

## **An Introduction to Industrial Hemp and Hemp Agronomy**

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Industrial hemp (*Cannabis sativa* L.) was at one time a major agronomic crop in Kentucky. In *A History of the Hemp Industry in Kentucky* (1951), author James F. Hopkins reported that it was a common crop on central Kentucky farms. This was true from the late 18<sup>th</sup> through the 19<sup>th</sup> century. Nearly all farms growing hemp at that time were mostly interested in the fiber it produced. Farms with limited labor pools grew less or no hemp. It was a very labor-intensive crop both at harvest and during processing.

*Cannabis sativa* is a summer annual plant. It is strongly photoperiodic (flowers according to day length/photoperiod; not physiological maturity). It is mostly dioecious in that male and female flowers occur on separate plants (i.e. there are both male plants and female plants). There are several monoecious commercial varieties (male and female flowers parts on the same plant). Different plant parts are harvested from hemp for specific purposes. Depending on the harvestable component of interest, (i.e. fiber, grain or cannabinoids) male plants and pollen might be vitally necessary or completely unwanted.

Industrial hemp is produced for one or sometimes dual purposes. Fiber from plant stems can be utilized in numerous ways ranging from low tech yarn and fabric to high tech electrical super-capacitors manufactured from biochar. Other potential uses of hemp fibers could include alternatives for wood in construction materials (chip-board or particle-board), strength-increasing components added to concrete (hempcrete), or fiber used in composite materials in place of synthetic fibers (molded, injected plastics). A complete list of the potential uses for hemp fibers is too long to provide here. Uses for hemp fibers today are different and much broader than when hemp was last grown in Kentucky. Today, there is not much need for hemp rope or perhaps large hemp linens for sailing ships, etc. as there was in the 19<sup>th</sup> century. But, fibers from hemp possess several very positive attributes that make them useful as modern natural fibers.

The grain (seed) of hemp can also be used in numerous ways. As a dietary supplement for humans, it contains a very desirable ratio of omega-3 and omega-6 fatty acids compared to many other potential sources. It is also relatively high in both oil and protein content. Hemp grain processors produce a wide array of consumer products including raw hemp hearts, toasted hemp seed, hemp seed oil, hemp flour, and even hemp coffee. It is also used as bird feed and livestock feed in some other countries, either whole or in part. Again, an entire list of potential uses of hemp grain is very long. It is not unusual for producers to harvest hemp grain with combines and subsequently harvest the remaining stems for fiber similarly to harvesting a hay crop. This is the most common example of a dual-purpose industrial hemp crop. Of course, if hemp does become a viable commodity crop in Kentucky and the U.S., seed production, especially certified seed, for establishing next year's hemp crops could be an excellent option for Kentucky producers. Our soils, climate and existing infrastructure are very conducive to hemp seed and grain production.

Cannabinoids are another harvestable component of *Cannabis* plants. They are plant-generated molecules that are known to have certain significant effects on humans. Cannabinoids are mainly but not exclusively produced by plants in the genus *Cannabis*. The most familiar cannabinoid is delta-9 tetrahydrocannabinol, or THC. This molecule is intoxicating and is responsible for the 'high' obtained from using marijuana. Under the 2014 Farm Bill, the concentration of THC (by dry weight) defines a *Cannabis* plant as either marijuana (>0.3% THC) or industrial hemp (= $\leq$ 0.3% THC). This is the only distinction between marijuana and industrial hemp. They are the same plant species. A simple analogy might be to compare sweet corn and field corn. They are both *Zea mays*, but sweet corn (marijuana) contains higher levels of sugar (THC) than field corn (industrial hemp) which is higher in starch (other cannabinoids).

There are dozens of other naturally-occurring cannabinoids besides THC. One particular molecule, cannabidiol or CBD, is currently of deep and broad interest among pharmaceutical and medical researchers. Cannabidiol is known to have strong potential for pharmaceutical applications. For example, certain epileptic patients treated with CBD experience highly significant reductions in the frequency and severity of seizures. There are other proposed, positive effects of CBD. Examples include potential uses as an

analgesic, appetite enhancer, and anti-depressant. Many of the cannabinoids identified to date have not been studied for their potential as pharmaceutical agents. It is also thought that some number of cannabinoids remain to be identified.

Cannabinoids are present throughout the plant, but are mostly concentrated in the bracts (actually in the trichomes on bracts) of female flowers. Cannabinoids are found at much lower concentrations in root, shoot and leaf tissues, and are not found in significant concentrations in hemp seed, seed oil or pollen. In the case of optimizing cannabinoid production on a field scale, it is not known if the entire plant would be harvested and processed for cannabinoids, or just the female flowers. Field-scale cannabinoid production *could* be a case where male plants are totally unwanted. The concentrations of cannabinoids in male plants is very low relative to female flowers. Also, it is reported anecdotally that unfertilized (un-pollinated) female flowers tend to produce more cannabinoids than when they are pollinated and allowed to produce seed following fertilization by male plants. As a result, in clonal propagation systems where all female plants are established, attempts would be made to prohibit male plants near the production field. We've conducted experiments to test the effects of pollination on cannabinoid production in both indoor and outdoor systems. We will publish these results as soon as possible.

### **General Production Information**

It is important to note that since the early 20<sup>th</sup> century and until 2015, there have been no U.S.-based agronomic research studies with industrial hemp. Information from previous research is important and useful, but may not always be optimal for modern production systems. It is already very clear that different varieties of industrial hemp will respond very differently to our latitude and basic agronomic inputs. This is especially true regarding varieties grown for different purposes. Varieties grown for fiber-only will be established, managed and harvested differently than varieties grown for grain or dual-purpose. Fiber and/or grain varieties will likely be established and managed very differently than those grown for cannabinoids. The University of Kentucky is conducting basic agronomic trials with varieties grown for all three harvestable components (fiber, grain, and cannabinoids). Until the information from these and other replicated research trials in the U.S. is available, we must rely on previous U.S.-based research and more recent research from other countries.

#### *Basic terms and definitions*

Pure live seed (PLS) is the seed in a container that will likely produce a viable plant when planted appropriately (depth, timing, etc.). Recommended seeding rates are always expressed as pounds of PLS/A. All containers of seed will have a mass or weight of materials in addition to PLS. This is usually expressed as a percentage of the total weight in the container. Examples include inert materials (soil, chaff, and other plant parts) as well as seed that will likely not germinate (immature or dead seed). Other contributions to reductions of PLS in a container are other crop seeds and weed seeds. The percentages of inert or other materials (non-crop seed) along with the germination percentage of the crop seed defines PLS. For example, a container includes 5% non-crop seed and has a germination rate of 75%. This means that 5% of the weight of the material in the container is not crop seed and that only 75% of the crop seed will likely germinate and produce a new plant. In order to calculate the amount of seed needed to accommodate recommended seeding rates, we need to increase the amount seed planted by 30% above the recommended seeding rate (5%+25%; the sum of non-crop seed and crop seed that will likely not germinate). For example, if the recommended seeding rate is 60 pounds of PLS/A, we divide the seeding rate (60) by the PLS percentage (0.70 which equals 70%). The result is we would need to apply approximately 86 pounds of this particular seed per acre to achieve the 60#PLS/A seeding rate. If germination percentages are not provided, it would be wise to have a germination test performed prior to seeding. This is true even if non-crop seed percentages are not available. We have witnessed very poor germination of some hemp varieties, and have received several anecdotal reports of the same. Poor germination equates to poor stand

establishment. Poor establishment leads to increased weed pressure, reduced yields, harvesting problems, or crop failures. Using the proper seeding rates based on PLS is imperative for successful hemp establishment and harvest. We note, too, that the 1000-seed weights vary significantly among hemp varieties. We are working on recommendations based on the number of plants per square meter for successful establishment rather than pounds of seed per acre. The 1000-seed weights can sometimes differ by 2X among varieties, which would have a highly significant impact on plant populations and successful establishment.

Nutrient application rates are expressed as units or pounds of nutrient per acre. The amount to apply using a specific fertilizer is calculated by dividing the desired nutrient application rate by the analysis of the fertilizer. For example, to apply 50 units of nitrogen (N)/A using urea (46-0-0), we divide 50 by 0.46 (46% N in urea) which equals approximately 109 pounds of urea applied per acre.

### *Site selection and inputs*

Although industrial hemp has been touted as a low-input crop highly adaptable to marginal lands, the scientific literature from other countries as well as research work at UK clearly indicates that maximum yields are realized with inputs equivalent to current grain production systems (e.g. wheat, corn) and on productive land (>170 bu/A corn). If maximum industrial hemp yields are the goal, select good corn land and plan on inputs equal to current grain crops. If maximum yields are not the goal, industrial hemp can be expected to perform on marginal lands with lower productivity and with reduced inputs much the same as our current commodity crops would.

### *Varietal responses*

Variety selection will be key to success for many reasons, most importantly days to maturity (latitudinal adaptation). There is much to know about selecting the proper variety. For example, varieties bred primarily for grain production could have significantly different maturity dates relative to each other, and therefore would have very different establishment dates for maximum yields and a crop that is harvestable with standard equipment. Producers should research varieties based on the harvestable component of interest (fiber, grain/fiber, or cannabinoids) and choose varieties that are proven performers. Hemp seed produced in Kentucky and certified under AOSCA guidelines will be available beginning in 2018. We expect domestic certified seed production will continue to increase. Standard industrial hemp variety trials are conducted at UK annually. The reports are posted on the UK agronomic hemp website: <http://hemp.ca.uky.edu/>.

### *Establishment from seed*

It appears that industrial hemp seed is quite sensitive to a lack of soil moisture at planting. This trait has not been quantified but could readily contribute to stand failures. Seed should be planted in soils with adequate moisture to encourage rapid germination. If soil moisture is inadequate for industrial hemp germination, it is likely still adequate to support the germination of many weed seeds. Without the availability of legal herbicide applications in industrial hemp production systems, we rely heavily on rapid industrial hemp canopy development and closure to reduce or eliminate competition from weeds. Adequate soil temperature ( $\geq 50^{\circ}\text{F}$ ) and moisture at planting will help accomplish this. Planting depth should never exceed one inch (1”), and 0.5 – 0.25 inch would be preferred. Industrial hemp seed can be successfully drilled with both conventional tillage and no-till protocols. Seeding dates will depend on the harvestable component (fiber, grain, or cannabinoids) and equally on variety. Fiber crops will be harvested at the onset of reproductive growth and should be planted as early as possible to maximize vegetative growth (biomass production). Days to maturity of grain crops will vary a great deal among varieties. As such, some grain varieties should be planted much later than others to manage crop height at maturity. Optimal, field-scale

cannabinoid production systems are not yet well-defined. Lacking appropriate research-based information, cannabinoid production from seed should be thought of similarly to grain production. In very general terms, industrial hemp seed can be planted in late April or early May in Kentucky. Seedling industrial hemp is tolerant of light frosts, but it is probably best to avoid the last killing frost while still taking advantage of good soil moisture and adequate soil temperatures common in spring.

### *Pesticides*

There are currently no pesticides (herbicides, insecticides, fungicides, nematocides, etc.) labeled for use in industrial hemp crops in the U.S. This is true for both indoor and outdoor (field-scale) production systems. This means that any pesticide applications to industrial hemp crops are off-label and therefore illegal. Work is underway to evaluate pesticides for use in industrial hemp production systems and also to investigate several options for emergency exemptions within the rules and policies of the U.S. EPA. Today, it is imperative to make good management decisions to reduce the negative effects of pests, particularly weeds. Variety selection, soil moisture at planting, seeding dates, seeding rates, and fertility are examples of management decisions that will potentially reduce competition from weeds and increase yields without herbicides. To date, we have not witnessed significant pressure from insect or disease pests in field-scale production systems for fiber or grain. We are aware of reports of disease issues in field-scale cannabinoid production systems, especially when clones are used as transplants. There have been serious reports of both disease and insect pests in indoor growing systems in Kentucky.

### *Harvest protocols*

Harvesting industrial hemp grain by combine is the norm in other countries and has been accomplished successfully in Kentucky. Again, variety selection is key as the growth habits of those varieties bred primarily for grain production are more conducive to harvest by combine. Grain from varieties bred primarily for fiber production could be very difficult or perhaps impossible to harvest efficiently by combine, especially if planted early. Harvesting fiber crops is more complex. Fiber crops will nearly always require retting prior to baling. Retting is essentially a quasi-controlled rotting process. During retting, microbial activity breaks down the pectin layer between the bast and hurd fibers thus allowing for efficient separation. Microbial activity will be very sensitive to temperature and moisture. Generally speaking, warm and moist conditions will encourage microbial activity. The equipment for optimal cutting and then management of the crop during retting does not yet exist in the U.S. Additionally, field-retting industrial hemp will require new skills remotely similar to those involved in making high quality hay. Successful field retting will be totally dependent on weather conditions just as is making good hay. Over-retting will dramatically reduce the quality of the fiber. Under-retting will make processing inefficient or impossible. Harvesting for fiber with standard hay equipment can be difficult. Current thinking involves mowing by sickle-bar or mower-conditioner without conditioning/macerating, retting in the field, followed by baling (round or square). Optimal harvest and processing/storage methods for cannabinoids are not well defined in field-scale systems. Research is on-going at UK to address all of these questions.

**General agronomic recommendations for the main harvestable components of industrial hemp.**

	Fiber	Grain/dual purpose	Cannabinoids*
Seeding Rate (PLS)	40-60#/A	20-40#/A	20-40#/A
Row spacing	8 inches	8-16 inches	8-16 inches
Applied Nitrogen	50 units/A	100 units /A	50-100 units/A
Available Phosphorus	60 units/A	60 units/A	60 units/A
Available Potassium	300 units/A	300 units/A	300 units/A
Harvest timing	<=20% male flowering	~70% grain maturity	~75% trichome maturity

\*Optimum agronomic protocols for cannabinoid production in field-scale systems have not been defined by replicated research methods. Much of what is practiced today is extrapolated from Cannabis production systems in U.S. states where it is legal and/or from other countries. Many production practices from these systems (e.g., fertility) pertain mostly to indoor and not field-scale production. Very important questions remain regarding field-scale systems to produce cannabinoids. These include understanding the effects of variety, establishment methods (e.g., direct seeding versus transplanting), and management decisions including nitrogen fertility and harvesting/processing/storage issues. Research is underway to address these questions.

*Other UK Extension publications regarding industrial hemp:*

Economic Considerations for Growing Industrial Hemp: Implications for Kentucky’s Farmers and Agricultural Economy. Department of Agricultural Economics, University of Kentucky.

July 2013. <https://www.uky.edu/Ag/AgEcon/pubs/reshempimpfarmer28.pdf>

Industrial Hemp Production. UK Center for Crop Diversification, University of Kentucky. September 2015. <http://www.uky.edu/ccd/sites/www.uky.edu/ccd/files/hempproduction.pdf>