



Missouri Industrial Hemp Production

*Producer's guide to regulation, agronomics,
economics and risks in producing industrial hemp
in Missouri*

Commissioned by the Missouri Hemp Producers Association with funding
from the Missouri Agricultural and Small Business Development Authority

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The following report was commissioned by the Missouri Industrial Hemp Steering Committee to prepare Missouri producers for the 2020 rollout of industrial hemp in the state. Funding was provided by Missouri Agricultural and Small Business Development Authority through its Missouri Value-Added Grant Program.

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Executive Summary

Following the Controlled Substances Act of 1970, all *Cannabis* (industrial hemp and marijuana) was illegal to produce. However, with the 2014 and 2018 federal farm bills and recent Missouri legislation (HB 2034 in 2018 and SB 133 in 2019), Missouri began allowing industrial hemp processing and is poised to allow commercial industrial hemp cultivation in the 2020 planting season. Growers will have to obtain a registration and/or permit from the Missouri Department of Agriculture (MDA) to grow industrial hemp. Producer applications will open in January 2020. Industrial hemp processors or higher education researchers do not need a permit or registration.

Consumers often confuse industrial hemp with marijuana. Both crops are produced from different varieties of *Cannabis sativa* L., an annual, herbaceous flowering plant. Crops of industrial hemp and marijuana plants look nearly identical in appearance. *Cannabis sativa* produces more than 100 phytochemical compounds called cannabinoids. Two key cannabinoids are tetrahydrocannabinol (THC) and cannabidiol (CBD). The legal difference between industrial hemp and marijuana is the level of THC in the plant.

THC is a psychoactive compound associated with marijuana. *Cannabis sativa* material with THC levels above 0.3 percent is legally considered marijuana in the U.S. and Canada. However, *Cannabis sativa* cultivated for marijuana production commonly has THC content ranging from 5 percent to 30 percent. Marijuana production remains federally illegal across all 50 states, though select states have enacted laws that decriminalize marijuana cultivation for medicinal or adult use.

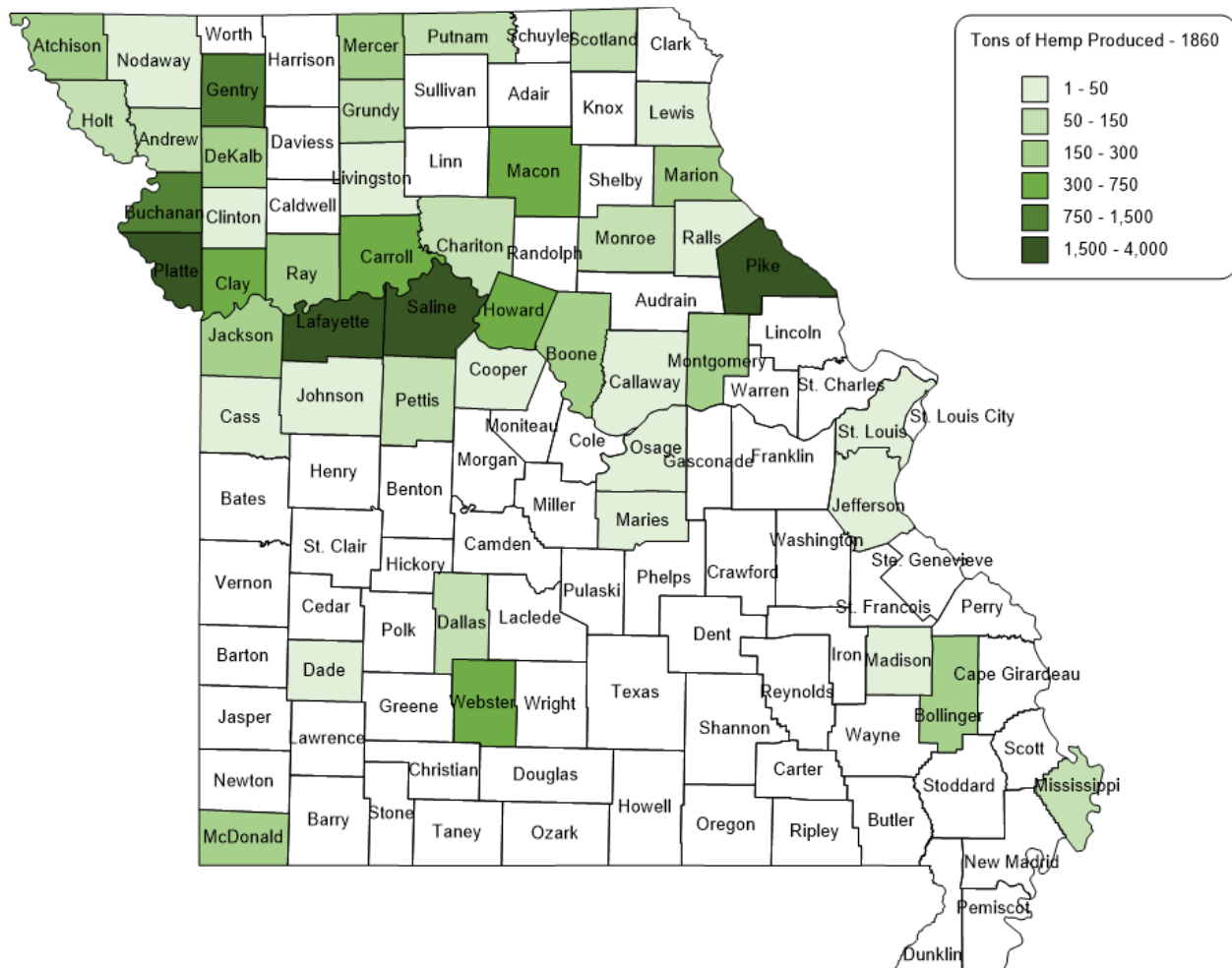
Cannabis sativa material with THC levels that don't exceed 0.3 percent is legally termed industrial hemp. Growers often cultivate industrial hemp for the crop's fiber, grain or cannabinoids such as CBD. Industrial hemp varieties are typically grown targeted to these end markets. Consumers purchase CBD for its therapeutic reasons such as treating chronic pain, anxiety and depression developed via evidence-based research. The concentration of CBD is typically higher in selected industrial hemp genetic varieties than in marijuana. An estimated 80 percent of the U.S. industrial hemp acreage in 2019 was intended for CBD production. The remaining acreage was planted for fiber or grain. Industrial hemp uses include grain for hempseed oil and food as well as fiber for textile, industrial and construction applications.

The following sections of this report detail many key considerations for industrial hemp growers in Missouri. Understanding the regulatory climate, agronomic needs, economics and risk profile involved in producing industrial hemp is important to help growers make well-informed decisions as they seek this opportunity.

1. Missouri Hemp History

The first reports of hemp being grown in Missouri as a crop date back to 1835 (USDA, 1914). Peak production in Missouri occurred from the mid- to late-19th century. During this period, Missouri ranked second in the U.S. in hemp production after Kentucky. Missouri hemp production peaked just before the Civil War. In 1860, Missouri production totaled 19,267 tons, which was 26 percent of the total U.S. crop (Secretary of the Interior, 1864). Exhibit 1.1 shows the distribution of hemp production in Missouri by county in 1860. The top five counties for hemp production were Saline (3,920 tons), Lafayette (3,558 tons), Platte (1,793 tons), Pike (1,758 tons) and Buchanan (1,479 tons). Missouri hemp production decreased over time due to increased profitability of other crops, challenges with transporting hemp to Eastern markets and unsatisfactory methods in cleaning fiber on hand brakes (USDA, 1914). Missouri's hemp production slipped to nearly zero by 1900. Missouri's reemergence as a hemp-producing state will require hemp derived products to capture market share from existing competing food and fiber industries.

Exhibit 1.1 – Missouri Hemp Production by County, 1860

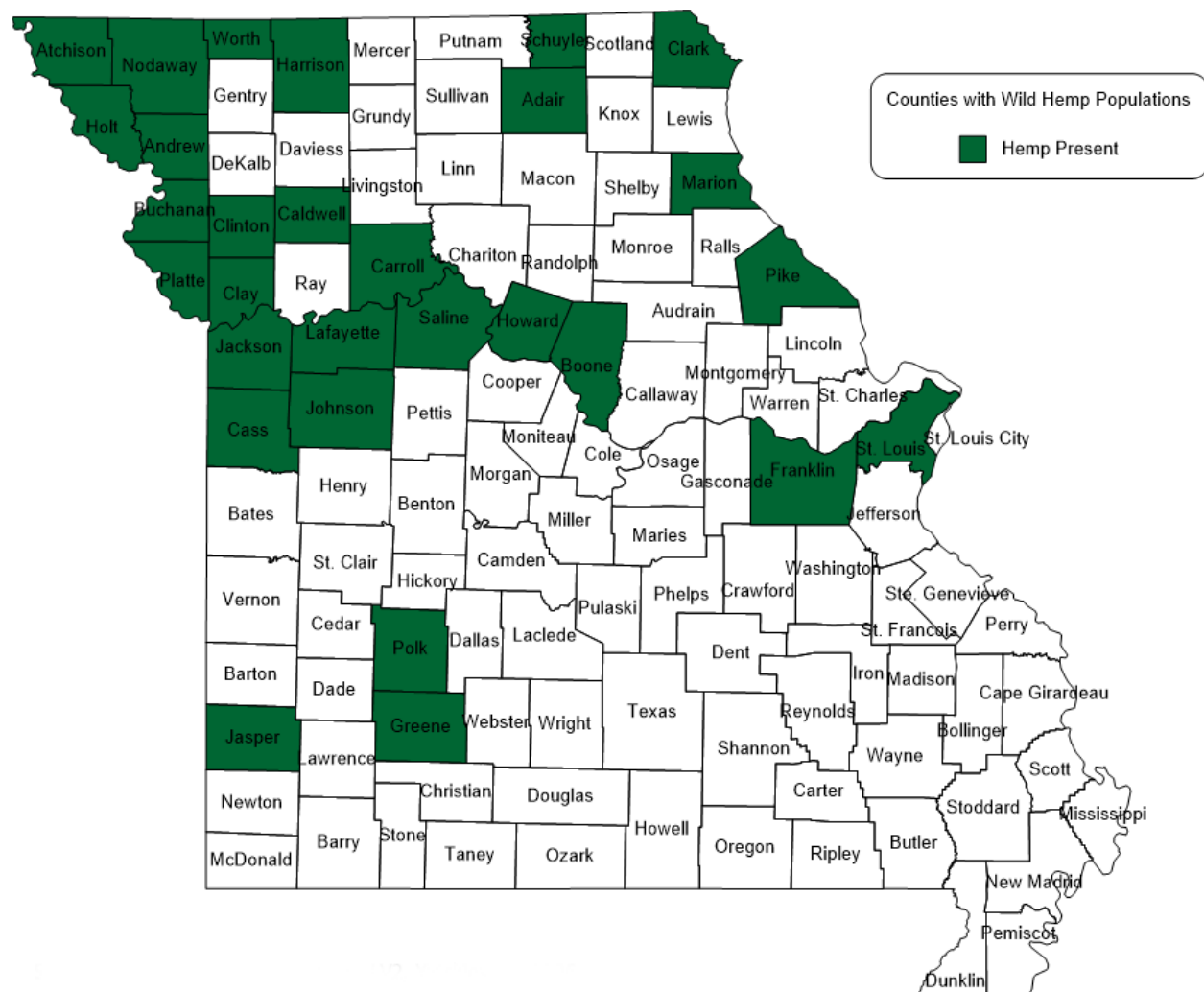


Source: Secretary of the Interior (1864)

Today, some areas in Missouri still have a wild hemp population. See Exhibit 1.2. Steyermark's Flora of Missouri, last updated in 2006, has continued to find wild hemp plants in certain counties. It is known to grow in rich, fertile ground of river floodplains and bottoms near streams, but it also grows in open and waste ground. Many counties that recorded hemp production in the 1800s are the same ones where wild hemp persists today.

These wild hemp plants, popularly known as “ditch weed,” may have positive and negative roles to play in Missouri's industrial hemp industry. With more than 150 years of acclimation to Missouri's climate and soils, they may find use as breeding material for future crossbreeding efforts by geneticists. Conversely, pollen drift from ditch weed could reduce cannabinoid levels in nearby CBD plantings.

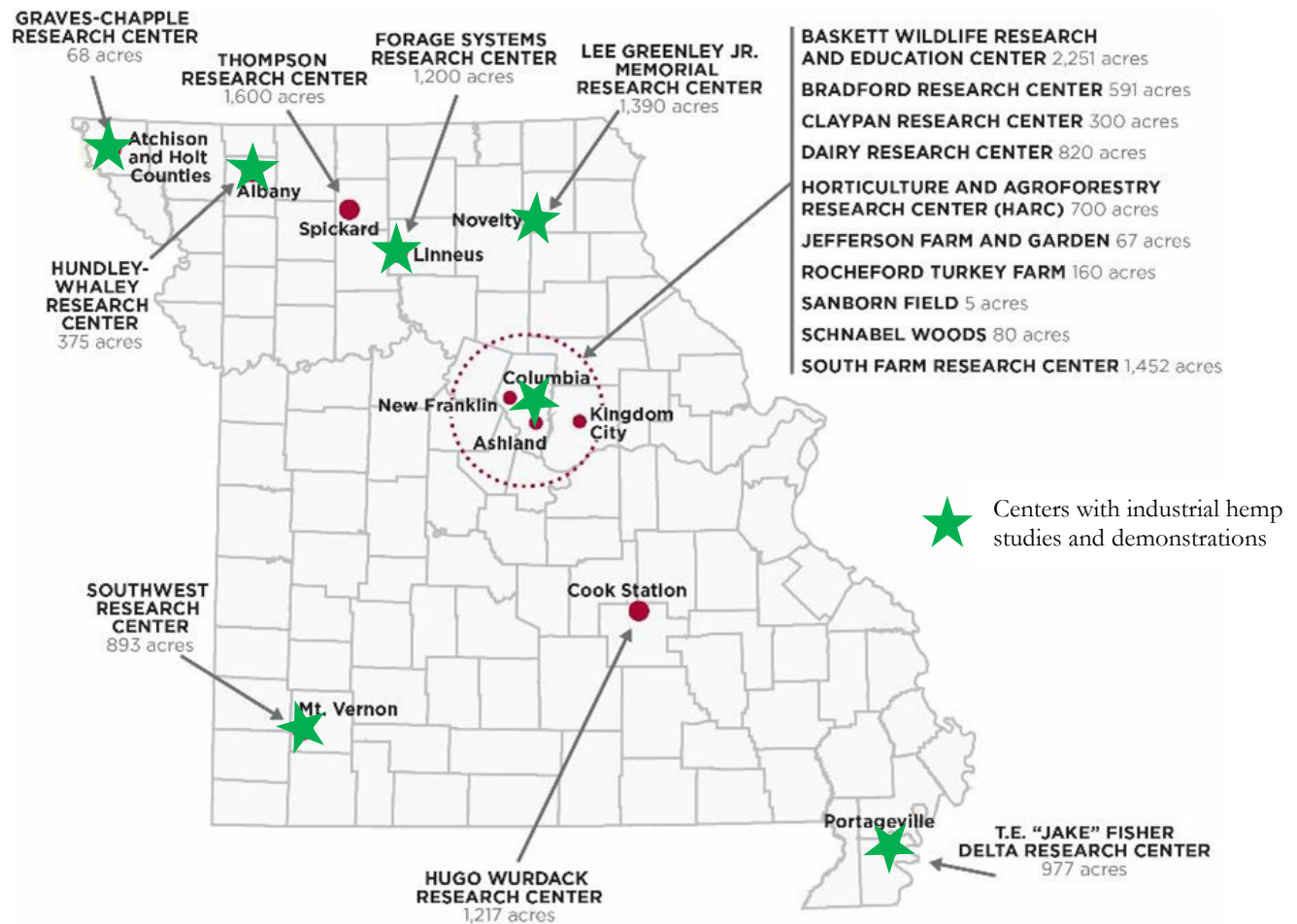
Exhibit 1.2 – Missouri Counties with Wild Hemp Populations



Source: Yatskievych (2006)

After the Missouri governor signed Senate Bill 133 into law on June 24, 2019, it immediately allowed institutions of higher education to engage in industrial hemp research and study industrial hemp growth, cultivation or marketing without a permit. Several institutions, such as the University of the Missouri, Lincoln University, and St. Louis University began to develop research projects after this date. The University of Missouri developed industrial hemp for fiber studies and demonstrations at seven agricultural experiment stations in 2019. See Exhibit 1.3 for each location.

Exhibit 1.3 – Locations of University of Missouri Industrial Hemp Studies and Demonstrations, 2019



Source: University of Missouri

Four industrial hemp varieties (CFX-2, Grandi, Katani and CRS-1) were planted at various locations. Seed was secured and donated by Tiger Fiber Hemp Company from St. Louis, Missouri. Two locations evaluated row spacing (7.5 inch and 30 inch). Observations were taken on insects and diseases. Soil conditions varied amongst research centers from moist to dry. Planting dates varied from late June to early July by location. Please note that these planting dates are much later than recommended for industrial hemp fiber production, but the university decided to push forward to gain some information and observations for informing Missouri producers.

Exhibit 1.4 showcases some industrial hemp for fiber pictures taken of the Greenley Research Center demonstrations in 2019. At this research center, the soil was rototilled and followed by a cultipacker. Seed was drilled at 7.5-inch and 30-inch rows. The planting date was June 28, 2019. The planting population was 40 pounds per acre. Fertilizer was applied in March (8-40-100) and was followed by a July 11, 2019 application (80-0-0). Irrigation was performed on July 12, 2019.

Exhibit 1.4 –University of Missouri Greenley Research Center Observations, 2019



Greenley Research Center – 10 days after Planting



Greenley Research Center – August 22, 2019

General observations from the 2019 University of Missouri demonstrations and studies include:

- Herbicide carryover can be an issue in fields
- No-till in late June/early July did not work very well
- Need for good seed to soil contact
- High soil temperatures can be an issue
- Narrow rows more productive, at least when planted late
- Weed pressure was significant at certain locations

2. Industrial Hemp Legislation and Regulation

2.1 Missouri Industrial Hemp Regulatory Program

The Missouri Department of Agriculture (MDA) is developing regulations and procedures for implementing industrial hemp production in Missouri. MDA published proposed rules (2 CSR 70-17) on Oct. 9, 2019. The agency collected comments on the proposed rules from Nov. 1 to Dec. 1, 2019. These proposed rules will be revised based on public comment and federal hemp regulatory guidance. MDA filed emergency rules on Dec. 17, 2019. More information about the Missouri rules and Missouri's Industrial Hemp Program can be found at agriculture.mo.gov/plants/industrial-hemp.

MDA Hemp Program Contact Information

Program Administrator: Alan Freeman
Program Coordinator: Erin Casey-Campbell
Phone: (573) 522-0351
Fax: (573) 751-0005
Email: hempprogram@mda.mo.gov

Permits

Under Missouri statute and MDA emergency rules, two Missouri industrial hemp cultivation registrations or permits are available. The specific permit or registration needed depends on the activity.

- An **agricultural hemp propagule and seed permit** is needed to sell, distribute or offer for sale industrial hemp transplants, cuttings, clones and viable seed.
- A **producer registration** is needed to grow viable (capable of growing or living) industrial hemp.

Industrial hemp processors or institutions of higher education do not need a permit or registration. Processing industrial hemp became legal in August 2019 when SB133 became law. The proposed and emergency rules include no limit on acreage or number of registrations. Separate registrations or permits are needed for noncontiguous land where industrial hemp will be produced, sold, distributed or offered for sale. Registrations or permits are good for a three-year period and will cost \$750 annually. Producer registration applicants and key participants must also pass a criminal background check that is paid by the applicant (\$41.75) through the Missouri State Highway Patrol automated system and is good for a three-year period.

Applications for permits or registrations will require the following information:

- Complete legal name, address and contact information for the applicant
- Applicant's state of residence or domicile
- Type of business entity
- Legal description, address, GPS coordinates and detailed map of industrial hemp operation
- Non-refundable application fee (\$750 annually for permit or registration)

Inspection, Testing and Sampling

All registered producers or permit holders are subject to inspection, investigation and sampling at any time. Raising hemp is legal only if a producer adheres to Missouri law and the representative sample of a crop tests at or below the acceptable industrial hemp THC level, using the post-decarboxylation delta-9-tetrahydrocannabinol (THC) as the reference standard. Under the emergency regulations, a certified industrial hemp sampler must collect samples to determine compliance with applicable law and regulations. Samples are to be collected in accordance with the MDA sampling protocol. Samples are to be obtained within 15 days prior to harvest. A testing laboratory that is registered with the Drug Enforcement Agency (DEA) or accredited with ISO 17025 standards must test samples for THC content, and the producer takes responsibility for paying testing fees. At the producer request, the certified sampler will provide a duplicate sample in the event the sample sent to the laboratory is not able to be tested. Each lot (contiguous area of the same variety) must be sampled. Certificates of analysis for all samples tested to determine regulatory compliance must be submitted to MDA.

The industrial hemp THC level is calculated using the laboratory's application of the measurement of uncertainty to the reported delta-9 THC content concentration level on a dry weight basis. If this concentration level produces a distribution range that includes three-tenths of one percent (0.3%) or less, it is acceptable. For any certificate of analysis that does not include a measurement of uncertainty, the measurement of uncertainty is deemed zero percent (0.0%). If the first test from a testing laboratory includes or is below 0.3 percent based on the measurement of uncertainty, then industrial hemp from the tested lot becomes a publicly marketable product and can be sold or further processed. If the first test measures above the acceptable THC level, the producer may request a retest by notifying the laboratory and MDA in writing. If the test exceeds the acceptable THC level, then the industrial hemp lot is considered out of compliance.

Producers must destroy lots testing out of compliance and follow the MDA's destruction protocol. Costs for destroying the crop and receiving a destruction certification are the producer's responsibility. Destruction will be verified by the Missouri State Highway Patrol or local law enforcement. No compensation is provided for the destroyed hemp crop.

Storage and Transportation

Harvested industrial hemp must not be commingled until a certificate of analysis shows the lot tests within the acceptable THC level using a post-decarboxylation method of testing. After a producer acquires the satisfactory certificate of analysis, the industrial hemp product is publicly marketable.

Transporting viable (capable of living or growing) industrial hemp in Missouri requires documentation for registered producers or permit holders. Documentation includes a copy of the producer registration; agricultural hemp propagule and seed permit; certificate of analysis for the lot(s) in transport; or bill of lading or chain of custody form if applicable. Third-party commercial transport of viable industrial hemp is exempt from permitting or registration requirements, but all viable industrial hemp being transported in Missouri must have accompanying documentation as listed above. Interstate transportation is not regulated by MDA.

Recordkeeping

An industrial hemp monitoring system must be established and kept for all registered producers and permit holders. Registered producers must maintain planting reports, sample analysis reports, destruction reports and harvest reports. Permit holders must maintain distribution/sales reports and destruction reports. Certificate of analysis copies must be provided by permit holders for each industrial hemp variety distributed or sold. This information should be made available for inspection and auditing during business hours or be furnished to the Missouri Department of Agriculture within ten business days of the request. All records, reports, data and certificate of analysis must be kept for 3 years from the date of the activity.

Hemp Seed Requirements

Permit holders have certain requirements if they are selling hemp seeds or propagules. Seed must be labeled with noxious weed seed content, seller contact information and purity percentages of pure seed, inert matter, other crop and weeds seed and treatment of seed (See Exhibit 2.1.1 for more information). Seed held for sale for other purposes (feeding or processing) must be marked on a label as such and is not subject to the other hemp seed labeling requirements.

Exhibit 2.1.1 – Missouri Agricultural Hemp Seed Labeling Requirements

Kind or Kind and Variety of Seed		
Pure seed (percent)	Germination (percent)	Net weight
Inert matter (percent)	Hard seed (percent)	Lot #
Other crop (percent)	Total germination and hard seed (percent)	Origin
Weed seed (percent)		Month/year of germination test
Noxious weed seeds per pound or per one hundred (100) grams		
The name and address of person or company held responsible for seed labeling should follow other information or should be printed on opposite side of label		

Source: 2 CSR 70-17.130

2.2 Missouri Law on Industrial Hemp

Missouri began its industrial hemp legislation when lawmakers passed House Bill 2238 in 2014. This legislation created a legal right for Missouri residents to obtain a neurologist-prescribed registration card for “hemp extracts” to treat intractable epilepsy. The state law defined a “hemp extract” as cannabis plant or material that contains at least 5 percent cannabidiol (CBD) and no more than 0.3 percent THC. The registration card program is administered by the Missouri Department of Health and Senior Services.

The law also authorized MDA to issue up to two cultivation and production facility licenses to non-profit entities to serve these patients. Current licensees in Missouri for growing hemp extract are as follows:

- Beleaf Company, based in Earth City, Missouri (beleafco.com/)
- Noah’s Arc Foundation, based in Chesterfield, Missouri (nafmo.com/)

Since the inception of this hemp extract program in 2014, 432 registration cards have been issued to Missouri residents (Missouri Department of Health and Senior Services, 2019). Per the 2018 calendar year, 148 registration cards were issued. Of those, 120 cards were issued to minor (below the age of 18) patients and adult patients held 28 cards. A total of 26 neurologists were recorded to be providing certification for registered patients.

In 2018, Missouri approved another hemp bill (House Bill 2034) to form a pilot program for industrial hemp and establish requirements for those applying to receive a permit or license to grow, harvest and cultivate the crop. This legislation exempted industrial hemp (defined as *Cannabis sativa* L. containing no more than 0.3 percent THC) from the definition of marijuana and list of controlled substances. MDA was tasked with program administration.

Before 2018, industrial hemp pilot program legislation could be implemented in Missouri, revisions to the previous year’s law were passed and approved by the governor after the 2019 legislative session. Senate Bill 133 made significant changes to Missouri’s industrial hemp law and included an emergency clause that made parts of the law effective on the signing date (June 24, 2019). The remainder took effect on Aug. 28, 2019.

Based on the 2018 and 2019 legislative sessions, below is a summary of industrial hemp legislation addressed in Missouri statutes (RSMo Sections 195.740 to 195.773).

- Any producer or seed supplier of industrial hemp must obtain a registration or permit from MDA.
 - An application for an industrial hemp registration or permit shall require the following:
 - Name and address of applicant and operation
 - Global positioning system (GPS) coordinates or legal description of property to be used for industrial hemp operation
 - Application fee
 - Other information deemed necessary by the department

- Applicants are subject to state and federal background checks. No registrations will be issued to a person guilty of a felony offense related to a controlled substance within the past 10 years.
- Permits and registrations are valid for a three-year term and renewable if the holder is in good standing.
- Every producer or permit holder shall keep records and be subject to inspections as required by MDA.
- If a crop averages a THC concentration that exceeds 0.3 percent or the maximum concentration allowed under federal law, then the department may retest the crop. If the second test exceeds this threshold, then the department may order a producer to destroy the crop.
- Each parcel of ground or indoor cultivation facility shall require a separate registration unless contiguous and owned by the same person.
- MDA will report coordinates to the Missouri State Highway Patrol and local law enforcement agencies to certify destruction of illegal industrial hemp.
- Institutions of higher education may engage in industrial hemp research and study industrial hemp growth, cultivation or marketing without a Producer Registration.
- The state may establish the “Industrial Hemp Fund” for MDA to collect funding and administer the program.
- Unless required by federal law, MDA shall not regulate the sale or transfer of nonviable hemp including, but not limited to, stripped stalks, fiber, dried roots, nonviable leaf material, nonviable floral material, nonviable seeds, seed oils, floral and plant extracts, unadulterated forage and other marketable agricultural hemp products within and outside the state.
- Fines will be assessed for violations of this law.

2.3 U.S. Federal Law on Industrial Hemp

Hemp has had a long and complicated history of legislation and actions that have challenged its U.S. production. However, the 2014 farm bill authorized certain state departments of agriculture and higher education institutions to grow industrial hemp under state-authorized pilot programs (Johnson, 2018). The farm bill also defined industrial hemp as “plant *Cannabis sativa* L. and any part or derivative of such plant, including seeds of such plant, whether growing or not, that is used exclusively for industrial purposes (fiber and seed) with a THC concentration of not more than 0.3 percent on a dry weight basis.” Many U.S. states embraced this pilot program opportunity and implemented state-level programs to grow and process industrial hemp. Although this legislation allowed hemp production, some issues still existed (Johnson, 2018). It did not remove industrial hemp from the controlled substances list. Interstate commerce was not allowed, so plants or seeds could not be transported across state lines. Import of viable hemp seed would require U.S. Drug Enforcement Administration registration and oversight.

The Agriculture Improvement Act of 2018 (farm bill) addressed the industrial hemp policy and opened the flood-gates for U.S. hemp production. The legislation removed industrial hemp from the schedule I controlled substances list and delegated authority to states to administer license programs for producing and marketing industrial hemp. The U.S. Department of Agriculture would provide federal oversight and approval for state-administered hemp programs. Existing pilot programs would be maintained for another year. The legislation also allows transfer of hemp and hemp-derived products across state lines. It also enabled hemp farmers to obtain federal crop insurance.

Several other agencies play a role in industrial hemp regulation. To protect public health, the U.S. Food and Drug Administration (FDA) regulates products used as drugs, foods and dietary supplements from cannabis. Its authority originates from the Food, Drug and Cosmetic Act. If a product is marketed with a therapeutic benefit or for disease treatment, it is considered a drug by FDA. All drugs must be approved by FDA for their intended use prior to entering interstate commerce. Epidiolex, a prescription drug product that contains cannabis-derived CBD for treating epilepsy, received FDA approval in 2018. No other CBD drug products have been approved by FDA to date. It is currently illegal by federal law to market CBD in interstate commerce by adding it to a food (including animal food or feed) or labeling it as a dietary supplement. During November 2019, the FDA announced that it lacked the scientific evidence to know whether CBD is safe, and it emphasized its view that CBD is not a generally recognized as safe ingredient in food meant for humans or animals (Food and Drug Administration, 2019).

FDA has reviewed generally recognized as safe (GRAS) notices for hemp seed-derived ingredients (hulled hemp seed, hemp seed protein and hemp seed oil) and had no questions regarding the safety of ingredients given the products’ specifications and use. As a result, they can be legally marketed in human foods as they contain only trace amounts of THC and CBD.

The Environmental Protection Agency (EPA) plays a role in the industrial hemp industry in pesticide approval. EPA authority oversees herbicides, insecticides and fungicides. Any off-label use of pesticides is illegal. Currently, a limited number of EPA-registered pesticides are available for use in industrial hemp. EPA received 10 product applications in fall 2019 to expand usage into industrial hemp production and approved them in December 2019 (EPA, 2019).

Exhibit 2.3.1 – Key Federal Agencies and Their Roles in the U.S. Industrial Hemp Industry

United States Department of Agriculture (USDA)	Food and Drug Administration (FDA)	Environmental Protection Agency (EPA)
<ul style="list-style-type: none">• Provide regulation, funding, and insurance for industrial hemp production• Provide review and approval of state industrial hemp programs	<ul style="list-style-type: none">• Regulate hemp and hemp-derived products in drug, food and dietary supplements• Oversight includes food for human and animals	<ul style="list-style-type: none">• Provides regulation of pesticides used in industrial hemp• Pesticide products must be approved and registered for industrial hemp use by EPA

3. Agronomic Considerations for Industrial Hemp

Agronomic assumptions in this section are estimates based on research from other states, such as Kentucky, who have been growing the crop in recent years. As the industrial hemp industry evolves in Missouri and other states, better agronomic recommendations will be researched and extended to farmers.

Industrial hemp is a summer annual. Industrial hemp reproduction (flowering) is triggered by the photoperiod. In general, industrial hemp is considered a short-day plant with its reproductive stage beginning a few weeks after the summer solstice (June 21). Industrial hemp varieties are predominantly dioecious (separate male and female plants); however, there are also some imperfect monoecious plants (separate male and female flowers on the same plant). Male plants typically flower and senesce earlier than female plants.

Industrial hemp production falls into three agronomic uses: fiber; grain; and cannabinoid extraction (primarily CBD). Some production work in dual-purpose grain and fiber systems is also being evaluated by universities. There is additional interest in metabolomics research involving cannabinoids from industrial hemp genetic varieties at the University of Missouri.

3.1 Industrial Hemp for Fiber Agronomy

Site Selection

Industrial hemp is an agronomic crop that responds to productive, well-drained soils with a soil pH range of 6.0 to 6.5. For successful fiber production, avoid poorly drained fields and compacted soils, identify fields that have a low weed seed bank and start weed-free prior to planting.

Variety Selection

The key components to identify when selecting a variety are percent germination, seed number per pound and suitability for fiber production in your geographic region. Developing a close working relationship with a fiber seed supplier that can help producers identify these components will be critical for success. Germination variability has ranged from 60 percent to 96 percent in some preliminary work in Kentucky; therefore, germination testing is recommended.



Exhibit 3.1.1 - Industrial Hemp for Fiber

Fiber varieties, in general, are plants that produce best under narrow row spacing. Universities that have studied varieties, such as the University of Kentucky, have listings on their respective websites. State departments of agriculture may also maintain lists of varieties available.

Soil Nutrients

There are limited U.S. research-based guidelines about soil nutrient needs in industrial hemp for fiber production. Like other agronomic crops, fertility rate for industrial hemp will depend on crop use, soil texture, available soil nutrients and organic matter levels. Nitrogen rates range from 50 pounds to 150 pounds of actual nitrogen (N) per acre. Preliminary university research gathered from meetings indicates applications of 50 pounds to 100 pounds of actual nitrogen (N) per acre increased fiber dry matter yield in general compared with an untreated application, while varieties evaluated did not have an increased response to additional nitrogen. Preliminary work also indicated that splitting nitrogen applications (pre-planting followed by early post-planting) did not improve yield compared with pre-planting only on the soil types evaluated. Phosphate (P_2O_5) and potassium (K_2O) recommendations will depend on available phosphorus and available potassium in the soil. Sulfur may be required as well. A soil test will help to identify nutrient needs, soil structure and suitability for industrial hemp production. Soil testing six months prior to planting is recommended.

Soil Fertility

- Apply 50 to 100 pounds of actual nitrogen (N) per acre
- Phosphate (P_2O_5) and potassium (K_2O) needs depend on available phosphorus and potassium in soil

Planting

Industrial hemp has a wide geographic range of production across numerous latitudes and dramatically different climates, which demonstrates different genotypes are adapted to different day lengths. This wide adaptation across latitudes can influence emergence, growth and development depending on origin of seed. Industrial hemp has a wide planting window;

however, identifying the ideal timeframe to maximize production is being investigated. In general, the current timeframe is May to June for fiber. Early planting of fiber varieties would potentially maximize vegetative growth prior to flowering and, therefore, potentially improve fiber yield. However, planting too early could delay or stagger germination, which could increase susceptibility to seedling blight and/or early weed competition.

Planting

- *Planting time:* May to June
- *Seeding rate:* 40 pounds to 60 pounds per acre
- *Seeding depth:* 0.25 inches to 0.75 inches

Hemp germination research at Virginia Tech evaluated seven cultivars originating from Canada, northern Europe and southern Europe. The data suggested an interaction between origin of seed and soil temperature. Germination percentages of 80 percent or greater ranged between 55 degrees Fahrenheit (F) and 80 degrees F with optimal soil temperatures for northern latitude cultivars between 60 degrees F and 68 degrees F and up to 77 degrees F for southern cultivars.

Plants grown for fiber should be drilled into a firm seedbed with good soil-to-seed contact. Production has been on tilled soils. Preliminary work from the University of Kentucky indicated that broadcast seeding proved to be inconsistent. No-till planting has not been thoroughly investigated.

Current seeding rate recommendations are presented in pounds per acre. It is critical that the seeding rate be adjusted for percent germination of seed. Due to variability among varieties, universities are looking at identifying some standard seeding rates based on seed number per acre. In general, a seeding rate between 40 pounds and 60 pounds per acre is recommended. Ideally, proper fiber seeding rate and date will produce tall plants with an approximate average stalk base diameter of less than 0.5 inches. With industrial fiber hemp being handled with hay equipment, the pencil sized stalks are most desirable.

Preliminary research indicates that a May planting date with approximately 500,000 plants per acre can maximize production. A seeding depth of 0.25 inches to 0.75 inches with a target of 0.5 inches is recommended. In general, industrial hemp planted by seed is susceptible to soil crusting as well as other stand loss issues associated with wet conditions or poorly drained soils.

Pest Management

In general, industrial hemp is susceptible to diseases, insects will feed on plants, and weeds compete for nutrients and light. Industrial hemp for fiber producers should follow an integrated pest management (IPM) plan. IPM practices include scouting crops; identifying pests; and developing an action plan that would include cultural, mechanical and, if warranted and/or available, chemical control practices.

Pest Management

- Develop an integrated pest management plan for your industrial hemp crop
- Monitor weed pressure; management in first 30 days after emergence is critical
- Recognize any off-label use of pesticides is illegal
- Contact Missouri Department of Agriculture to ask questions about pesticide use and legality

The two challenges for industrial hemp production are lack of research data on the actual influence that pests (weeds, insects, plant pathogens) have on yield under the three basic crop uses and the lack of registered pesticide products traditionally used to manage pests in other crops, if warranted. Producers must remember that any off-label use of pesticides is illegal. Currently, there are a limited number of labeled pesticides available for hemp in the U.S. Prior to use of any biological, synthetic and/or organic crop protectants, refer to EPA's pesticide registration list for hemp, contact MDA for any questions on pesticides that may or may not be registered in the state and always read and follow label directions.

Like in other summer crops, reducing weed competition during the first 30 days after emergence are critical. Identifying fields with a low weed seed bank and knowing the herbicides used with its plant-back restrictions are important. Cultural and mechanical weed management practices are standard in industrial hemp production systems. Cultural practices include uniform stands and narrow row spacing that establish an early crop height differential to promote inter-row and intra-row shading. Mechanical weed management includes machine and/or hand cultivation.

Insect pest research is currently being conducted by universities to identify if defoliation actually reduces yield or if any insects cause adverse effects on production. Two common insect pests identified on industrial hemp are corn earworm (*Helicoverpa zea*) and Japanese beetle (*Popillia japonica*).

Industrial hemp is a host for a number of common disease-causing pathogens that are present in other row crops including numerous *Fusarium* species and the root knot nematode (*Meloidogyne* spp.). Research is being conducted to better understand how disease pathogens affect industrial hemp production.

Irrigation and Water

Industrial hemp production occurs in various climates: the moderate northwest coast climate of Washington and Oregon; the arid cool climate of Colorado; and the humid warm climate, with potentially hot dry conditions, of the mid-South. That variability indicates hemp's ability to cope with different moisture environments. The productivity of industrial hemp is susceptible to more problems in wet conditions and poor soil drainage. However, the level of industrial hemp stress from lack of moisture during hot, dry conditions is not fully understood. Hemp water needs are thought to be similar to those of soybeans and corn — approximately 25 inches to 30 inches. However, no established Missouri water use and transpiration research data are available to determine how many total inches of rainfall industrial hemp plants require at various growth stages and under variable rainfall patterns. This type of research would help develop an irrigation-scheduling program based on critical growth stages.

The amount of irrigation water needed also depends on the variety and planting density. The soil types and its ability to hold moisture content also affect the amount and frequency of irrigation. Since industrial hemp thrives in well-drained soils, it is important to irrigate at the right time and to not over-irrigate. The two irrigation practices that have been used are overhead pivot/traveling gun irrigation or plastic drip tape laid in row. No furrow irrigation is being used or has been investigated for potential use.

Harvest

Fiber industrial hemp can be harvested with traditional hay harvesting equipment. Harvesting fiber is achieved by cutting when approximately 20 percent of the male plants are flowering and prior to seed set. Leave 4 inches to 6 inches of stubble to reduce ash content. Hemp grown for fiber has two basic components: the outer vascular cambium called “bast” fiber layer, which represents of 20 to 30 percent of the stalk, and the inner core called “hurd,” which is the majority of the stalk.

Production

- Fiber industrial hemp must rett in field for several weeks before baling
- *Moisture:* Bale below 15 percent
- *Estimated yield:* 4 tons to 8 tons per acre (50 percent less for dual-purpose crops)

For fiber processing, hemp must go through a controlled rotting process called retting. Retting is driven by microbial degradation, and it generally requires plants to lay in the field two weeks to five weeks prior to baling. Begin baling using traditional baling equipment when plants have dried down below 15 percent moisture. Monitor all moving parts, such as power take off (PTO), for excessive fiber wrapping. Yield for fiber has ranged from 4 tons to 8 tons per acre in Kentucky when grown for fiber alone. Dual-purpose yield potential is approximately 50 percent less (2 tons to 4 tons).

3.2 Industrial Hemp for Grain Agronomy

Site Selection

Industrial hemp is an agronomic crop that responds to productive, well-drained soils with a soil pH range of 6.0 to 6.5. Avoiding poorly drained fields and compacted soils, identifying fields that have a low weed seed bank, and starting weed-free prior to planting are critical for successful grain production.

Variety Selection

The key components to identify when selecting a variety is percent germination, seed number per pound and suitability for grain production in your geographic region. Maintaining a close working relationship with a grain seed supplier that can help with identifying these components will be critical for success. Germination testing is recommended.

Varieties, in general, are grown for producing feminized seed that is used by the CBD industry or raising grain for processing. Feminized seeds are seeds that have been modified to produce almost 100 percent female plants. University information on varieties specific for seed and grain production is limited in most cases to dual-purpose trials.



Exhibit 3.2.1- Industrial Hemp Grain in Comparison with a Nickel and Soybeans

Soil Nutrients

Limited research-based fertility guidelines exist for industrial hemp grain production in the U.S. Like for other agronomic crops, the rate depends on crop use, soil texture, available soil nutrients and organic matter levels.

Nitrogen rates range from 50 pounds to 150 pounds of actual nitrogen (N) per acre.

Approximately 100 pounds of N for dual-

purpose production and approximately 125 pounds to 150 pounds of N for grain only. Phosphate (P_2O_5) and potassium (K_2O) recommendations, like in other agronomic crops, will depend on available phosphorus and available potassium in the soil. Sulfur may be required as well. A soil test will help to identify nutrient needs, soil structure and suitability for industrial hemp production. Soil testing six months prior to planting is recommended.

Soil Fertility

- 50 pounds to 150 pounds of actual nitrogen (N) per acre
- Phosphate (P_2O_5) and potassium (K_2O) needs depend on available phosphorus and potassium in soil

Planting

Industrial hemp has a wide geographic range of production across numerous latitudes and dramatically different climates, which demonstrates different genotypes are adapted to different day lengths. This wide adaptation across latitudes can influence emergence, growth and development depending on the seed's origin. Industrial hemp for grain or seed has a wide planting window; however, identifying the ideal timeframe to maximize production is being investigated. In general, the current timeframe is June for seed and grain production. Hemp for seed and grain production appears to have had the least amount of preliminary research. However, the general planting timeframe is based on the photoperiodism of hemp to potentially reduce plant height for ease of harvest with conventional grain harvesting equipment (i.e., combine). As with fiber hemp, target soil temperature for grain and seed hemp ranges from 55 degrees F to 80 degrees F with optimal soil temperatures for northern-latitude cultivars between 60 degrees F and 68 degrees F and up to 77 degrees F for southern cultivars, according to research from Virginia Tech.

Planting

- *Planting time:* June
- *Seeding rate:* 20 pounds to 30 pounds per acre
- *Seeding depth:* 0.25 inches to 0.75 inches

Plants grown for seed or grain should be planted into a firm seedbed in either 7.5- or 15-inch rows to help ensure good soil-to-seed contact and early shading to reduce weed competition. Planting with a 15-inch row spacing, in combination with later planting dates, may promote shorter plants with more branching for seed head production. Like fiber hemp, seed and grain production are generally grown on tilled soils. No-till planting has not been thoroughly investigated.

Current seeding rate recommendations are presented in pounds per acre. In addition, this rate should be adjusted for percent germination. Due to variability among varieties, universities are looking to identify some standard seeding rates based on seed number per acre. In general, a seeding rate between 20 pounds and 30 pounds (half of a fiber hemp rate) per acre is recommended. Ideally, proper seed and grain seeding rate, planting date and row spacing will produce shorter branched plants. A seeding depth of 0.25 inches to 0.75 inches with a target of 0.5 inches is recommended. In general, industrial hemp planted by seed is susceptible to soil crusting as well as other stand loss issues associated with wet and/or poorly drained soils.

Pest Management

In general, industrial hemp for grain or seed production is susceptible to diseases, insects will feed on plants and weeds compete for nutrients and light. Industrial hemp producers, as with producers who grow other agronomic crops, should follow an integrated pest management (IPM) plan. IPM practices include scouting crops; identifying pests; and developing an action plan that would include cultural, mechanical and, if warranted and/or available, chemical control practices. The two challenges for industrial hemp production are

Pest Management

- Develop an integrated pest management plan for your industrial hemp crop
- Monitor weed pressure; management in first 30 days after emergence is critical
- Recognize any off-label use of pesticides is illegal
- Contact Missouri Department of Agriculture to ask any questions about pesticide use and legality

lack of research data on the actual influence that pests (weeds, insects, plant pathogens) have on yield under the three basic crop uses and the lack of registered pesticide products traditionally used to manage pests in other crops, if warranted. Producers must remember that any off-label use of pesticides is illegal. Currently, there are a limited number of labeled pesticides available for hemp in the U.S. Prior to use of any biological, synthetic and/or organic crop protectants, refer to EPA's pesticide registration list for hemp, contact MDA for any questions on pesticides that may or may not be registered in the state and always read and follow label directions.

Like in other summer crops, reducing weed competition during the first 30 days after emergence is critical. Also, identify fields with a low weed seed bank and know previous crop herbicides used with plant-back restrictions. Cultural and mechanical weed management practices are standard in industrial hemp production systems. Cultural practices include uniform stands and narrow row spacing that establish an early crop height differential to promote inter-row and intra-row shading. Mechanical weed management includes machine and/or hand cultivation. Current insect research is looking into yield effects on floral (CBD) and fiber production. Two common insect pests identified on industrial hemp are corn earworm (*Helicoverpa zea*) and Japanese beetle (*Popillia japonica*).

Industrial hemp is a host for a number of common disease-causing pathogens that are present in other row crops including numerous *Fusarium* species and the root knot nematode (*Meloidogyne* spp.). Research is being conducted to better understand how disease pathogens affect industrial hemp production. Researchers have also observed birds feeding on hemp grain.

Irrigation and Water

Industrial hemp production occurs in various climates: the moderate northwest coast climate of Washington and Oregon; the arid cool climate of Colorado; and the humid warm climate, with potentially hot dry conditions, of the mid-South. That variability indicates hemp's ability to cope with different moisture environments. The productivity of industrial hemp is susceptible to more problems in wet conditions and poor soil drainage. However, the level of industrial hemp stress from lack of moisture during hot, dry conditions is not fully understood. Hemp water needs are thought to be similar to those of soybeans and corn — approximately 25 inches to 30 inches. However, no established Missouri water use and transpiration research data are available to determine how many total inches of rainfall industrial hemp plants require at various growth stages and under variable rainfall patterns. This type of research would help develop an irrigation-scheduling program based on critical growth stages.

The amount of irrigation water needed also depends on the variety and planting density. The soil types and its ability to hold moisture content also affect the amount and frequency of irrigation. Since industrial hemp thrives in well-drained soils, it is important to irrigate at the right time and to not over-irrigate. The two irrigation practices that have been used are overhead pivot/traveling gun irrigation or plastic drip tape laid in row. No furrow irrigation is being used or has been investigated for potential use.

Harvest

Industrial hemp raised for seed and grain can be harvested with traditional combine equipment. However, like when harvesting fiber, monitor all moving parts, especially dual rotor combines, for excessive fiber wrapping. Seed shattering is an issue; therefore, timely harvest at 70 percent to 80 percent grain maturity is critical. Harvest moisture will range from 12 percent to 18 percent. Reduce fiber intake by cutting seed heads only, but this may result in not harvesting heads that may be lower in the canopy. Draper headers are preferred to reduce potential damage.

Combine settings have been similar to those used for canola and wheat in North Dakota. Minimize post-harvest grain handling and use conveyor augers if possible. Seed spoilage can occur within six hours if left on a truck or in a bin with aeration. To maintain seed quality for storage, clean seed and post-harvest, quickly air-dry it down to 9 percent moisture. Specific long-term storage information is not available at this time.

Production

- Harvest at 70 percent to 80 percent maturity to reduce seed shattering
- *Moisture at Harvest:* 12 percent to 18 percent.
- Clean seed and quickly air-dry down to 9 percent moisture
- *Estimated yield:* 750 pounds to 1,050 pounds per acre (10 percent less for dual-purpose crops)

Yield potential for seed and grain will vary among cropping environments. Yield has ranged between 750 pounds and 1,050 pounds per acre for grain production, and dual-purpose yield potential is approximately 10 percent less.

3.3 Industrial Hemp for Cannabidiol (CBD) Agronomy

Site Selection

Industrial hemp is an agronomic crop that responds to productive, well-drained soils with a soil pH range of 6.0 to 6.5. Avoiding poorly drained fields and compacted soils, identifying fields that have a low weed seed bank, and starting weed-free prior to planting are critical for successful CBD production.

Variety Selection

The first step prior to selecting a variety is understanding that cannabinoids, such as CBD, are extracted from plants — in particular, from the glandular trichomes (hairs) of the female hemp plant. Glandular trichomes are found on the bracts closely associated with the flowers. In general, the flower bearing structures (inflorescences) in female plants have the highest CBD concentration. Therefore, female plants are greenhouse-started as clones from a “mother” plant or “feminized” seed derived from a chemical process. The second reason for focusing on female plants is that it is generally understood that CBD as a percent of dry matter decreases after pollination. Therefore, the industry standard method is to transplant (set) female plants into the



Exhibit 3.3.1- Industrial Hemp for CBD Field

ground using a vegetable or tobacco planting model. Maintaining a close working relationship with a CBD processor can help producers identify varieties that best fit CBD production needs in a given geographic region. State departments of agriculture may maintain a list of industrial hemp varieties available in a given state.

Soil Nutrients

Limited research-based guidelines on fertility are available for U.S. industrial hemp production. Nitrogen rates for hemp grown for CBD have been the most variable when looking at production systems in other states. In general, actual nitrogen (N) rates per acre exceed the 50 pounds to 150 pounds recommended for CBD production.

The standard application practice is to split-apply nitrogen — pre-plant followed by early post, approximately 10 days after transplant. There is research interest on identifying the relationship of nitrogen rate to CBD as it relates to biomass production and potential dry matter dilution effect as well as varietal responses. Phosphate (P_2O_5) and potash (K_2O) needs will depend on available phosphorus and available potassium in the soil. Currently, soil testing labs do not offer soil test

Soil Fertility

- 50 pounds to 150 pounds of actual nitrogen (N) per acre
- Phosphate (P_2O_5) and potassium (K_2O) needs depend on available phosphorus and potassium in soil

recommendations for industrial hemp grown for CBD production. However, a soil test is recommended to identify the soil acidity level as well as available phosphorus and potassium. Soil testing six months prior to planting is recommended.

Planting

Industrial hemp has a wide planting window; however, identifying the ideal timeframe to maximize CBD production is being investigated. In general, the current timeframe is May through June for CBD; however, planting has continued into July, especially in 2019 due to weather delays. Preliminary research indicates that hemp's strong photoperiodism induced 50 percent flowering in North Carolina by mid-August regardless of transplant date. However, preliminary yield data indicated that May planting was optimal.

Planting

- *Planting time:* May to June
- *Plant populations:* 1,500 plants to 4,000 plants per acre

For three main reasons, female plants are often transplanted using a vegetable or tobacco production model. The first reason is the cost of clones and feminized seedling plants. With these two models, plants are on a wide inter- and intra-row spacing that ranges from 3 feet to 5 feet. Plant populations for CBD production range from 1,500 plants to 4,000 plants per acre. The second reason is that in many of the CBD production regions, producers are established vegetable or tobacco producers who have existing equipment, labor and an understanding of how to manage transplants. The third reason is the wide spacing will produce a shorter, branched plant, which can potentially produce more flower material and simplify harvest. Planting has varied among producers. A traditional vegetable system typically uses raised (hipped) beds with or without plastic. A traditional tobacco system typically involves planting flat on bare soil. Also, with no labeled herbicide options the wide spacing allows for easier mechanical weed control. Plastic weed barriers may reduce cultivation, but this could potentially increase disease challenges.

Pest Management

In general, industrial hemp for CBD production is susceptible to diseases, insects will feed on plants, and weeds compete for nutrients and light. Industrial hemp producers, as with producers who raise other agronomic crops, should follow an integrated pest management (IPM) plan. IPM practices include scouting crops; identifying pests; and developing an action plan that would include cultural, mechanical and, if warranted and/or available, chemical control practices. The two challenges for hemp production are lack of research data on the actual influence that pests (weeds, insects, plant pathogens) have on yield under the three basic crop uses and the lack of registered pesticide products traditionally used to manage pests in other crops, if warranted. Producers must remember that any off-label use of pesticides is illegal. Currently, there are a limited number of labeled pesticides available for hemp in the U.S. Prior to use of any biological, synthetic and/or organic crop protectants, refer to EPA's pesticide registration list

Pest Management

- Develop an integrated pest management plan for your industrial hemp crop
- Monitor weed pressure; management is critical through machine and/or hand cultivation
- Recognize any off-label use of pesticides is illegal
- Contact Missouri Department of Agriculture to ask questions about pesticide use and legality

for hemp, contact MDA for any questions on pesticides that may or may not be registered in the state, and always read and follow label directions. In a contract, CBD processors may provide a list of potential pesticide residues that are tested in CBD biomass.

Identifying fields with a low weed seed bank and knowing previous crop herbicides used with plant-back restrictions will be critical. Cultural and mechanical weed management practices are standard in industrial hemp production. Mechanical weed management includes machine or hand cultivation.

Because the majority of U.S. industrial hemp acres are for CBD production, current insect research is looking primarily into yield effects on CBD production. Two common insect pests identified on industrial hemp are corn earworm (*Helicoverpa zea*) and Japanese beetle (*Popillia japonica*).

Industrial hemp is a host for a number of common disease-causing pathogens that are present in other row crops including numerous *Fusarium* species and the root knot nematode (*Meloidogyne* spp.). Research is being conducted to better understand how disease pathogens affect industrial hemp production.

Irrigation and Water

Industrial hemp production occurs in various climates: the moderate northwest coast climate of Washington and Oregon; the arid cool climate of Colorado; and the humid warm climate, with potentially hot dry conditions, of the mid-South. That variability indicates hemp's ability to cope with different moisture environments. The productivity of industrial hemp is susceptible to more problems in wet conditions and poor soil drainage. However, the level of industrial hemp stress from lack of moisture during hot, dry conditions is not fully understood. Hemp water needs are thought to be similar to those of soybeans and corn — approximately 25 inches to 30 inches — for the entire growth cycle. However, no established Missouri water use and transpiration research data is available to determine how many total inches of rainfall industrial hemp plants require at various growth stages and under variable rainfall patterns. This type of research would help develop an irrigation-scheduling program based on critical growth stages.

The amount of irrigation water needed also depends on the variety and planting density. The soil types and its ability to hold moisture content also affect the amount and frequency of irrigation. Since industrial hemp thrives in well-drained soils, it is important to irrigate at the right time and to not over-irrigate. North Carolina research has studied the root systems of clones versus those of seedlings from feminized seed. Clones produce what researchers observed as a fibrous root system, and seedlings produce a tap root system. Some preliminary research from the University of Tennessee focused on understanding water use by hemp and identifying drought-tolerant varieties.

Many producers have irrigation available to ensure maximum production and reduce stress during the summer. The two irrigation practices that have been used are overhead pivot/traveling gun irrigation or plastic drip tape laid in rows. No furrow irrigation is being used or has been investigated for potential use. Typically drip irrigation systems are more effective in watering small areas or plants that require a specific watering schedule.

Harvest

To harvest industrial hemp for CBD, producers have used two general approaches: hand harvest and mechanical harvest of the whole plant. Producers should have a close relationship with processors and clearly understand processors' expectations for how the plants are dried and how the flowers, leaves and stems are removed and stored before processing.

Production

- Work closely with your processor to understand harvest and drying needs
- *Estimated yield:* 1 to 2 pounds of dry matter per plant and 8 to 10 percent CBD per pound of dry matter

The standard method in tobacco-growing regions is hand harvesting whole plants, hanging them upside down and air-drying or heat-drying in barns like you would find in a tobacco system. Heat-drying occurs in a flue-cure barn at 150 degrees F for three to five days. Air-dried hemp is hung and spaced in tobacco barns that encourage good airflow. After dry-down, industrial hemp flowers (buds) are stripped from the main stem (bucking) and bagged; discarding the remaining stem. The benefit is less biomass dilution of CBD percentage by dry weight. This harvest system's limitations are time, labor needs and drying space.

Some producers mechanically harvest hemp. Mechanical harvest methods include the following three options: front loader-mounted platform draper headers that side-load into a wagon or truck; three-point hitch, whole-plant harvesters that load on wagons; and whole-plant chopping with silage equipment and batch drying.

As the industry evolves, harvest efficiency will be critical, and manufacturers continue to improve the harvest process. Again, producer-processor communication will also be necessary to produce and deliver a harvested crop to market.

Yield has varied among geographic climates and planting systems. Yield for CBD is a function of both pounds of dry matter per plant and percent CBD per pound of dry matter. The yield goal is 1 pound to 2 pounds of dry matter per plant and 8 percent to 10 percent CBD per pound of dry matter.

3.4 Industrial Hemp Agronomy Resources

Below are some resources that were used to develop the preceding sections. They are good sources for additional information regarding agronomic considerations. Producers should be cautious and vet all sources of information in order to make the best-informed decisions.

Colorado State University

Hemp Resource Center: hemp.agsci.colostate.edu/

Cornell University

School of Integrative Plant Science/Hemp: hemp.cals.cornell.edu/

NC State University

Industrial Hemp: industrialhemp.ces.ncsu.edu

North Dakota State University

Industrial Hemp Crop Management: ag.ndsu.edu/langdonrec/crop-production-management

University of Kentucky

Hemp Agronomy: hemp.ca.uky.edu

Hemp Disease: kyhempdisease.com

Tobacco: www2.ca.uky.edu/agcomm/pubs/ID/ID160/ID160.pdf

4. Economics and Planning Budgets for Industrial Hemp

4.1 Farmer Value Proposition

Hemp production currently focuses on producing one of three products: CBD, hemp fiber or hemp grain. In addition, research and development continues on equipment, varieties, and agronomic systems for producing dual- or tri-crops that would allow harvesting all three products from one acre of hemp.

Each crop market — CBD, fiber, grain — compensates farmers differently for the industrial hemp they raise and harvest. Farmers growing industrial hemp for CBD are paid on the CBD content found in biomass sold — dollar value per percent CBD content per pound biomass. Hemp fiber is sold based on retted and baled tonnage — dollars per ton — similar to hay crops. Hemp grain is sold based on pounds of grain delivered. Many buyers and processors will have specifications in their farmer production contracts that will detail delivery point, form, acceptability, final pricing mechanics and deductions that will apply to crops.

Estimated gross returns per acre for different systems of industrial hemp production are shared in Exhibit 4.1.1. Keep in mind these are general gross (not net) returns expected per acre from across the U.S. and are not prices available to Missouri producers at this time. The industrial hemp industry is in its early stages in the U.S., and market pricing will evolve over time. Most farmers who have adopted industrial hemp early have targeted CBD production, given the profit potential available. But hemp fiber and grain markets have seen growth with processors entering into these markets.

Exhibit 4.1.1 – Industrial Hemp Farmer Value Proposition

Market	Income Based on	Expected Gross Return per Acre Range
CBD	CBD (<i>per percent CBD content per pound</i>)	\$5,000 to \$36,000
Hemp fiber	Baled fiber (<i>per ton</i>)	\$500 to \$700
Hemp grain	Seed (<i>per pound</i>)	\$500 to \$1,000
Dual crop (fiber and grain)	Baled fiber (<i>per ton</i>) Seed (<i>per pound</i>)	\$500 to \$1,500

With a new crop such as industrial hemp, pricing data in the market tends to be limited. But there has been some movement to add price transparency to the CBD marketplace. Hemp Benchmarks® (hempbenchmarks.com/) provides a monthly market price and intelligence report. PanXchange (panxchange.com) started reporting data on hemp biomass prices in 2019. It posts monthly reports on biomass spot prices for Colorado, Kentucky and Oregon. Industrial hemp fiber and grain have been much smaller markets in the U.S. to date, and price data is held closely by those contracting companies. Online markets now exist for hemp products and processing equipment. They offer farm products through intermediate processed materials all the way to retail products. Examples include Hemp Raw Marketplace (hemp.rawmarket.place/) and Kush (kush.com/).

To assist producers in their decision-making, Missouri industrial hemp budgets for 2020 were developed; they are available in the following sections (4.2, 4.3, 4.4 and 4.5) and also located on the University of Missouri Extension website.

- Industrial Hemp for Grain (40 acres) (extension.missouri.edu/g668)
- Industrial Hemp for Fiber (40 acres) (extension.missouri.edu/g669)
- Industrial Hemp for Grain/Fiber (Dual) (40 acres) (extension.missouri.edu/g670)
- Industrial Hemp for Cannabidiol (CBD) (2.5 acres) (extension.missouri.edu/g671)

The general framework of these budgets assumes prices as of November 2019. Importantly, note that industrial hemp has not been produced in Missouri for decades. Assumptions used in these budgets are from states, such as Kentucky, Tennessee and North Dakota, that have recently grown industrial hemp. Farmers should understand that these assumptions may not fit Missouri production. Each budget has an accompanying spreadsheet model that can be customized for a farming operation. A sensitivity analysis is included with each budget to show the impact of profit with various yields and market prices. Exhibit 4.1.2 presents some basic economic recommendations to assist farmers who are considering industrial hemp production.

Exhibit 4.1.2 – General Economic Recommendations for Farmers Considering Industrial Hemp Production

- Contract or engage with processors or sales markets prior to growing an industrial hemp crop.
- Investigate the financial stability and integrity of any contracting entity or processor. Contracts with reputable businesses are essential.
- Understand the risk and your willingness or ability to accept it.
- Spend time investigating industrial hemp production and talking with other farmers.
- Understand your cost of production and sensitivity to production and pricing decreases.
- Comply with regulatory agencies' rules and standards.

4.2 Industrial Hemp for Grain Planning Budget (extension.missouri.edu/g668)



Industrial Hemp for Grain Planning Budget

This budget presents information useful to farmers considering industrial hemp production for grain. Table 1 presents income and cost estimates for industrial hemp grain production in Missouri. Assumptions were based on price forecasts as of November 2019. Detailed assumptions are summarized in Tables 2 and 3. Production was assumed to be done on 40 acres. Hemp has not been produced in Missouri for decades. Several assumptions used in this budget are from states such as Kentucky, Tennessee, and North Dakota that have recently grown hemp. Farmers should understand that these assumptions may not fit Missouri production. A sensitivity analysis showing the impact on profit of various yields and market prices is included in Table 4.

Because this budget contains much anecdotal, as opposed to research-based information, we suggest that farmers customize the budget by using the Missouri Hemp Budget Generator Tool (<https://extensiondata.missouri.edu/Pro/AgBusinessPolicyExtension/Docs/IndustrialHempBudget.xlsx>).

Table 1. Missouri industrial hemp for grain planning budget for 2020.

	Dollars per acre ¹	Your estimate
Income		
Hemp grain	720.00	
Total income	720.00	
Operating costs		
Seed	90.00	
Fertilizer	61.20	
Machinery operating cost	28.41	
Custom hire and rental	76.00	
Registration and background check	20.00	
Sampling costs	7.50	
Operating interest	7.79	
Total operating costs	290.90	
Ownership costs		
Machinery ownership	71.89	
Real estate charge	125.00	
Total ownership costs	196.89	
Total costs	487.79	
Income over operating costs		
	429.10	
Income over total costs		
	232.21	

¹ Totals may not sum due to rounding.

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Income considerations

Missouri-specific hemp yield and variety trial information does not currently exist to guide producers. The yields used in this budget are estimates from other states, which also have limited research results and different growing conditions. Modest yields are used in this budget until the agronomic recommendations for Missouri have been better defined. The market for hemp grain is also immature with little price history. The hemp grain prices used in this budget are the authors' best estimate given limited market information.

It is suggested producers secure a contract to sell their hemp grain before producing the crop. Use the contract price to estimate income. Typical contracts may specify the quality of hemp grain delivered. To meet contract specifications and be assured a market and price, farmers need to be confident that they can deliver clean, dry grain. Additional storage, cleaning, or drying equipment, not included in this budget, may be necessary to obtain the contracted price. Delivered grain that fails to meet contract specifications may not be marketable. Because of this emerging industry's dynamics, hemp grain processors may issue contracts that they are unable to honor at harvest time.

Growing hemp includes a legal risk. Production of hemp is legal only if produced in accordance with Missouri law and the plant tests at or below postdecarboxylation 0.3% delta-9-tetrahydrocannabinol (THC). Under proposed regulations, the producer will be responsible for taking composite samples for each variety produced. Samples for varieties testing greater than 0.3% may result in crop destruction. Producers required to destroy varieties testing out of compliance must do so according to the Missouri Department of Agriculture's destruction protocol. Costs for destroying the crop and destruction certification are the responsibility of the producer. Destruction will be verified by the Missouri State Highway Patrol or local law enforcement. No compensation is provided for the destroyed hemp crop.

Agronomic considerations

The production contracts that farmers sign may specify the seed variety planted; harvesting, storage, and delivery methods used; and expected yields. These contract specifications will affect the agronomic practices used and costs incurred to produce hemp for grain.

Seeding rate for this hemp grain budget was set at 30 pounds per acre. Other states report seeding rates of 20 to 30 pounds per acre. The cost of seed reported by other states varies dramatically. We chose a seed price of \$3 per pound because of the relative scarcity of hemp seed. As seeds become more plentiful, the cost of seed may merge closer to the expected price of the sold hemp grain, \$0.60 per pound in this budget.

Nitrogen (N), phosphorus (P), and potassium (K) fertilization is necessary for hemp production. No Missouri-specific recommendations exist yet. Purdue University states, "Hemp requires about the same fertility requirements as a high-yielding crop of wheat, or corn."

No pesticides are currently labelled for use on hemp. This increases the risk of low yield because hemp is subject to weed, insect, and disease pressure. This budget assumes disking to kill weeds prior to planting. Weed management is currently limited to planting in a clean field, obtaining good emergence and assuming the quick-growing hemp will canopy and suppress weed growth. Any disease or insect problems will reduce yields, and the farmer will have few chemical options to control them.

This budget includes cost estimates for a required background check on the farmer and for registration of production with the Missouri Department of Agriculture. We assumed the farmer would send two samples to a lab to test for THC levels. Regulations require only one test per variety showing THC levels below 0.3 percent. The additional test is necessary if the first test shows the field exceeds legal limits. These

Table 2. Input assumptions used in Missouri industrial hemp for grain planning budget for 2020.

Selected input quantities	Per acre	Selected input prices	Dollars per unit
Grain yield, pounds	1,200	Grain price, per pound	0.60
Seeding rate, pounds	30	Seed, per pound	3.00
Nitrogen rate, pounds N	100	Nitrogen, per pound N	0.31
Phosphorus rate, pounds P ₂ O ₅	30	Phosphorus, per pound P ₂ O ₅	0.40
Potassium rate, pounds K ₂ O	20	Potassium, per pound K ₂ O	0.31
Lime rate, tons	0.6	Lime, per ton	20.00
Fuel for machinery and drying, gallons	5.16	Fuel, per gallon	3.04
Labor, hours	0.64	Labor, per hour	20.00

Table 3. Machinery used in Missouri industrial hemp for grain planning budget for 2020, on a per acre basis.

Machinery activity (including custom fieldwork)	Labor (hours)	Fuel (gallons)	Operating costs ¹ (dollars)	Ownership costs ¹ (dollars)	Total costs (dollars)	Trips across field
Anhydrous application, 200 MFWD	0.08	0.64	3.49	7.30	10.79	1
Tandem disk, fold (21 feet), 160 MFWD	0.16	1.48	7.78	19.92	27.70	2
Presswheel drill (16 feet), 105 MFWD	0.15	0.61	4.81	10.05	14.85	1
Combine flex platform (25 feet), 375 HP	0.13	2.04	8.89	27.29	36.18	1
Rotary mower/conditioner (12 feet), 75 HP	0.11	0.38	3.44	7.35	10.79	1
Dry fertilizer application, custom charge					13.50	2
Grain drying, custom charge					11.00	
Hauling grain to bin, custom charge					2.50	
Hauling grain to market, custom charge					9.00	
Seed cleaning, custom charge					40.00	
Total²	0.64	5.16	28.41	71.89	176.31	8

¹ Machinery operating cost is the sum of fuel, repairs and maintenance, and the value of labor.

² Machinery ownership cost is the sum of overhead and depreciation.

Totals may not sum due to rounding. Abbreviations: MFWD = modified front-wheel drive tractor; HP = horsepower.

regulatory costs are spread over 40 acres of hemp for grain production.

Machinery considerations

This budget assumes field operations that budgets from other states have recommended. The farmer is expected to apply nitrogen fertilizer with owned equipment. P and K fertilizers are assumed to be applied by the fertilizer dealer. Preplant weed control is disking twice. If planting does not occur soon after disking, then weeds may emerge, and a subsequent field cultivation may be necessary. The farmer is assumed to own the necessary grain drill to plant the hemp as well as the necessary equipment to harvest the hemp.

Anecdotal evidence indicates that harvesting hemp grain is more difficult than harvesting traditional grain crops. Wrapping and fire danger have been reported. The costs of repair and time to cover a single acre might be greater than estimated in this budget. After harvest, it is expected that the extensive hemp

residue will be mowed and left on the field. Future markets for low-quality hemp fiber may emerge as the industry evolves. This budget also includes custom drying and farm-to-market transportation charges.

Sensitivity analysis

Uncertainty abounds when new crops are grown. Sensitivity analysis illustrates the impact on income over total costs of varying two critical factors. Yield and market price uncertainty significantly impact income. The gray highlights of Table 4 show the scenario that corresponds to this budget with a 1,200 pound yield per acre and \$0.60 per pound market price.

Table 4. Sensitivity analysis: income over total costs per acre.

Market price (dollars per pound)	Grain yield (pounds per acre)				
	800	1,000	1,200	1,400	1,600
0.40	-167.79	-87.79	-7.79	72.21	152.21
0.50	-87.79	12.21	112.21	212.21	312.21
0.60	-7.79	112.21	232.21	352.21	472.21
0.70	72.21	212.21	352.21	492.21	632.21
0.80	152.21	312.21	472.21	632.21	792.21



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4.3 Industrial Hemp for Fiber Planning Budget (extension.missouri.edu/g669)



Industrial Hemp for Fiber Planning Budget

This budget presents information useful to farmers considering industrial hemp production for fiber. Table 1 presents income and cost estimates for industrial hemp fiber production in Missouri. Assumptions were based on price forecasts as of November 2019. Detailed assumptions are summarized in Tables 2 and 3. Production was assumed to be done on 40 acres. Hemp has not been produced in Missouri for decades. Several assumptions used in this budget are from states such as Kentucky, Tennessee, and North Dakota that have recently grown hemp. Farmers should understand that these assumptions may not fit Missouri production. A sensitivity analysis showing the impact on profit of various yield and market prices is included in Table 4.

Because this budget contains much anecdotal, as opposed to research-based information, we suggest that farmers customize the budget by using the Missouri Hemp Budget Generator Tool (<https://extensiondata.missouri.edu/Pro/AgBusinessPolicyExtension/Docs/IndustrialHempBudget.xlsx>).

Table 1. Missouri industrial hemp for fiber planning budget for 2020.

	Dollars per acre ¹	Your estimate
Income		
Hemp fiber bales	625.00	
Total income	625.00	
Operating costs		
Seed	150.00	
Fertilizer	59.90	
Machinery operating cost	21.44	
Custom hire and rental	156.00	
Registration and background check	20.00	
Sampling costs	7.50	
Operating interest	11.41	
Total operating costs	426.25	
Ownership costs		
Machinery ownership	47.21	
Real estate charge	125.00	
Total ownership costs	172.21	
Total costs	598.46	
Income over operating costs		
	198.75	
Income over total costs	26.54	

¹ Totals may not sum due to rounding.

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extension.missouri.edu

g669

Income considerations

Missouri-specific hemp yield and variety trial information does not currently exist to guide producers. The yields used in this budget are estimates from other states, which also have limited research results and different growing conditions. Modest yields are used in this budget until the agronomic recommendations for Missouri have been better defined. The market for hemp fiber is also immature with little price history. The hemp fiber prices used in this budget are the authors' best estimates given limited market information.

It is suggested producers secure a contract to sell their hemp fiber before producing the crop. Use the contract price to estimate income. Because of this emerging industry's dynamics, hemp fiber processors may issue contracts that they are unable to honor at harvest time.

Growing hemp includes a legal risk. Production of hemp is legal only if produced in accordance with Missouri law and the plant tests at or below postdecarboxylation 0.3% delta-9-tetrahydrocannabinol (THC). Under proposed regulations, the producer will be responsible for taking composite samples for each variety produced. Samples for varieties testing greater than 0.3% may result in crop destruction. Producers required to destroy varieties testing out of compliance must do so according to the Missouri Department of Agriculture's destruction protocol. Costs for destroying the crop and destruction certification are the responsibility of the producer. Destruction will be verified by the Missouri State Highway Patrol or local law enforcement. No compensation is provided for the destroyed hemp crop.

Agronomic considerations

The production contracts that farmers sign may specify the seed variety planted; harvesting, storage, and delivery methods used; and expected yields. These contract specifications will affect the agronomic practices and costs of producing hemp for fiber.

Seeding rate for this hemp fiber budget was set at 50 pounds per acre. Other states report seeding rates of 35 to 80 pounds per acre. The cost of seed reported by other states varies dramatically. We chose a seed price of \$3 per pound because of the relative scarcity of hemp seed. Nitrogen (N), phosphorus (P), and potassium (K) fertilization is necessary for hemp production. No Missouri-specific recommendations exist yet. Purdue University states, "Hemp requires about the same fertility requirements as a high-yielding crop of wheat, or corn."

No pesticides are currently labelled for use on hemp. This increases the risk of low yield because hemp is subject to weed, insect, and disease pressure. This budget assumes disking to kill weeds prior to planting. Weed management is currently limited to planting in a clean field, obtaining good emergence and assuming the quick-growing hemp will canopy and suppress weed growth. Any disease or insect problems will reduce yields, and the farmer will have few chemical options to control them.

This budget includes cost estimates for a required background check on the farmer and for registration of production with the Missouri Department of Agriculture. We assumed the farmer would send two samples to a lab to test for THC levels. Regulations require only one test per variety showing THC levels below 0.3 percent. The additional test is necessary if the first test shows the field exceeds legal limits. These regulatory costs are spread over 40 acres of hemp for fiber production.

Table 2. Input assumptions used in Missouri industrial hemp for fiber planning budget for 2020.

Selected input quantities	Per acre	Selected input prices	Dollars per unit
Fiber yield, tons	5	Fiber price, per ton	125.00
Seeding rate, pounds	50	Seed, per pound	2.00
Nitrogen rate, pounds N	50	Nitrogen, per pound N	0.31
Phosphorus rate, pounds P ₂ O ₅	50	Phosphorus, per pound P ₂ O ₅	0.40
Potassium rate, pounds K ₂ O	40	Potassium, per pound K ₂ O	0.31
Lime rate, tons	0.6	Lime, per ton	20.00
Fuel for machinery and drying, gallons	3.22	Fuel, per gallon	3.04
Labor, hours	0.55	Labor, per hour	20.00

Machinery considerations

This budget assumes field operations that budgets from other states have recommended. The farmer is expected to apply nitrogen fertilizer with owned equipment. P and K fertilizers are assumed to be applied by the fertilizer dealer. Preplant weed control is disking twice. If planting does not occur soon after disking, then weeds may emerge, and a subsequent field cultivation may be necessary. The farmer is assumed to own the necessary grain drill to plant the hemp as well as the necessary equipment to mow and rake the hemp stalks.

Anecdotal evidence indicates that harvesting fiber is more difficult than harvesting traditional forage crops. Wrapping and fire danger have been reported. The costs of repair and time to cover a single acre might be greater than estimated in this budget. If contract specifications

require on-farm storage, then additional tarping or shed costs may be necessary.

This budget also includes a custom charge for baling the fiber into large rectangular bales and transportation of hemp fiber bales to market.

Sensitivity analysis

Uncertainty abounds when new crops are grown. Sensitivity analysis illustrates the impact on income over total costs of varying two critical factors. Yields and market price uncertainty significantly impact income. The gray highlights of Table 4 show the scenario that corresponds to this budget with a 5 ton yield per acre and \$125 per ton market price.

Table 3. Machinery used in Missouri industrial hemp for fiber planning budget for 2020, on a per acre basis.

Machinery activity (including custom fieldwork)	Labor (hours)	Fuel (gallons)	Operating costs ¹ (dollars)	Ownership costs ¹ (dollars)	Total costs (dollars)	Trips across field
Anhydrous application, 200 MFWD	0.08	0.64	4.61	7.30	10.79	1
Tandem disk, fold (21 feet), 160 MFWD	0.16	1.48	10.78	19.91	27.70	2
Presswheel drill (16 feet), 105 MFWD	0.15	0.61	5.15	10.05	14.85	1
Sickle mower, 75 HP tractor	0.12	0.35	3.95	6.90	10.32	1
Hay rake (30 feet), 40 HP tractor	0.08	0.13	2.24	3.05	4.99	2
Dry fertilizer application, custom charge					13.50	2
Large rectangular bales, custom charge					85.00	1
Moving large rectangular bales, custom charge					57.50	1
Total²	0.58	3.22	21.44	47.21	224.65	10

¹ Machinery operating cost is the sum of fuel, repairs and maintenance, and the value of labor. Machinery ownership cost is the sum of overhead and depreciation.

² Totals may not sum due to rounding.

Abbreviations: MFWD = modified front-wheel drive tractor; HP = horsepower.

Table 4. Sensitivity analysis: income over total costs per acre.

Market price (dollars per ton)	Fiber yield (tons per acre)				
	3	4	5	6	7
75	-5373.46	-298.46	-223.46	-148.46	-73.46
100	-298.46	-198.46	-98.46	1.54	101.54
125	-223.46	-98.46	26.54	151.54	276.54
150	-148.46	1.54	151.54	301.54	451.54
175	-73.46	101.54	276.54	451.54	626.54



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4.4 Industrial Hemp for Grain/Fiber Planning Budget (extension.missouri.edu/g670)



Industrial Hemp for Grain and Fiber Planning Budget

This budget presents information useful to farmers considering industrial hemp production for grain and fiber. Table 1 presents income and cost estimates for industrial hemp grain and fiber production in Missouri. Assumptions were based on price forecasts as of November 2019. Detailed assumptions are summarized in Tables 2 and 3. Production was assumed to be done on 40 acres. Hemp has not been produced in Missouri for decades. Several assumptions used in this budget are from states such as Kentucky, Tennessee, and North Dakota that have recently grown hemp. Farmers should understand that these assumptions may not fit Missouri production. A sensitivity analysis of this budget is included in Tables 4 and 5. These tables show how various yield and market price scenarios impact profitability.

Table 1. Missouri industrial hemp for grain and fiber planning budget for 2020.

	Dollars per acre ¹	Your estimate
Income		
Hemp fiber bales	375.00	
Hemp grain	450.00	
Total income	825.00	
Operating costs		
Seed	120.00	
Fertilizer	90.90	
Machinery operating cost	35.32	
Custom hire and rental	143.25	
Registration and background check	20.00	
Sampling costs	7.50	
Operating interest	11.47	
Total operating costs	428.44	
Ownership costs		
Machinery ownership	74.50	
Real estate charge	125.00	
Total ownership costs	199.50	
Total costs	627.94	
Income over operating costs	396.56	
Income over total costs	197.06	

¹ Totals may not sum due to rounding.

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Because this budget contains much anecdotal, as opposed to research-based information, we suggest that farmers customize the budget by using the Missouri Hemp Budget Generator Tool (<https://extensiondata.missouri.edu/Pro/AgBusinessPolicyExtension/Docs/IndustrialHempBudget.xlsx>).

Income considerations

Missouri-specific hemp yield and variety trial information does not currently exist to guide producers. The yields used in this budget are estimates from other states, which also have limited research results and different growing conditions. Modest yields are used in this budget until the agronomic recommendations for Missouri have been better defined. Markets for hemp grain and fiber are also immature and have little price history. The prices used in this budget for hemp grain and fiber are the authors' best estimates given limited market information.

It is suggested producers secure a contract to sell their hemp grain and fiber before producing the crop. Use the contract price to estimate income. Typical contracts may specify the quality of hemp grain delivered. Fiber contracts may specify the process to ret (partially break down) the fiber. To meet the contract specification and be assured a market and price, farmers need to be confident that they can deliver clean, dry grain and quality fiber. Additional storage, cleaning or drying equipment, not included in this budget, may be necessary to obtain the contracted price. Grain delivered outside of contract specifications may be unmarketable. Because of this emerging industry's dynamics, hemp processors may issue contracts which they are unable to honor at harvest time.

Growing hemp includes a legal risk. Production of hemp is legal only if produced in accordance with Missouri law and the plant tests at or below postdecarboxylation 0.3% delta-9-tetrahydrocannabinol

(THC). Under proposed regulations, the producer will be responsible for taking composite samples for each variety produced. Samples for varieties testing greater than 0.3% may result in crop destruction. Producers required to destroy varieties testing out of compliance must do so according to the Missouri Department of Agriculture's destruction protocol. Costs for destroying the crop and destruction certification are the responsibility of the producer. Destruction will be verified by the Missouri State Highway Patrol or local law enforcement. No compensation is provided for the destroyed hemp crop.

Agronomic considerations

The production contracts that farmers sign may specify the seed variety planted; harvesting, storage, and delivery methods used; and expected yields.

These contract specifications will affect the agronomic practices and costs of producing hemp for grain and fiber.

Seeding rate for this hemp fiber budget was set at 40 pounds per acre, between the seeding rates for grain or fiber. The cost of seed reported by other states varies dramatically. We chose a seed price of \$3 per pound because of the relative scarcity of hemp seed. As seed becomes more plentiful, the cost of seed may merge closer to the expected price of the sold hemp grain, \$0.60 per pound in this budget.

Nitrogen (N), phosphorus (P), and potassium (K) fertilization is necessary for hemp production. No Missouri-specific recommendations exist yet. Purdue University states, "hemp requires about the same fertility requirements as a high-yielding crop of wheat, or corn."

No pesticides are currently labelled for use on hemp. This increases the risk of low yield because hemp is subject to weed, insect, and disease pressure. This budget assumes disking to kill weeds prior to planting. Weed management is currently limited to planting in a clean

Table 2. Input assumptions used in Missouri industrial hemp for grain and fiber planning budget for 2020.

Selected input quantities	Per acre	Selected input prices	Dollars per unit
Fiber yield, tons	3	Fiber price, per ton	125.00
Grain yield, pounds	750	Grain price, per pound	0.60
Seeding rate, pounds	40	Seed, per pound	3.00
Nitrogen rate, pounds N	150	Nitrogen, per pound N	0.31
Phosphorus rate, pounds P ₂ O ₅	50	Phosphorus, per pound P ₂ O ₅	0.40
Potassium rate, pounds K ₂ O	40	Potassium, per pound K ₂ O	0.31
Lime rate, tons	0.6	Lime, per ton	20.00
Fuel for machinery and drying, gallons	5.26	Fuel, per gallon	3.04
Labor, hours	0.72	Labor, per hour	20.00

field, obtaining good emergence and assuming the quick-growing hemp will canopy and suppress weed growth. Any disease or insect problems will reduce yields, and the farmer will have no chemical options to control them.

This budget includes cost estimates for a required background check on the farmer and for registration of production with the Missouri Department of Agriculture. We assumed the farmer would send two samples to a lab to test for THC levels. Regulations require only one test per variety showing THC levels below 0.3 percent. The additional test is necessary if the first test shows the field exceeds legal limits. These regulatory costs are spread over 40 acres of hemp for grain and fiber production.

Machinery considerations

This budget contains field operations that budgets from other states have recommended. The farmer is expected to apply nitrogen fertilizer with owned

equipment. P and K fertilizers are assumed to be applied by the fertilizer dealer. Preplant weed control is disking twice. If planting does not occur soon after disking, then weeds may emerge and a subsequent field cultivation may be necessary. The farmer is assumed to own the necessary grain drill to plant the hemp.

Because both grain and fiber are to be harvested, the farmer is expected to own a combine with a flex platform for hemp grain harvest and a mower and rake for fiber harvest. Anecdotal evidence indicates that harvesting hemp grain and fiber is more difficult than harvesting traditional grain and forage crops. Wrapping and fire danger have been reported. The costs of repair and time to cover a single acre might be greater than estimated in this budget. If contract specifications require on-farm hemp fiber storage, then additional tarping or shed costs may be necessary.

This budget also includes custom charges for large rectangular baling, grain drying and transportation of both grain and fiber to market.

Table 3. Machinery used in Missouri industrial hemp for grain and fiber planning budget for 2020, on a per acre basis.

Machinery activity (not custom fieldwork)	Labor (hours)	Fuel (gallons)	Operating costs ¹ (dollars)	Ownership costs ² (dollars)	Total costs (dollars)	Trips across field
Anhydrous application, 200 MFWD	0.08	0.64	3.49	7.30	10.79	1
Tandem disk, fold (21 feet), 160 MFWD	0.16	1.48	7.78	19.92	27.70	2
Presswheel drill (16 feet), 160 MFWD	0.15	0.61	4.81	10.05	14.85	1
Sickle mower, 75 HP tractor	0.12	0.35	3.95	6.90	10.32	1
Hay rake (30 feet), 40 HP tractor	0.08	0.14	1.94	3.06	4.98	2
Combine flex platform (25 feet), 375 HP	0.13	2.04	8.89	27.29	36.18	1
Dry fertilizer application, custom charge					13.50	2
Large rectangular bales, custom charge					51.00	
Moving large rectangular bales, custom charge					34.50	
Grain drying, custom charge					9.00	
Hauling grain to bin, custom charge					1.88	
Hauling grain to market, custom charge					3.38	
Seed cleaning, custom charge					30.00	
Total³	0.72	5.26	30.32	74.50	248.08	10

¹ Machinery operating cost is the sum of fuel, repairs and maintenance, and the value of labor.

² Machinery ownership cost is the sum of overhead and depreciation.

³ Totals may not sum due to rounding.

Abbreviations: MFWD = modified front-wheel drive tractor; HP = horsepower.

Sensitivity analysis

Uncertainty abounds when new crops are grown. Sensitivity analysis illustrates the impact on income over total costs of varying two critical factors. Yields and market price uncertainty significantly impact income. The gray highlights of Table 4 show the scenario that corresponds to this budget with 750 pounds of grain yield per acre and \$0.60 per pound grain price.

Table 5 looks at the uncertainty of both grain and fiber yield on income over total costs. The gray highlights of Table 5 show the scenario that corresponds to this budget with 750 pounds of grain yield per acre priced at \$0.60 per pound of grain and three tons of industrial hemp fiber priced at \$125 per ton.

Table 4. Sensitivity analysis: income over total costs per acre.

Market price (dollars per pound)	Grain yield (pounds per acre)				
	500	750	1,000	1,250	1,500
0.40	-52.94	47.06	147.06	247.06	347.06
0.50	-2.94	122.06	247.06	372.06	497.06
0.60	47.06	197.06	347.06	497.06	647.06
0.70	97.06	272.06	447.06	622.06	797.06
0.80	147.06	347.06	547.06	747.06	947.06

Table 5. Sensitivity analysis: income over total costs per acre assuming grain price of \$0.60/pound and fiber price of \$125/ton.

Fiber yield (tons per acre)	Grain yield (pounds per acre)				
	500	750	1,000	1,250	1,500
1	-202.94	-52.94	97.06	247.06	397.06
2	-77.94	72.06	222.06	372.06	522.06
3	47.06	197.06	347.06	497.06	647.06
4	172.06	322.06	472.06	622.06	772.06
5	297.06	447.06	597.06	747.06	897.06

4.5 Industrial Hemp for CBD Planning Budget (extension.missouri.edu/g671)



Industrial Hemp for CBD Planning Budget

This budget presents information useful to farmers considering industrial hemp production for cannabidiol (CBD). Table 1 presents income and cost estimates for industrial hemp CBD production in Missouri. Assumptions were based on price forecasts as of November 2019. Detailed assumptions are summarized in Tables 2, 3 and 4. Production was assumed to be done on 2.5 acres. Several assumptions used in this budget are from states such as Kentucky, Tennessee, and North Dakota that have recently grown hemp. Farmers should understand that these assumptions may not fit Missouri production. A sensitivity analysis of this budget is included in Tables 5 and 6. The two tables show how various yields and market prices impact profitability.

Table 1. Missouri industrial hemp for CBD planning budget for 2020.

	Dollars per acre ¹	Your estimate
Income		
Hemp CBD biomass	24,000.00	
Total income	24,000.00	
Operating costs		
Clones	7,623.00	
Fertilizer	102.00	
Irrigation - supplies and fuel	557.62	
Custom hire, machinery fuel, and variable costs	122.27	
Supplies	624.21	
Labor	3,718.98	
Registration and background check	320.00	
Sampling costs	600.00	
Operating interest	375.87	
Total operating costs	14,043.95	
Ownership costs		
Machinery ownership	41.90	
Real estate charge	125.00	
Drying and storage facility	1,950.00	
Irrigation well and pump	284.00	
Total ownership costs	2,400.90	
Total costs	16,444.85	
Income over operating costs	9,956.05	
Income over total costs	7,555.15	

¹ Totals may not sum due to rounding.

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g671

Because this budget contains much anecdotal, as opposed to research-based information, we suggest that farmers customize the budget by using the Missouri Hemp Budget Generator Tool (<https://extensiondata.missouri.edu/Pro/AgBusinessPolicyExtension/Docs/IndustrialHempBudget.xlsx>).

This CBD budget assumes a “horticultural” style of growing hemp to maximize CBD production per plant. It is assumed that drip tape irrigation with plastic mulch will be used. The high financial costs and labor requirements likely limit the number of acres a farmer can grow.

Income considerations

Missouri-specific CBD yield and variety trial information does not currently exist to guide producers. The yields used in this budget are estimates from other states, which also have limited research results and different growing conditions. Modest yields are used in this budget until the agronomic recommendations for Missouri have been better defined. The prices used in this budget for CBD hemp are the authors’ best estimates given limited market information.

The market for CBD is volatile as new demand and possible state and federal regulations influence prices. The market for CBD is also immature with little price history. It is suggested producers secure a contract to sell their hemp flower/CBD biomass before planting a crop. Use the contract price to estimate income.

Typical contracts require that farmers deliver high-quality material. In order to obtain the contract price, farmers need to be confident that they can meet the contract’s quality specifications for clean, dry flowers and biomass. We included a drying and storage facility in this budget to help maintain quality. Contract terms may require storage in a facility with a controlled environment.

Growing hemp includes a legal risk. Production of hemp is legal only if produced in accordance with Missouri law and the plant tests at or below postdecarboxylation 0.3% delta-9-tetrahydrocannabinol (THC). Under proposed regulations, the producer will be responsible for taking composite samples for each variety produced. Samples for varieties testing greater than 0.3% may result in crop destruction. Producers required to destroy varieties testing out of compliance must do so according to the Missouri Department of Agriculture’s destruction protocol. Costs for destroying the crop and destruction certification are the responsibility of the producer. Destruction will be verified by the Missouri State Highway Patrol or local law enforcement. No compensation is provided for the destroyed hemp crop.

Agronomic considerations

The production contracts that farmers sign may specify the seed and variety planted, planting and harvesting dates, expected yields, and delivered biomass quality. These contract specifications will affect the agronomic practices and costs of producing hemp for CBD.

We assume that feminized clones selling for \$4 each are planted at the rate of 1,906 per acre. Obtaining feminized clones may be difficult given the increased demand for CBD and the difficulty of actually producing feminized clones. Farmers are encouraged to buy from clone distributors that have a reputation for delivering quality feminized clones. The presence of only a few male plants in a field can greatly reduce CBD yield.

Nitrogen (N), phosphorus (P), and potassium (K) fertilization is necessary for hemp production. No Missouri-specific recommendations exist yet.

No pesticides are currently labelled for use on hemp. This increases the risk of low yield because hemp is

Table 2. Input assumptions used in Missouri industrial hemp for CBD planning budget for 2020.

Selected quantities	Per acre	Selected prices	Dollars per unit
Biomass yield, pounds	1,200	Biomass price, per pound per percent CBD	2.00
CBD content, percentage	10		
Clones purchased	1,906	Clone, per plant	4.00
Nitrogen rate, pounds N	150	Nitrogen, per pound N	0.31
Phosphorus rate, pounds P ₂ O ₅	70	Phosphorus, per pound P ₂ O ₅	0.40
Potassium rate, pounds K ₂ O	50	Potassium, per pound K ₂ O	0.31
Lime rate, tons	0.6	Lime, per ton	20.00
Fuel for machinery and drying, gallons	2.9	Fuel, per gallon	3.04
Labor, hours	246.3	Unskilled labor, per hour	15.00

subject to weed, insect, and disease pressure. This budget assumes two disking activities to kill weeds prior to planting. In addition, plastic mulch is applied to the field with drip irrigation under the mulch. The plastic mulch is necessary for weed control because the planting rate is insufficient to create a canopy to combat weeds. Any disease or insect problems will reduce yields, and the farmer will have few chemical options to control them.

Drip irrigation assumes that an existing water supply can provide sufficiently clean water for drip lines in the field.

This budget also estimates the total number of labor hours needed to lay black plastic, plant, irrigate, harvest plants, dry plants, and harvest biomass. Two hundred forty-six hours per acre are estimated as necessary for CBD hemp production (see Table 3). Labor availability may limit the number of acres a farmer can devote to CBD hemp production.

This budget includes cost estimates for a required background check on the farmer and for registration

of production with the Missouri Department of Agriculture. We assumed the farmer would send 10 samples to a lab to test for THC and CBD levels. Regulations require only one test per variety showing THC levels below 0.3 percent. One additional test may be necessary if the first test shows the sample exceeds legal limits. The additional eight tests are for fine-tuning production activities to maximize CBD content and minimize THC content. These costs are spread over 2.5 acres of industrial hemp for CBD production.

Machinery considerations

This budget contains field operations that budgets from other states have recommended (see Table 4). The farmer is expected to apply nitrogen fertilizer with owned equipment. P and K fertilization is assumed to be applied by the fertilizer dealer. Preplant weed control is disking twice.

Table 3. Labor assumptions used in Missouri industrial hemp for CBD planning budget for 2020, on a per acre basis.

Labor activity	Hours per acre	Dollars per hour	Total cost (dollars)	Description
Labor for pre-plant and planting	4.8	20	96.48	Disking, fertilizer, laying plastic and drip tape, planting clones
Labor for irrigation	10.0	15	150.00	
Labor for in-season weed control	50.0	15	750.00	Hand hoeing
Labor for in-season "trimming"	61.0	15	907.50	Two minutes per plant to increase bud development
Labor for harvest	61.0	15	907.50	Cut and haul plants to barn
Labor for post-harvest	61.0	15	907.50	Harvest dried material and load into totes
Total	246.3		3,718.98	

Table 4. Machinery used in Missouri industrial hemp for CBD planning budget for 2020, on a per acre basis.

Machinery activity (including custom fieldwork)	Labor (hours)	Fuel (gallons)	Operating costs ¹ (dollars)	Ownership costs ¹ (dollars)	Total costs (dollars)	Trips across field
Anhydrous application, 200 MFWD	0.08	0.64	3.49	7.30	10.79	1
Tandem disk, fold (21 feet), 160 MFWD	0.16	1.48	4.51	19.91	24.42	2
Black plastic mulch layer, 80 HP	1.41	0.38	1.15	7.35	8.49	1
Water wheel planter, 80 HP	3.17	0.38	1.15	7.35	8.49	1
Dry fertilizer, custom rate					13.50	2
Hauling hemp to processor, custom rate					100.00	
Total²	4.82	2.88	10.30	41.90	165.70	7

¹ Machinery operating cost is the sum of repairs and maintenance. Machinery ownership cost is the sum of overhead and depreciation.

² Totals may not sum due to rounding.

Abbreviations: MFWD = modified front-wheel drive tractor; HP = horsepower.

Laying plastic mulch and transplanting feminized clones into the mulch requires special equipment expected to be owned by the farmer. Harvest involves cutting individual plants, which are put on trailers and transported to barns where they are dried. After drying, the flowers and other biomass will be stripped from the plants, put into totes, and stored. Hauling the totes is considered a custom charge, though the farmer may have sufficient truck equipment to haul the totes. We estimated that 1,300 square feet of drying and storage capacity per acre would be necessary for delivering quality biomass.

Sensitivity analysis

Uncertainty abounds when new crops are grown. Sensitivity analysis illustrates how two critical

factors can influence income. Yields and market price uncertainty significantly impact income. Assuming that CBD hemp yields 1,200 pounds of biomass per acre, Table 5 presents multiple income over total costs estimates. The gray highlights show the scenario that corresponds to this budget with 10 percent CBD yield per pound of biomass and a \$2 market price per CBD percentage per pound.

Income over total costs assuming \$2 per CBD percentage point per pound can be found in Table 6. The gray highlights show the scenario that corresponds to this budget where the CBD yield column (10%) intersects the biomass yield row (1,200 pounds). Table 6 can be used to estimate income over total costs for various biomass yields and CBD yield measurement.

Table 5. Sensitivity analysis: income over total costs per acre, assuming 1,200 pounds of biomass per acre

Market price (dollars per percent CBD content per pound)	CBD yield (percent CBD content per pound biomass)							
	7	8	9	10	11	12	13	14
1.00	-8,045	-6,845	-5,645	-4,445	-3,245	-2,045	-845	355
1.50	-3,845	-2,045	-245	1,555	3,355	5,155	6,955	8,755
2.00	355	2,755	5,155	7,555	9,955	12,355	14,755	17,155
2.50	4,555	7,555	10,555	13,555	16,555	19,555	22,555	25,555
3.00	8,755	12,355	15,955	19,555	23,155	26,755	30,355	33,955

Table 6. Sensitivity analysis: income over total costs per acre, assuming \$2.00 per percent CBD.

Biomass yield (pounds biomass per acre)	CBD yield (percent CBD content per pound biomass)							
	7	8	9	10	11	12	13	14
800	-5,245	-3,645	-2,045	-445	1,155	2,755	4,355	5,955
1,000	-2,445	-445	1,555	3,555	5,555	7,555	9,555	11,555
1,200	355	2,755	5,155	7,555	9,955	12,355	14,755	17,155
1,400	3,155	5,955	8,755	11,555	14,355	17,155	19,955	22,755
1,600	5,955	9,155	12,355	15,555	18,755	21,955	25,155	28,355

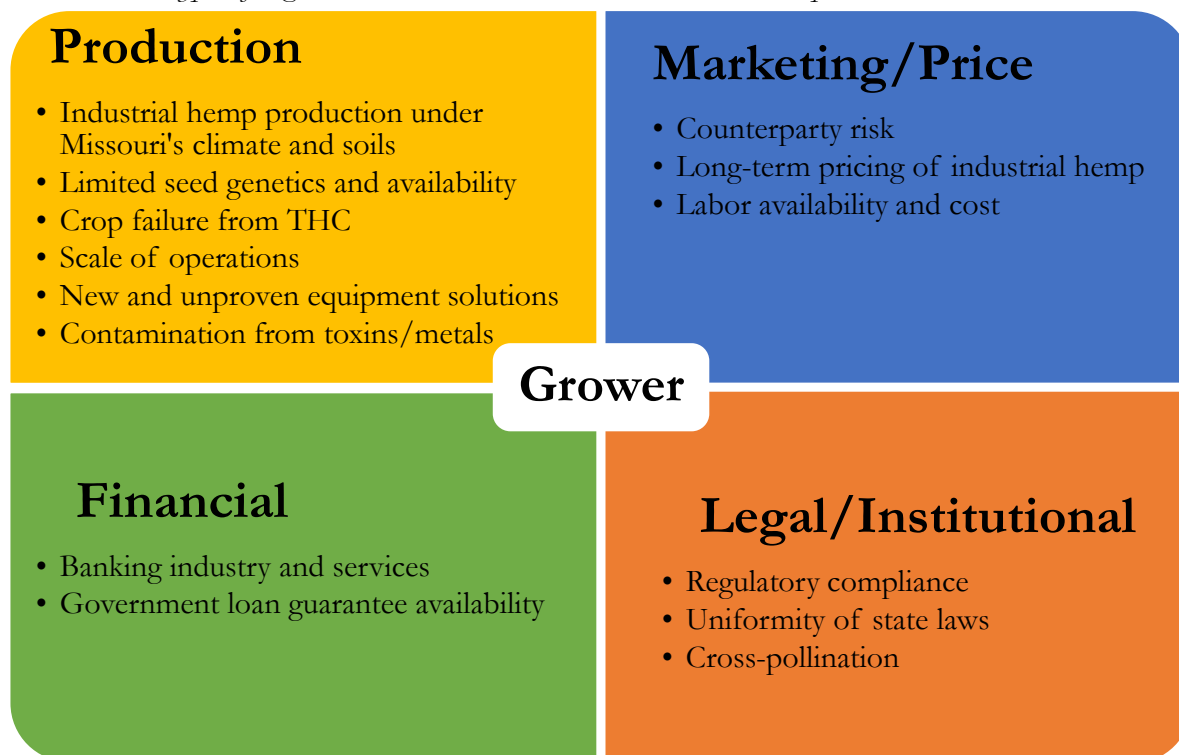


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5. Missouri Industrial Hemp Grower Risks and Mitigation

Farmers face many risks that generally fit into one or more of these categories: production, marketing/price, financial and legal/institutional. The following sections explain key risks that farmers should consider in their decision-making process with industrial hemp.

Exhibit 5.1 – Types of Agricultural Risks Associated with Industrial Hemp Production



5.1 Production Risk

Industrial Hemp Production under Missouri's Climate and Soils

Because hemp has not been commercially grown in Missouri for decades, very limited research and field data exists on hemp production given Missouri's climate and soils. It is unknown if crop yields achieved in other states under different conditions can be reached in Missouri. Additionally, it is unknown what production system is most desirable/suitable for planting, growing and harvesting in Missouri for each type of industrial hemp. Pressure from insects, weeds and diseases are unknown for industrial hemp under Missouri's climate. Currently, no chemical solutions (herbicides, insecticides and fungicides) are labeled for pest management in industrial hemp, so there are limited control methods. Farmers should do their due diligence and spend time investigating industrial hemp production and talking with other farmers who have successfully grown it.

Crop insurance is evolving for industrial hemp. The USDA announced that certain industrial hemp producers could seek coverage in 2020 through the Whole-Farm Revenue Protection (WFRP) program. Eligibility includes having a contract for the insured industrial hemp and complying with state and federal laws. Provisions include that replant and high THC levels are not insurable losses. WFRP has not seen much historical usage in Missouri. In June 2019, the Federal Crop Insurance Corporation developed a cooperative agreement with AgriLogic Consulting to develop a federal multi-peril pilot crop insurance program for industrial hemp. It is unknown when a pilot program will be developed in the U.S. and offered in Missouri to industrial hemp growers.

Limited Seed Genetics and Availability

Hemp seed and clones have been expensive and difficult to obtain in recent years. Some suppliers have reportedly sold poor quality genetics that do not produce the promised results. For CBD production, some producers have received clones that had a high proportion of male plants (Chandra et al., 2017). Additionally, some seed sold as feminized has turned out to include a high proportion of male seeds. Certified or approved genetics provide guaranteed information concerning quality, genetic purity and varietal identity. It is advisable to secure a seed or clone source from a reputable vendor in advance of production.

Crop Failure from High THC

An industrial hemp crop must be sampled and tested for THC content. If the crop is found to exceed the 0.3 percent limit, then it may be ordered to be destroyed by MDA. This would leave the farmer with no revenue and the responsibility for production costs incurred. Producers should understand that stresses to the hemp plant (e.g., nutrients, drought, flooding) or the plant's growth stage may cause a spike in THC levels, though these causes are not well-documented or -researched. Obtaining industrial hemp varieties known to have minimal or no THC is another strategy to minimize this risk.

Scale of Operations

Other considerations relate to scale of operations. If an industrial hemp crop was not sellable due to lack of buyers or destroyed due to high THC levels, then what would happen to the farming enterprise? Producers new to industrial hemp should consider their financial risk tolerance. Current industrial hemp growers have advised others to learn the production system under a smaller acreage footprint in the first year before trying to increase their scale of operations.

New and Unproven Equipment Solutions

New equipment technologies are being developed and promoted for planting, weeding and harvesting industrial hemp. Examples include specialized hemp planters, robotic weeding machines and harvesters for flower biomass. Many of these equipment solutions have not been proven at a commercial scale and tested for durability to date. Carefully consider solutions before making a significant capital investment. Seek out other producers who have used these equipment options, and ask for their testimonials.

Contamination from Toxins and Heavy Metals

Due to hemp's deep root system, it naturally cleans soils contaminated with a multitude of toxic substances – a process known as “bioremediation” or “phytoremediation.” Industry sources in California suggest around 50 percent of manufacturers' intake of biomass flower material are failing the California Bureau of Cannabis Consumption Category 3 Testing compliance, which tests for the presence of mycotoxins (mold), heavy metals, pesticides and fungicides. As other states develop regulations around acceptable levels of toxins and heavy metals, processors will decline to purchase hemp crops that do not pass testing.

5.2 Marketing and Price Risk

Counterparty Risk

Farmers face counterparty risk when contracting with processing companies. A processor may commit with a contract to buy a crop, but it may realize later it cannot pay at harvest or does not have the capacity to process the crop under contract. If the processor defaults on the contract, then the farmer could be left with the industrial hemp crop and be forced to find a different purchasing party. Know that contracts are essential, and do your homework about the contracting entity or processor.

Long-Term Pricing of Industrial Hemp

Pricing for industrial hemp will remain volatile as markets and regulation evolve. Given the large 2019 estimated U.S. industrial hemp acreage (largely in industrial hemp for CBD production), the markets could be saturated quickly and decrease the profitability and returns realized by industrial hemp growers. Markets demanding hemp grain and hemp fiber have been limited to date and are in their infancy. Because of these factors, the long-term pricing of industrial hemp and its co-products is uncertain. To mitigate marketing risks, entering into contracts with defined pricing structures from reputable companies is advised prior to beginning industrial hemp production. Farmers should also understand their cost of production and sensitivity to price changes.

Labor Availability and Cost

Finding affordable and quality labor can be a challenge in Missouri. Current production systems used to raise industrial hemp for CBD are very labor-intensive. Mechanical solutions that can achieve scale might alleviate the labor challenge in the future. But current industrial hemp growers have utilized H-2A temporary agricultural visas for foreign nationals to provide much of this labor.

5.3 Financial Risk

Banking Industry and Services

Credit has been difficult to obtain for industrial hemp growers in the past. Many banks are still uncertain about the policies related to lending to industrial hemp farmers and the risks associated with farming, storing, processing and marketing industrial hemp. Because of this, many farmers have turned to self-financing or private equity sources.

As state and federal regulations are clarified for industrial hemp and hemp-derived products, such as CBD, further guidance to the banking industry will be given to financial institutions that may alleviate credit problems. A well-designed federal crop insurance program for industrial hemp could provide some stability in lending and banking services.

Government loan guarantee availability

Federal and state loan guarantee programs are commonly used by farmers with high leverage to secure financing from lenders unwilling to lend to higher risk clients. Hemp producers using USDA Farm Service Agency direct and guaranteed loans will be required to have a contract for their production and to purchase crop insurance. Whole Farm Revenue insurance will be available for hemp production in 2020.

5.4 Legal/Institutional Risk

Regulatory Compliance

The industrial hemp industry will be heavily influenced by regulatory agencies and decisions made for compliance. The U.S. Food and Drug Administration (FDA) is tasked with regulating hemp and hemp-derived products, such as CBD, when used in drugs, foods and dietary supplements. Some products such as hemp seeds, hemp seed protein and hemp seed oil achieved generally recognized as safe (GRAS) status. But the CBD industry could change dramatically when the FDA provides clearer regulatory guidance. Federal regulation of industrial hemp from the FDA will greatly impact the future and potential growth of certain markets and companies joining the marketplace.

Uniformity of State Laws

Industrial hemp has been legal in some states and illegal in others. Because of this, there have been cases of legal crops being seized and drivers arrested for transporting harvested product through states where industrial hemp is not legal. Even though industrial hemp is now federally legal and no longer listed as a controlled substance, state laws are not uniform and should be obeyed. For example, industrial hemp is legal, but smokable flowers from industrial hemp are not allowed in certain states. It is important for producers and processors to understand industrial hemp and hemp-derived product laws in states where they plan to operate.

Cross-pollination

Note, Missouri is in the process of developing a medicinal marijuana industry. Applications were accepted in fall 2019 and permit announcements are expected in January 2020. The state plans to license a minimum of 60 cultivation facilities, 192 dispensaries, 86 manufacturing facilities and 10 testing labs. Cross-pollination presents a risk. Male hemp plants can pollinate female plants, which can influence the THC levels in marijuana and cannabinoid (CBD and CBG) levels in industrial hemp. Male plants are common in industrial hemp raised for fiber and grain. Additionally, Missouri has many counties with wild hemp populations. Pollen drift lawsuits in states such as Oregon with significant acreages of industrial hemp and marijuana have been widely reported (Perkowski, 2019). States have seen lawsuits claiming damages for lost crops due to cross-pollination issues. Isolation zones (3 miles to 15 miles) between industrial hemp and marijuana fields have been recommended or required in various U.S. states. Farmers should know about local growing areas that might impact their operations or another nearby operation.

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