, regular mesclun from California or Arizona cost an average of $8.64 per 3-pound carton (ranging from $7.50 to $10.00) and organic mesclun cost $9.72 per 3-pound carton (ranging from $7.75 to $10.75). The monthly organic premium averaged 14 percent, ranging from 8 percent in November to 22 percent in December.

Mesclun is a relatively new commercial crop in the United States. Initially, mesclun was a very small market; it was produced organically and garnered high prices. Other producers—both organic and regular—entered the mesclun market, attracted by high returns. By 1996, only about 30 percent of the mesclun in the Boston wholesale market was organic. As production expanded, mesclun prices declined and the premium between organic and regular mesclun narrowed. Industry insiders say that as long as there is a large supply of regular mesclun, organic prices will continue to be low. The market will bear a very small premium for organic mesclun.

As the gap between organic and regular mesclun prices decreased, organic mesclun producers could remain in the market because variable production costs are not much higher than for regular mesclun. Since the lettuces and greens are harvested when quite small, they are not in the ground very long and are less prone to insect and disease problems than other organic crops.

The investment required to make land certified for organic production can be significant. Some industry experts think the organic share of the mesclun market will continue to decrease. But, since the production of organic mesclun requires little, or no, specialized investment, producers exiting the market will shift to other organic crops that yield a higher return on relatively expensive certified organic land.

Appendix III
State Report Summaries

Summary
Report to the Governor's Hemp and Related Fiber Crops Task Force
Commonwealth of Kentucky,
June 1995

- Most analysts forecast long-term increases in world demand for all types of fibrous materials, and some predict limitations in production capacity. New fiber crops, new industrial uses of nonwood fibers, and agricultural diversification in general are therefore subjects of widespread interest. Kentucky agriculture is not alone in efforts to pursue these possibilities, and will be required to compete with producers in other states and nations.

- Kentucky history, as well as recent research in other temperate zone countries, demonstrates that hemp can be produced in the Commonwealth. Selection of adapted varieties, crop management practices, harvesting technology and several other agronomic aspects may require a significant research and development effort if hemp is to be a large scale crop. Yet there is no reason to believe that these production issues are insurmountable.

- The historical advantages (for example: favorable climate, naturally fertile soils, labor supply) held by Kentucky hemp producers, particularly hemp seed producers, have been made somewhat less important by modern agronomic technology.

- Hemp and kenaf may have a slight advantage over certain other annual row crops with regard to potential environmental impacts. This might result from projected requirements for less pesticide and modest reductions in soil erosion.

- Currently, established markets for hemp in the U.S. are generally limited to specialty/novelty textiles, oils, foods, paper and other materials. The specialized nature of this market does not require competition with other fiber sources. The potential market size is difficult to predict, but it is unlikely to support the large acreage of a major new field crop.

- Bast fibers contribute an exceedingly small fraction of world textile fiber supply, which is overwhelmingly dominated by cotton. Increasing world demand and price for cotton in recent years has generated some interest in alternative fibers. However, extraction and processing of bast fibers for high-quality textiles is more difficult than for cotton. A large investment, and perhaps some technological innovation, will be required by the textile industry if bast fibers are to become competitive as mass market textiles.

- Use of annual fiber crops for most paper applications or for building materials, as a substitute for wood or recycled fiber, could create a very large but relatively low value market. Crop prices above $60/ton would probably be required to interest most producers; this price might preclude extensive competition in this market. Vast quantities of fibrous waste materials (sugar cane bagasse, straw) are available world wide and would also compete for such applications.

- A large and long-term USDA effort on kenaf has addressed many production and processing challenges. Infrastructure for significant utilization of kenaf fiber is beginning to develop in the southern U.S. The University of Kentucky College of Agriculture is actively investigating kenaf production. Development of this alternative fiber crop in Kentucky will be dependent on nearby location of processing facilities and a profitable market for farmers.

- Legal prohibition of *Cannabis* cultivation is the overriding obstacle to reintroduction of fiber hemp production in Kentucky. Significant progress on agronomics, marketing, or infrastructure development is unlikely, and of relatively little importance, unless legal issues are resolved. Legislative action would be required at both the state and federal level. Such consideration would likely receive strong diverse reactions from both private and public sectors.

Source: McNulty.

Summary

Feasibility of Industrial Hemp Production in the United States Pacific Northwest

May 1998

For many centuries hemp (*Cannabis sativa* L.) has been cultivated as a source of strong stem fibers, seed oil, and psychoactive drugs in its leaves and flowers. Environmental concerns and recent shortages of wood fiber have renewed interest in hemp as a raw material for a wide range of industrial products including textiles, paper, and composite wood products. This report assesses the agricultural feasibility of industrial hemp production in the Pacific Northwest (PNW).

Hemp is an herbaceous annual that develops a rigid woody stem ranging in height from 1 to over 5 meters (3 to 19 feet). Hemp stalks have a woody core surrounded by a bark layer containing long fibers that extend nearly the entire length of the stem. Plant breeders have developed hemp varieties with increased stem fiber content and very low levels of delta-9-tetrahydrocannabinol (THC), the psychoactive ingredient of marijuana.

Historically, hemp fiber was used mainly for cordage, but it can also be made into textiles, paper, and composite wood products. Demand for hemp cordage peaked in the late 1800's, and world hemp production has continuously declined since that time, except for brief increases during both World Wars. Hemp fiber has largely been replaced by relatively inexpensive natural and synthetic fibers.

Although hemp is well adapted to the temperate climatic zone and will grow under varied environmental conditions, it grows best with warm growing conditions, an extended frost-free season, highly productive agricultural soils, and abundant moisture throughout the growing season. When grown under proper conditions, hemp is very competitive with weeds, and herbicides are generally not required in hemp production. Although a number of insect pests and diseases have been reported on hemp, significant crop losses from pests are not common. High levels of soil fertility are required to maximize hemp productivity. Cultural requirements and production costs are quite similar to those of corn. Reported hemp yields range from 2.5 to 8.7 tons of dry stems per acre.

The climatic and soil requirements of hemp can be met in some agricultural areas of the PNW, however, hemp will almost certainly require irrigation to reliably maximize productivity in the region. The requirement for supplemental irrigation will place hemp in direct competition with the highest value crops in the PNW, limiting available acreage. Stem yields will have to be substantially higher than those previously recorded for hemp to be economically feasible in the PNW at current prices. It is unlikely that the investment needed to improve hemp production technology will be made until legislative restrictions are removed from the crop.

Source: Ehrensing.

Executive Summary
Economic Impact of Industrial Hemp in Kentucky
July 1998

In recent years, industrial hemp has been viewed worldwide as a versatile and environmentally friendly plant that has many industrial applications. Although it is currently grown in many European and Asian countries and even in Canada, industrial hemp is still prohibited from being grown in the United States.

This situation exists even though the current consumer and business environment in the United States may make industrial hemp cultivation and processing commercially feasible. Many consumers are starting to prefer products made from natural materials. The industrial hemp plant is a good source of natural raw materials for a number of products and is a superior source in some cases. Moreover, many farmers in Kentucky and throughout the nation are looking to alternative crops to replace their current crops, and some have touted hemp as an excellent rotation crop with much potential for agriculture.

Kentucky should be in a position to benefit from the establishment of an industrial hemp cultivation and processing industry in the United States. Historically, Kentucky has been a good location to grow hemp. Before hemp cultivation was outlawed, it had been a major crop in Kentucky and grew well in the climate. In the 1800's, Kentucky regularly accounted for one-half of the industrial hemp production in the United States. The climate, soil, and growing season in Kentucky also make the state a superior location for growing certified hemp seed to be planted by farmers raising an industrial hemp crop.

The Kentucky Hemp Museum and Library contracted with the University of Kentucky Center for Business and Economic Research to conduct an analysis of the potential economic impact of industrial hemp in Kentucky. This study looks at the different markets for hemp products, examining both the current markets in which foreign-grown hemp is being used, and potential or burgeoning markets that may have uses for industrial hemp.

In the report, we estimate costs for growing industrial hemp in Kentucky and provide information on potential prices farmers could expect for their hemp crop. We also compare the return from cultivating industrial hemp with the returns for other crops in Kentucky. In addition, we detail the costs of a hemp processing facility to separate the hemp into fiber and other materials. Finally, we estimate the potential jobs and earnings impacts of growing industrial hemp in Kentucky under several scenarios.

Among the key findings of this report are:

- A market for industrial hemp exists in a number of specialty or niche markets in the United States, including specialty papers, animal bedding, and foods and oils made from hemp.

- Additional markets could emerge for industrial hemp in the areas of automobile parts, replacements for fiberglass, upholstery, and carpets.

- Using current yields, prices, and production technology from other areas that have grown hemp, Kentucky farmers could earn a profit of approximately $320 per acre of hemp planted for straw production only or straw and grain production, $220 for grain production only, and $600 for raising certified seed for planting by other industrial hemp growers. In the long run, it is estimated that Kentucky farmers could earn roughly $120 per acre when growing industrial hemp for straw alone or straw and grain, and $340 an acre from growing certified hemp seed.

- Industrial hemp, when grown in rotation, may reduce weeds and raise yields for crops grown in following years. Several agronomic studies have found that industrial hemp was more effective than other crops at reducing selected weeds. One study found that industrial hemp raised yields by improving soil ventilation and water balance.

- The economic impact if Kentucky again becomes the main source for certified industrial hemp seed in the United States is estimated at 69 full-time equivalent jobs and $1,300,000 in worker earnings. The total economic impact in Kentucky, assuming one industrial hemp processing facility locating in Kentucky and selling certified seed to other growers, would be 303 full-time equivalent jobs and $6,700,000 in worker earnings. If two processing facilities were established in Kentucky, industrial hemp would have an economic impact of 537 full-time equivalent jobs and $12,100,000 in worker earnings. If one processing facility and one industrial hemp paper-pulp plant were established in Kentucky, industrial hemp would have an economic impact of 771 full-time equivalent jobs and $17,600,000 in worker earnings.

- These economic impact estimates reflect possible outcomes for Kentucky given a national industrial hemp industry that is focused in specialty niche activities that have been demonstrated to work in Europe. It is important to remember, however, that technologies are under development that may allow industrial hemp products to compete in bulk commodity markets. The economic impacts that would occur if these technologies were found to be commercially feasible would be substantially greater than those identified in this report.

Source: Thompson et al.

Executive Summary
Industrial Hemp as an Alternative Crop in North Dakota
July 1998

This preliminary study reports on current efforts to define existing world markets and possible United States markets for industrial hemp as well as resulting economic feasibility should production be legalized. A large percentage of the information available on industrial hemp is by non-agriculturists. This indicates a need for North Dakota to continue working with its agricultural counterparts to bring this potential alternative crop into the agricultural research domain.

- The industrial hemp world market consists of over 25,000 products in nine submarkets: agriculture, textiles, recycling, automotive, furniture, food/nutrition/beverages, paper, construction materials, and personal care. These products are made or manufactured from raw materials derived from the industrial hemp plant: fiber, hurds, and hemp seed/grain.

- World hemp fiber production has declined from over 400,000 tons in 1961 to 113,000 tons in 1996. India, China, Russia and Korea are the major low cost producers. This constitutes about 250,000 acres under production worldwide. Preliminary figures for 1997 indicate that this downward trend continues.

- A revitalization of industrial hemp may be occurring as indicated by projected increased demand (retail sales) from $75 million in 1997 to $250 million by 1999 worldwide (*Wall Street Journal*, April 24, 1998). Various reasons that would explain this phenomenon include technological advances in processing, an increase in pricing, or interpretation of existing information.

- The largest market opportunity for North Dakota identified in this report may be hemp seed oil. This opportunity was also identified by the University of Kentucky (July 1998).

- North Dakota may have a comparative advantage because a state of the art multi-oil processing facility already exists that is capable of processing hemp seed.

- Hemp hurds appear to be price competitive with wood chips, fine wheat straw, other types of animal bedding, and other high-end pet needs. Hurds may also be a complement or substitute material in strawboard production.

- Certified seed production is a market opportunity.

- Initially, hemp appears to be comparable to barley. However, a 1998 Kentucky study projects higher returns from $220.15 per acre for producing hemp seed for crushing to $605.91 for certified seed.

- Historically, imported jute and abaca were intense competitors with American industrial hemp.

- Law enforcement agencies have legitimate concerns about their ability to enforce laws regulating industrial hemp production. Advances in biotechnology such as terminator genes may create solutions.

- Recommendations. Since industrial hemp may have potential as an alternative rotation crop, it is recommended that the North Dakota Legislature consider action that would allow controlled experimental production and processing, then, necessary baseline production, processing, and marketing data could be collected and analyzed. For example, all new enterprises would require a critical threshold volume in order to succeed in terms of economic profit. What is the volume and the acreage required to produce it? At the same time the concerns and costs of law enforcement agencies could be addressed.

Source: Kraenzel et al.