Science Societies

Making hemp a 21st century commodity in Oregon—and beyond

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Jay Noller (left), director and lead researcher of the Oregon State University Global Hemp Innovation Center, and Lloyd Nackley, a hemp researcher, at the launch of the center. Photo courtesy of Oregon State University.

With passage of the 2018 farm bill, hemp has been re-established as a legal crop, and with that has come a resurgent enthusiasm for its production. The Global Hemp Innovation Center (GHIC) was launched in June of 2019 as the largest and most comprehensive hemp research center in the nation. Since its launch, the GHIC has been busy engaging the many industry sectors that touch on all aspects of hemp supply chains and organizing faculty around these sectors to help solve the challenges hemp faces to become a 21st century commodity. Following are general observations about hemp specifically grown in Oregon but with reference to production elsewhere.

The Global Hemp Innovation Center (GHIC) was launched in June of 2019 as the largest and most comprehensive hemp research center in the nation—a response to the recently decriminalized crop and an emerging industry in need of scientific information. Before its launch, director Jay Noller had spent years cultivating relationships across the globe, preparing for the inevitable shift in policy that would legalize this versatile crop. Since its launch, the GHIC has been busy engaging the many industry sectors that touch on all aspects of hemp supply chains and organizing faculty around these sectors to help solve the challenges hemp faces to become a 21st century commodity. Following are general observations about hemp specifically grown in Oregon but with reference to production elsewhere.

Hemp, A New ‘Old’ Crop

As has been repeatedly recited, hemp can be used in the manufacture of tens of thousands of products. In 1938, *Popular Mechanics* magazine ran an article reporting that there were more than 25,000 products that could be made from hemp—that hemp was a billion-dollar crop. The potential for producing many of the same products still exists today, but hemp has even greater potential to contribute to a new biobased economy that replaces petroleum in the production of medicines, high-performance textiles, and advanced materials manufacturing. An updated outline is shown in Figure 1 of the wide range of market classes and products that can be produced from hemp grain, fiber, and essential oils.

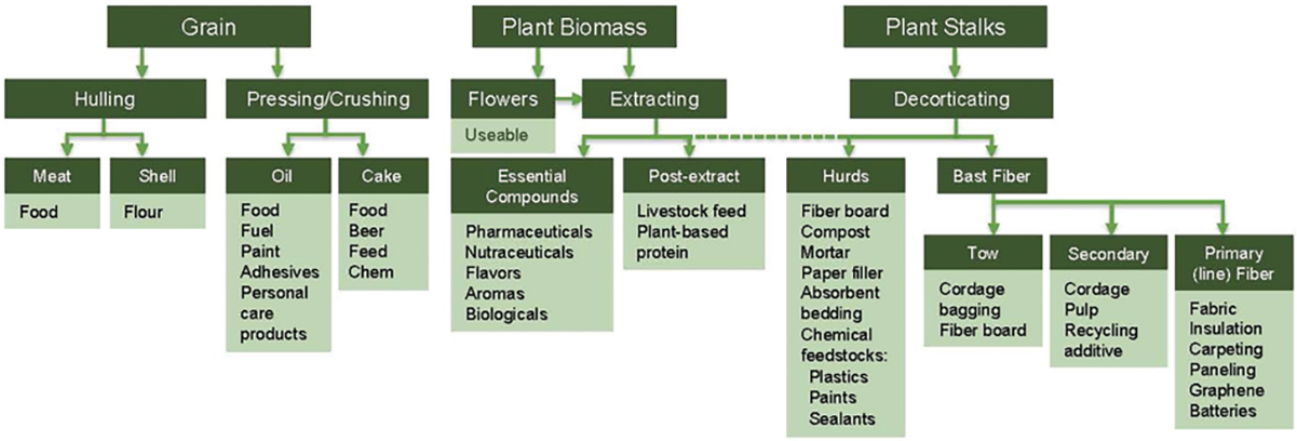


Figure 1, *The many kinds of products that can be made from hemp grain, biomass, and fiber. Adapted from Congressional Research Service Report, "Hemp as an Agricultural Commodity," RL32725, 2018.*

With passage of the 2018 farm bill, hemp has been re-established as a legal crop, and with that has come a resurgent enthusiasm for its production. As a result, the number of planted acres rapidly increased in Oregon, primarily for the production of cannabinoids such as cannabidiol (CBD) produced in flowers and other plant parts. However, with business plans not being fully thought through, incomplete supply chains that should link production fields to consumer markets, and regulatory uncertainty around products made from hemp that limit its market outlets, many

growers and processors are still holding hemp biomass and processed extract inventories. For grain hemp, consumer markets are still developing, and regulations prevent it from being used as a livestock feed. For hemp fiber to be produced, highly capitalized facilities that process plant stalks must be built to produce the fibers for use in textile and other product manufacturing. On top of this, the exclusive use of feminized plants in Oregon to produce cannabinoids and other natural compounds precludes the introduction of grain and fiber varieties because these diecious plants would produce pollen that could pollinate feminized plants and cause them to produce seeds, which is an inconvenience to usable flower markets and interferes with extraction and processing of cannabinoids from biomass.

Because of the only recent re-introduction of hemp into agricultural landscapes, there is a general lack of knowledge on where different hemp essential oil, grain, and fiber market classes should be grown and how these could be sustainably incorporated into already established agricultural production systems. A greater understanding is also needed in sourcing the best-adapted genetics to optimize dependable production of high quality materials to supply processing facilities that produce products meeting manufacturer and end-user quality specifications.

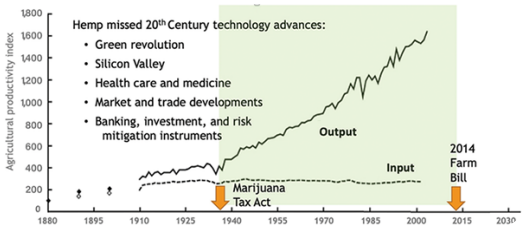


Figure 2, *Eighty years of discovery and innovation have propelled agricultural productivity to this point in time when more food, feed, and fiber are produced for so many, by so few, than ever before. Hemp-*

*based agriculture must catch up to challenge other agricultural commodities in the market. Adapted from: Persistence Pays by Alston et al., 2010. Springer. Figure **2**, **3**, p. 15. See **https://bit.ly/3d48rqe**.*

Most of these fundamental agricultural production principles have been worked out for other agricultural commodity over the past 80 years (Figure **2**). Hemp in the meantime has been buried in a time capsule and has not benefited as other agricultural commodities have from the science, business, and policy innovations that now produce high-value products that reach markets and consumers worldwide. The hemp industry now needs to advance at an accelerated pace to be brought up to a competitive position alongside other U.S. agricultural commodities and products. In nearly every aspect of production from genetics to agronomy, pest management to harvest and processing, best practices for growing, contracting, insuring, and marketing hemp need to be established and validated.

Those engaged in hemp farming can be described as ranging in experience from fourth-generation farm families who have never grown hemp to those whose families have not been involved in agriculture for four generations. Being a new "old" crop, there is a lack of experience dealing with hemp. Much of present knowledge on hemp is based on marijuana production led by advisers and producers who may not have field-scale agriculture experience. Traditional agricultural institutions such as land grant universities in general do not have any experience with hemp because they were shut out from working with the crop until the past two years. Therefore, special efforts are needed to tap into existing and emerging knowledge about hemp to determine what works or doesn't work. The expression of the land grant mission of research, extension, and education has been evolving over the past decades, and with hemp, further adjustment will need to be ongoing. Oregon State University (OSU) has begun to do this with establishment by engagement of faculty not only on campus, but

around the state at our branch research and extension centers.

Need to Establish Where Hemp Market Classes Will Be Produced



CBD-infused oil made from hemp. Photo by REUTERS/Lucy Nicholson and courtesy of Adobe Stock.

The commodities predominantly grown in different regions across the U.S. fit where they do because there is relatively dependable production year after year and mature supply chains and markets have been established to utilize what farmers produce. The USDA's Economic Research Service (ERS) has created a national framework outlining what commodities are produced where and who produces it. This is a good starting place to understand the existing geographic specialization of farm commodities and to figure out how hemp would best fit where you want to farm (Figure 3). The costs and returns of hemp farming need to benchmarked to existing commodities.

A systematic understanding is needed not only about the adaptability of hemp to different production environments, but also how hemp essential oil, grain, and fiber types can be incorporated in ways that complement already established agricultural production systems. Field-grown hemp is widely adapted to many U.S. growing conditions from the tropical Puerto Rico and Hawaii to temperate seasonal climates found across the continental border with Canada and in Alaska. The wide adaptability of hemp has been demonstrated with the production of essential oil-type hemp varieties grown throughout the U.S. where it is legal to do so. Much of the outdoor essential oil production has evolved as scaled versions of marijuana production using similar methods regarding use of transplants planted in wide-spaced configurations,

use of expensive fertilizers injected into irrigation systems, plastic mulches to control weeds, and great labor inputs, particularly around harvest. Biomass hemp emerged as a significant crop in just the past few years because of easy accessibility by new and small-scale growers, driven by the potential for great returns based on high sale prices of CBD. This expansion in production was also possible because the technology required to extract essential compounds from flowers and other plant parts is well understood and available.



Figure 3, *The USDA Economic Research Service has created a set of agricultural production regions that describe geographic specialization of commodities at the U.S. farm level. Adapted from USDA-ERS Farm Resource Regions, Agricultural Information Bulletin Number 760, September 2000. See* ***https://bit.ly/3cZgaWP****.*

The production of hemp for grain is generally similar to cereal grains, so the required production, harvest, and processing technology are well understood and available. Grain hemp has been grown in Canada since 1998. With passage of USDA farm bill legislation, North Central states of North Dakota and Montana have emerged as the primary producers of hemp grain. There is emergent production of hemp grain in Wisconsin, Minnesota, and Washington. However, like any grain crop, the configuration and settings for optimal results from conditioning or processing need to be determined.

Hemp fiber can be produced from dual-purpose grain and fiber varieties or from fiber-type varieties such as those grown in Europe and China. In Canada, the production of fiber is viewed as a co-product with grain as it is in the grain-producing states. However, hemp fiber quality is optimal sooner than grain maturity, so for high quality fiber production to occur, dedicated fiber production will be needed as is done in Asia

and Europe. Until it has been demonstrated where the high quality fiber hemp can be best grown and economically linked to handling and processing facilities, the capital investment needed to build out a domestic hemp fiber industry in the U.S. will not occur. Presently there is interest in establishing hemp fiber processing from traditional textile producers such as North Carolina, to Texas and Montana, to Washington. How this sorts out is still to be seen.

Hemp Genetics Need to Be Systematically Evaluated



Inspecting a field of hemp. Photo by REUTERS/Francois Lenoir and courtesy of Adobe Stock.

Coordinated state and regional commodity variety trials are commonly used for crops such as wheat, soybeans, and potatoes. Networks such as these have not been established for hemp. A first coordinated national hemp variety testing effort was begun in 2020 through the USDA National Institute of Food and Agriculture sponsored regional research committee S1084, "Industrial Hemp Production, Processing, and Marketing in the U.S.," made up of land grant university members from around the country. Oregon State University leads the essential oil-testing effort while the University of Kentucky leads the grain/fiber variety testing.

Most commodity-testing efforts of this kind involve defined crop growth, yield, and quality measures that are used by all of the participants. Researchers at OSU are developing a set of plant growth descriptors for hemp with input from the S1084 university cooperators, commercial seed companies, and the newly established hemp germplasm curator at the USDA-ARS located in Geneva, NY. Crop growth descriptors

are used to compare standard sets of varieties grown in different production environments across the country. For the essential oil variety trials in 2020, six commercial varieties varying in photoperiod sensitivity, growth habit, and end-product quality were grown in Kentucky, Tennessee, Virginia, West Virginia, Louisiana, Alabama, New York, Vermont, Wisconsin, Montana, California, and Oregon. Standardized sampling protocols were set up, and the flower samples are being analyzed for a 12-cannabinoid profile to determine yields. The information gained from this experiment will be used to determine how different growing environments affect the performance of a standard set of varieties and to identify the number of different growing environments that are needed to set up testing location networks.

Because hemp production is regulated based on delta-9 tetrahydrocannabinol (TCH) levels at harvest, another aspect of this research is establishing a plant-based criterion for determining when to harvest essential oil hemp varieties that comply with regulated THC levels. Using popular information describing optimal harvest timing for marijuana, published journal articles, and consulting knowledgeable individuals, an initial benchmark was developed based on the color of secretions on the capitate-stalked trichomes found on the dominant inflorescence of plants of each variety (Figure **4**). The initial trigger for terminal sampling was set at 50% or more amber-colored secretions. Cannabinoid analyses are being run in parallel to the secretion color development observations to determine the effectiveness of the criteria for timing harvest.

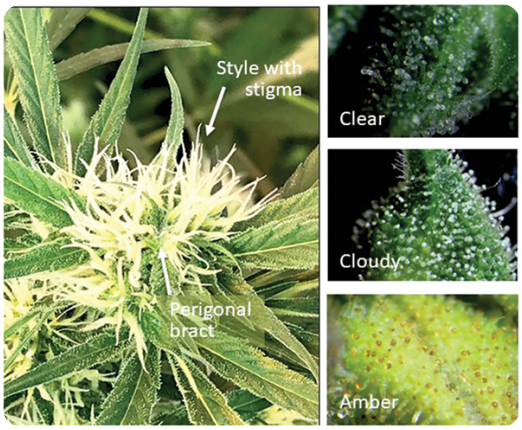


Figure 4, *The timing of hemp harvest can affect the concentrations of cannabinoids present in the inflorescences. For hemp to be compliant with state and federal regulations, the THC concentration cannot be more than 0.3%. Researchers are trying to find easy-to-observe indicators of hemp maturity in the field. One method being tested is to observe the progression in color development of exudates that form on glandular trichomes. The color of exudates in some hemp varieties change with maturity from clear, to cloudy, to amber. This measure appears to work for some varieties but not for others but may prove to be helpful to use in combination with more expensive laboratory analyses for cannabinoid concentrations.*

Since USDA and state compliance regulations are based on a specified plant-sampling protocol, two locations at the University of California–Davis and one at OSU coordinated their efforts to determine the effects of inflorescence positions on the plant at three sampling time THC levels. Primary, secondary, and tertiary inflorescences were sampled with trichome secretion colors recorded. Cannabinoid contents are being determined by high-performance liquid chromatography methods developed by the USDA-ARS in Peoria, IL. Cannabinoid testing results can vary greatly among analysis methods and the kind of instruments that are used, so the ARS is developing methods that will work universally across laboratories to get the same results.

The results from these and other kinds of field experiments are early but have begun to show how good quality essential oil varieties can perform in different environments. Much of the present genetic material used to develop essential oil varieties originated from above 40°N latitude. Often when these materials are grown further south, the response to daylength can greatly affect how they grow. Varieties may differ in their ability to stand up to summer abiotic stresses

as well as their susceptibility to diseases, particularly when exposed to diseases that are endemic to areas away from where the varieties were developed. The effects of management have just begun to be observed. Our trials were conducted using high-density plantings in rows similar to vegetable production systems with an eye on reducing production costs through mechanical cultivation and harvest.

Hemp Production Needs to Be Linked to Markets

Agricultural statistics have been established to document the production costs and value of many commodities and contribute to establishment of orderly markets. This is still a work in progress for hemp. Agricultural economists in many states have begun to survey hemp production and create tools such as enterprise budgets. These efforts will lead to the inclusion of hemp in the USDA Census of Agriculture that is conducted every five years by the USDA National Agricultural Statistics Service, which publishes agricultural data for every county in the United States.

In the meantime, estimates indicate the farm-gate value of 2019 Oregon hemp and that grown in other states may have broken it into the upper tiers of agricultural commodity value. However, this boom was short lived. Without guaranteed and honored contracts and incomplete supply chains to markets that would absorb production, many farmers and allied supply chain participants in 2020 were still holding 2019 inventory. As a result, 2020 production dropped to 25% of what it was in the previous season. This effect is still carrying on into 2021 that is resulting in the value of hemp seeds, biomass, and products being less now that at the same time a year ago. There are always risks in agricultural markets, but risks of production exceeding demand must be reduced.

Other common production system approaches can be taken to increase returns to farmers and processors. By-products from corn grain ethanol production and meal

produced from extraction of oils from cotton seed are commonly utilized by livestock-feeding operations as a component of feeds. Hemp is presently not an approved feed for food animal livestock, but the post-extraction hemp by-product has a feed value similar to alfalfa (Figure **5**). A team of OSU animal nutrition researchers is partnering with the USFDA to establish rules for feeding livestock spent hemp by-product supplements. To do this, the researchers are determining cannabinoid residuals in sheep, beef cattle, and poultry meat and dairy cattle milk as well as looking at the health and performance of the animals fed the by-product. This research is critical on several fronts. First, to feed hemp to livestock, any cannabinoid residues found in food products need to be determined by the USFDA to be at safe levels. Without USFDA approval, hemp cannot be fed to livestock produced for human consumption. Second, hemp by-product will provide another option to livestock producers when sourcing feeds and serve as a new market outlet for an additional revenue stream for hemp producers and processors to increase their profitability. This research will quickly be translated to help develop science-based policies and demonstrate the utility of hemp as a safe and high-performance feed for livestock.

With the decline in hemp essential oil production nationwide, there has been increased interest in fiber hemp. However, for hemp to be established as a significant source of natural fiber for use in textiles and the manufacture of advanced materials, the needed infrastructure to process fiber constituents from stems will have to be build up from scratch. Also, there are many different technology routes that take the fiber to different kinds of products (Figure 1), and these will also need to be developed, based on research that demonstrates the superior performance of these products manufactured with hemp instead of other natural fibers or non-renewable source materials. Complete supply chains must be clearly designed and the development costs described to establish their feasibility, and hemp production must be built to meet the operational specification of the processing facilities.



Figure 5, *In preparation to beginning feed ration treatments, lambs need to be acclimated to the different feed components, including the post-extract hemp by-product. It is during this period that the lambs are observed for how well they finish their meals. As it turns out, the different subjects initially have different preferences.*

To get a sense of the scale needed for hemp to make a dent in the existing natural fiber market, we can look at cotton as a model. There are about 550 cotton gins in the U.S. The average gin has the capacity to process forty 500-lb bales per hour, which translate into 40,000 bales of lint per season. Like hemp, cotton is a biological material, and because fiber quality declines with time while waiting to be ginned, most

gins operate for only a 90-day season. This pressure to quickly process the fiber to maintain quality presses up against the desire to extend the length of the ginning season to better amortize the capital expense investment required to build ginning facilities. This and many other factors will need to be considered, addressed, and financed to ramp up domestic hemp fiber production and optimize the necessary linked handling and processing systems before hemp fiber becomes an established commodity. Also, there is much that must be done to support expanding markets and commerce in hemp fiber for textiles. As has been done for cotton, classing, testing, and standards will have to be established for hemp fiber.

An Opportunity to Build an Equitable Industry

The GHIC is responsive to the questions and needs of all people, no matter their background, level of expertise, or time engaged in agriculture. As a core value of GHIC, we recognize there are many who don't know the established paths that can be followed through a land grant university to find the information, technology, and talent needed to help them be successful. We also recognize there are those who have experienced systemic racism and not had access to emergent agricultural business opportunities such as presented by hemp. So especially now, the center wants to help provide Black, Indigenous, and People of Color (BIPOC) communities network and other assistance so as to have equitable access to emergent hemp opportunities. To this purpose, at least 10% of the center's discretionary resources are directed to partnerships that express that commitment. We believe to build a truly sustainable hemp-based economy, attention must be given to social justice approaches and actions that are inclusive and equitable for all. Please contact GHIC if you want to learn more about how you can partner in our efforts or contribute.

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