

The NMSU Center of Excellence in Value-Added Agriculture

1. Development of an NMSU Hemp Program - White Paper on Research and Extension/Education Expertise, Interests, and Resource Needs

Executive Summary

Approval of the New Mexico Department of Agriculture Rule followed by the 2018 Farm Bill provides opportunity for permitted production of industrial hemp. New Mexicans recognize that agriculture underpins the state's economy and we must continually investigate crops/products that diversify farming practices and provide alternative income streams for agricultural producers and processors. Unlike hemp, few crops have the potential for vertical integration to produce thousands of products including food, fuel, textiles, cordage, oils, medicals, industrial components, furniture, and construction materials. The global market value of hemp is expected to reach \$20 Billion by 2022.

NMSU is well-positioned with the interest and expertise to help industrial hemp producers in New Mexico to be profitable and sustainable. This will take place through appropriate, interdisciplinary, collaborative research directed at different aspects of industrial hemp production, processing and marketing, and engagement through Extension activities to pass research results to producers and stakeholders.

The development of a comprehensive hemp research and education center is estimated to cost just over \$9.1 Million over 4 years, with recurring costs for personnel and expendable supplies each year following year 4. The hemp genetics and value-added programs will be key components of NMSU's Center of Excellence in Value-added Agriculture, a unit in development in association with the Agricultural Modernization and Educational Facilities (GO Bond D facilities) approved by election in 2018.

Research Expertise and Interests

Production

Potential NM hemp producers, including the sovereign Pueblos, Jicarilla Apache Nation, Mescalero Apache Tribe, Fort Sill Apache Tribe, and the Navajo Nation are seeking technical assistance on best management practices for hemp production targeting a variety of markets. Although industrial hemp is said to grow well across several regions, New Mexico climate and soils offer many challenges that have not been addressed previously. Therefore, research activities are needed to develop best management practices at different locations in New Mexico.

Production related research questions include:

- i. Which hemp varieties are adaptable to different soils (including calcareous, saline/sodic and polluted)/climatic zones/elevations/latitudes of NM?
- ii. Which varieties are best suited to targeted products with THC levels below 0.3%?
- iii. What are optimal tillage, fertility, and crop protection (weed/insect/pathogen/avian and other pest control) strategies for hemp?
- iv. What are irrigation requirements for hemp production based on utility & climatic zone using a variety of irrigation delivery systems (flood, sprinkler, drip) under differing water qualities (saline, oil and gas produced water, treated municipal wastewater, municipal potable water, ground water, surface water)?

- v. Could hemp act as an insectary for beneficial arthropods that could be predators or parasitoids of insect pests of hemp, particularly grasshoppers and bollworm?
- vi. What is the potential weedy invasiveness of hemp?
- vii. What are the diseases and arthropod pests that may limit production in New Mexico? What are management strategies will be most effective reducing the impact of disease and arthropod pests on hemp?
- viii. What are the best propagation, timing and density of planting, harvesting and post-harvesting technologies for different products of hemp?
- ix. Are there water thrifty genetics to select from hemp that better utilize scarce water resources?

The College of Agricultural, Consumer and Environmental Sciences has state-wide reach to help New Mexico farmers utilize their resources more effectively and profitably through the Agricultural Experiment Station (<https://aces.nmsu.edu/aes/>) and the Cooperative Extension Service (<https://extension.nmsu.edu/>). Specific expertise includes genetics; plant physiology, pathology, and propagation; irrigation engineering, weed science, soil and environmental sciences, nutrition, food, and animal sciences. While no faculty have worked with hemp, faculty have expertise in standard operating procedures for conducting rigorous, peer-reviewed crop and soil research with oilseed, forage, fiber, and medicinal crops.

Genetics

Tetrahydrocannabinolic acid (THC) is the major cannabinoid in marijuana and cannabidiolic acid (CBD) in hemp. The expression of THC synthase is higher in marijuana, suggesting that transcriptional regulation of the pathway may be one factor controlling desired cannabinoid production and/or profiles. Genes with a role in the biosynthetic pathways of the less-abundant cannabinoid derivatives with other medicinal properties, have not been identified. Phytocannabinoids accumulate in the secretory cavity of the glandular trichomes, which largely occur in female flowers and in most aerial parts of the plants. In North America, to be legally classified as hemp, the crop may not contain more than 0.3% of THC. The main objective of a genetic research program is to find a genetic means to eliminate THC production and increase CBD synthesis in hemp regardless of environmental conditions. Two approaches to increase CBD levels would be to increase their synthesis or increase the density of the trichomes. An additional approach would be to use the genomic data available to design molecular markers for the purpose of breeding for high CBD and low THC and for other traits like adaptability to different environmental conditions and disease resistance.

Potential Experimental approaches:

- i. Using transcriptome and/or proteome analysis of trichomes, we will identify genes, which could include genes for transcription factors that have role in trichome formation and development. Overexpression of these genes in a tissue/flower-specific manner could increase the number of trichomes in the flowers.
- ii. Determine the regulatory mechanism underlying the expression of THC synthase and CBD synthase in marijuana and hemp. This should allow us to design genetic engineering approaches to manipulate the levels of THC (decrease) and CBD (increase). For the purpose of manipulating the expression of some of the targeted genes, besides using conventional methods of overexpressing or down regulating expression using antisense or siRNA, we propose to use CRISPR-Cas9 to edit genes. This technology has been successfully used not only in animal systems including humans, but also in plants.

- iii. To identify other key genes involved in the biosynthetic pathways of the less-abundant cannabinoid derivatives using a combination of metabolomics with genome-based functional characterizations of gene products. These genes could be used for both genetic engineering and/or for generating molecular markers for breeding purposes.
- iv. For any genetic engineering endeavor, it is crucial that we are able to introduce modified genes into hemp cells and grow them into whole plants. While there are some claims of success in transforming cannabis, there have been no convincing reports on the production of a transformed plant. There are reports of using *A. rhizogenes* to produce transformed hairy roots and *A. tumefaciens* to produce transformed suspension culture and embryos, however, they do not produce seeds or phytocannabinoids. Thus, a major thrust will be to develop an efficient transformation and regeneration system for hemp.

Value-Added

Industrial hemp could have many practical uses in New Mexico, such as absorbing heavy-metal from soils. NMSU research can quantify this process by testing plant tissue, seed and oil to ensure that products made from hemp grown in these conditions do not contain unhealthy amounts of heavy metals. Research could also investigate hemp's use in crop rotation with chile, cotton, forage grasses, and silage corn, as well as its effectiveness in suppressing weeds or suppressing soil borne pathogens. Research is also needed to determine the impacts of hemp on the weed seedbanks and on soil borne pathogens in our irrigated cropping systems.

NMSU research could help hemp processors maximize use of the entire plant while extracting useful proteins, cannabidiol (CBD) and antioxidants from the hemp seed meal as well as oil extraction, non-seed residues of the inflorescences, and the use of essential oils from hemp as an insecticide. Steam distillation of hemp inflorescences produces an essential oil that contains several monoterpenes and sesquiterpenes that have been shown to be effective against larvae of mosquitoes, houseflies, and aphids, without harming beneficial insects. The Department of Chemical & Materials Engineering (CHME) has the equipment for both supercritical CO₂ extraction and steam distillation that can be applied to hemp inflorescence fractions. CHME also has thermochemical processing capabilities for conversion of the unused lignocellulose portions of plant to produce liquid fuel intermediates (bio-crude oil) and chars that can be used to make activated carbons for adsorption applications. Thermochemical processing may enable recovery of some economic return if a crop has to be destroyed due to excessive THC levels.

NMSU could research extraction and characterization of proteins from hemp seed to be used in functional foods, nutraceuticals and extruded snacks and aquaculture feed. Hemp seeds' amino acid profile is comparable to meat, milk, eggs and soy protein. Fish, Wildlife and Conservation Ecology could research how hemp seed meal and protein can be used as a potential plant protein source for aquaculture feed. Shrimp could be used for initial research and later expanded to fish species (e.g., tilapia, hybrid striped bass). The bioactive compounds from hemp plants and seed meal can be extracted and characterize for antioxidant activity. The bioactive compounds can be extracted and microencapsulated for functional foods and nutraceuticals. Hemp seeds are a rich source of dietary fiber (20%), vitamins A, C, and E, contain all essential amino acids, and an optimal ratio of omega 6 to omega 3 fatty acids. Seeds can be a functional ingredient in new food products.

Hemp products have tremendous potential in the livestock industry but would first need FDA's Generally Recognized as Safe (GRAS) status. Specifically, hemp seeds and meals could be excellent source of protein, which will be competitive with current ethanol industry co-products (e.g. dried distiller's grains) and animal by-products (e.g. fish meal). NMSU could research its palatability and use as a low-cost roughage

source. Hemp seed and hemp meal contain cannabidiol (CBD), which possess antioxidant and anti-inflammatory characteristics. Research with lab animals shows promise but more research with livestock is needed. Hemp products in livestock feeds might help the industry reduce antibiotic use. The anti-inflammatory response from CBD supplementation has been shown to reduce insulinitis (damage to insulin producing pancreatic cells), which can be problematic for grazing livestock.

Hemp fibers are strong, durable, and elastic. They are also resistant to UV light damage and mildew and can withstand high and low temperatures. Their antimicrobial properties may help protect wearers. Hemp enhanced fabrics could be used in outerwear, work clothes, military uniforms, and fabric blends with cotton or silk. Hemp bio-leather can be used to make shoes, jackets, and car seats. All this potentially could be researched at NMSU.

Economics, Industry Development and Marketing

Hemp may provide New Mexico with opportunities for farmers and up through the supply-chain to processors, manufacturers, and retailers. Hemp is valued both for its economic potential to provide both fiber and seed (grain). As markets develop, opportunities arise, and barriers fall, New Mexico farmers, processors, retailers and entrepreneurs are poised to find new economic areas that hemp introduces. Although hemp has a long history of use, its reintroduction to U.S. producers, manufacturers, and consumers requires efforts and measures to acclimate, retrofit, and innovate. Less clear is the potential scope and scale of possible markets for hemp-based products.

NMSU has the expertise to provide economic analysis and feasibility studies to help the hemp industry understand the potential costs and returns, identify industries with the greatest potential for economic profitability and sustainability and provide guidance for entrepreneurs interested in establishing hemp related businesses in NM.

Extension and Education

Both at the state- and county-levels, NMSU Extension is our ticket to getting valuable research-based information out to stakeholders and bringing the most pressing questions back to the university for research. As interest in hemp production increases in New Mexico, our priority is to equip NMSU Extension agents, specialists, and classroom educators to serve the statewide community and hemp stakeholders. To do this, we must provide up to date education to the general public, undergraduate and graduate students, as well as to hemp growers and industry workers.

Funding to support the following Extension and education efforts is needed for an effective Hemp Extension and education effort:

1) Train the Trainers

- Registration fees and travel for a select group of NMSU Extension/academic faculty to attend national hemp conferences and recruit research and industry experts as presenters for future hemp workshops in NM
- Provide funds for working tours of existing hemp farms and related industries in NM and surrounding states by a select group of NMSU Extension/academic faculty

2) Outreach to the General Public and Hemp Growers

- Website management (<http://hemp.nmsu.edu>) to ensure current and appropriate information for all stakeholders, including the public, and a fact sheet link for NMDA requirements and regulations for growing hemp

- Film production by the NMSU Media Productions film team to capture successful hemp industry operations in other states
- Hemp workshop development for NM growers
- Creation of videos to explain FAQ about the new hemp industry in NM by our NMSU Learning Games Labs. Young adults primarily use social media for building knowledge and skills. Short how-to videos are an effective and fun tool for getting new information out to the public.

3) Proposed New Courses for NMSU Students

- An interdisciplinary survey course for undergraduates (with a graduate elective option) that covers *hemp production, processing, products, and economics/regulation*.
- Hemp Regulations & Law
- Hemp Production Economics

Currently, the Department of Plant and Environmental Sciences offers agronomic, genetics and medicinal chemistry courses that will include aspects of hemp production. Hemp educators will collaborate with researchers in production, genetics, value-added products and business to bolster and advocate for New Mexican hemp production and producers.

Resources Needs

NMSU has faculty and staff with fundamental expertise that could greatly benefit the hemp industry in NM. Additionally, there is a lot of interest within the university in developing research, extension and education programs in this area. However, currently, there is no funding within NMSU directed toward research, extension, and education on hemp. Faculty with research interest and expertise in hemp will seek external funding to support their research efforts. This will undoubtedly provide some faculty with resources to begin these efforts. If a coordinated research program is desired, funding for personnel, equipment, and operations is needed.

Likewise, NMSU, through the Cooperative Extension Service and the teaching faculty, has the ability to provide educational training for producers, processors, college students, and the public. Personnel dedicated to this effort, such as a Hemp Specialist and program manager, would be helpful in establishing an effective coordinated effort to support the Extension and education needs of our stakeholders.

Each of the areas noted above will advance a program further with targeted resources. The amount of funding needed is dependent on research priorities. Investment in specific program areas, such as genetic improvement, crop production, development of value-added products, or market analysis and development, will kick start research in those areas. In order to develop a comprehensive hemp program at NMSU, however, investment needed in each of these areas.

Below is a budget summary outlining resource needs for each component of the program and a total for the development of a comprehensive Hemp Research and Extension Center (\$9,170,303). Following year 4, recurring funding of \$771,305 will be needed for salaries (Program Director, Administrative Assistant, and 4 faculty) and \$11,000 operations for the Director's office. All other resource needs following year 4 will be obtained through external funding.

More information on each of these program areas as well as a detailed budget is available on request.