An Introduction to Industrial Hemp, Hemp Agronomy, and UK Agronomic Hemp Research

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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 very common crop on the vast majority of central Kentucky farms. This was true from the late 18th through the 19th century. Nearly all farms at that time grew hemp, mostly for the fiber it produced. However, farms with limited labor pools grew less or no hemp. It was a very labor-intensive crop both in the field and during processing.

An excellent history of the scope and legality of industrial hemp production in Kentucky can be found in the UK extension publication *Economic Considerations for Growing Industrial Hemp: Implications for Kentucky's Farmers and Agricultural Economy.* Since that publication was released in 2013, the 2014 Farm Bill has provided for pilot research projects under the auspices of the Kentucky Department of Agriculture. In addition, the Kentucky General Assembly passed legislation supporting the pilot research program. UK is an approved participant in the pilot research program as administered by the Kentucky Department of Agriculture.

Cannabis sativa is a summer annual plant. It is strongly photosensitive (flowers according to day length; 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 a few monoecious varieties (male and female flowers on the same plant), but most cultivated hemp varieties are dioecious. 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 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 carbon nanosheets. Other potential uses of hemp fibers could include alternatives for wood in construction materials (chip board or particle board), components added to concrete (hempcrete), or bast fibers used in composite materials in place of synthetic fibers (molded 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 as much need for hemp rope or perhaps large hemp linens for sailing ships, etc. as there was in the 19th 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 is very rich in omega-3 and omega-6 fatty acids compared to many other potential sources. It is also relatively high in oil content. Hemp grain processors in Canada produce a wide array of consumer products including toasted hemp seed, hemp seed oil, hemp flour, and even hemp coffee. It is also used as bird feed and livestock feed, either whole or in part, much the same as soybean hulls are used today. Again, an entire list of potential uses of hemp grain is very long. It is not uncommon for producers to harvest hemp grain with combines and subsequently harvest the remaining stems for fiber. 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 for establishment of the subsequent year's hemp crops could be an excellent option for producers. Our soils and climate are very conducive to high hemp seed and grain yields.

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 produced by plants in the genus *Cannabis.* The most familiar cannabinoid is delta-9 tetrahydrocannabinol, or THC. This molecule is psychoactive and is responsible for the ‘high’ obtained from using marijuana. Under the 2014 Farm Bill, the concentration of THC (by weight) defines a Cannabis plant as either marijuana (>0.3% THC) or industrial hemp (=/<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) has much more 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 pharmaceutical effects. For example, certain epileptic patients treated with CBD experience highly significant reductions in the frequency and severity of seizures. There are other known, positive effects of CBD. Examples include 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 probably very low relative to female flowers. Also, it appears that unfertilized female flowers tend to produce more cannabinoids than when they are allowed to produce seed following fertilization by male plants.

General Production Information

It is important to note that there have been very few U.S.-based agronomic research studies with industrial hemp since the early 20th century. 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 differently to 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 and others will conduct basic agronomic trials beginning in 2015 with varieties grown for all three harvestable components (fiber, grain, and cannabinoids). Until the information from this and other work in the U.S. is available, we must rely on previous U.S.-based research and more recent research from other countries as provided below.

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 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 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, variety selection will define days to maturity (regional adaptation). There is much to know about selecting the proper variety; too much information to include here. 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. Producers should research varieties based on the harvestable component of interest (fiber, grain/fiber, or cannabinoids) and choose varieties that are proven performers in other countries. Also, consider the latitude from which the variety originates. If it is significantly different than Kentucky, the size of the plant at flowering in Kentucky may be much smaller or much larger than the plant would be when grown where it was originally adapted. It appears that germination can be affected by several factors including seed quality (maturity at harvest, age, storage conditions) as well as variety. Today, work is underway to define and then implement standards for the production and sale of certified industrial hemp seed in the U.S. Until that work is complete, we must rely on the standards of other countries, or in some cases, have no standard information from unbiased sources about the varieties that are available.

Establishment from seed

It appears that industrial hemp seed could be quite sensitive to 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 (>/=50°F) and moisture at planting will help accomplish this. Planting depth should never exceed one inch (1”), and 0.25-0.50 inch would be preferred. It appears that industrial hemp seed can be successfully drilled with both conventional tillage and no-till protocols. Seeding dates will depend on the harvestable component 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. Days to maturity of grain crops can vary a great deal among varieties. As such, some grain varieties should be planted much later than others. 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 should 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.

Pesticides

There are currently no pesticides (herbicides, insecticides, fungicides, nematicides, 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. 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. 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 was accomplished successfully in Kentucky in 2014. 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 much more complex. Fiber crops will require retting prior to baling or chopping. 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 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. Today, harvesting for fiber will be difficult at best. Current thinking involves mowing by sickle-bar, retting in the field, followed by baling (round or square). Another option is harvest by forage chopper, but this presents new issues such as efficient transportation and storage prior to processing. Harvesting methods for fiber crops will also depend heavily on the intended use of the fiber (e.g., longer fiber for yarns and fabric compared to shorter fiber for industrial uses or animal bedding). Optimal harvest methods for cannabinoids are not well defined in field-scale systems.

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

	Fiber	Grain/dual purpose	Cannabinoids*
Seeding Rate (PLS*)	60#/A	20-40#/A	20-40#/A
Row spacing	4-8 inches**	8-16 inches	8-16 inches
Applied Nitrogen	50 units/A	150 units /A	50-100 units/A
Harvest	</=20% male flowering	~70% grain maturity	~75% trichome maturity

*PLS=pure live seed and would be equal to the amount of seed necessary to achieve 100% germination; taking into account the amount of crop seed, other seeds, inert material, and the germination rate.

**Broadcast seeding (e.g., Brillion seeder) following by cultipacking can be an acceptable method of establishing industrial hemp for fiber.

Optimum agronomic protocols for cannabinoid production in field-scale systems have not been defined. Much of the available information is extrapolated from Cannabis production systems in U.S. states where it is legal and/or from other countries. Nearly all of these systems are indoor and not field-scale, or are very limited in scale. Very important questions remain regarding field-scale systems to produce cannabinoids. These include variety selection, establishment methods (e.g., seeding rates, direct seeding versus transplanting), and management decisions including nitrogen fertility and harvesting methods.