Volume 2

Article 1

2021

Science of Hemp: Production and Pest Management Meeting Proceedings (2021)

Science of Hemp: Production and Pest Management
2021 Meeting Proceedings

Hemp (*Cannabis sativa* L. with <0.3% tetrahydrocannabinol content) is one of the oldest agricultural commodities and can be grown for fiber, grain, and cannabinoids. For most of the last century, *C. sativa* has been a Schedule I controlled substance in the United States. However, the 2014 and 2018 U.S. Farm Bills allowed hemp production under a pilot research program and a commercial program, respectively. As a result, there has been a huge resurgence in hemp production in the U.S. but without modern scientific data with which to maximize production.

The first meeting of the Science of Hemp: Production and Pest Management was held in Lexington, Kentucky in October 2019 and brought together agricultural scientists to share early data on hemp. COVID-19 derailed plans to hold a 2020 meeting, but we resumed in 2021 with a virtual meeting. The 2021 virtual meeting was hosted by Auburn University and took place on November 19th, 2021. One hundred twenty-nine participants joined us online for scientific presentations, breakout sessions, workshops, and poster and oral student competitions. Attendees presented 41 oral talks, 13 posters, 8 workshops, and 3 *Lunch and Learns*.

Discipline specific workshops (entomology, plant pathology, weed science, and agronomy) were offered by experts and designed for attendees to learn the basics of a discipline outside their own. Other workshop topics included greenhouse lighting, pesticide use, impact reporting, and biological control. Our *Lunch and Learns* were selected to help researchers extend hemp information to their communities. They included tutorials on creating infographics, teaching via Zoom, and livestreaming to social media.

We were excited to be able to hold a student competition for traditional oral presentations and *Flash and Dash* poster presentations. It is encouraging that the next generation of scientists are conducting valuable applied research on hemp. Eighteen students competed in the competitions and the top three in each oral and poster competition were awarded cash prizes. All students received feedback from judges on their presentations.

While we could not meet in person, the virtual event proved successful and concluded with a virtual social. Prizes were given for the best virtual background and winners of hemp trivia.

Sincerely,
Katelyn Kesheimer, Assistant Professor and Extension Specialist, Auburn Department of Entomology and Plant Pathology
Nicole Gauthier, Professor, University of Kentucky Department of Plant Pathology
Kimberly Leonberger, Extension Associate, University of Kentucky Department of Plant Pathology

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Evaluation of Biopesticides for the Management of *Helicoverpa zea* in Hemp

Meeting Overview – Friday, November 19th, 2021

10:00 – 10:30am: General Session

10:30 – 12:00pm: Student Oral Competition

12:00 – 12:15pm: Lunch Break

12:15 – 1:00pm: *Lunch and Learn*

1:00 – 3:00pm: Breakout Sessions

- Agronomy 1
- Agronomy 2
- Pest Management 1
- Pest Management 2

3:00 – 3:15pm: Snack Break

3:15 – 3:45pm: Student Poster *Flash and Dash* Competition

3:50 – 4:15pm: Workshops #1 (The same sessions will be held twice; attendees can choose and attend 2 each)

- Entomology
- Plant Pathology
- Agronomy
- Weed Science

4:15 – 4:30pm: Snack Break

4:30 – 4:55pm: Workshops #2 (The same sessions will be held twice; attendees can choose and attend 2 each)

- Greenhouse lighting
- Pesticides
- Impact Reporting
- Biological Control

5:00 – 6:00pm – General Poster Session and Virtual Social

General, Student, and Breakout Sessions

GENERAL SESSION

Name	Time (ET)
Larry Smart – Cornell University	10:00 - 10:15am
Adam Rabinowitz – Auburn University	10:15 - 10:30am

STUDENT ORAL COMPETITION

Presenter	Title	Time (ET)
Paul Cockson	The impact of differing concentrations of micronutrients on the growth, mineral accumulation, and reproduction of Cannabis sativa	10:30 - 10:40am
Kyle Owsley	Evaluation of Biological Insecticides Efficacy forSpider Mites on Greenhouse Hemp.	10:40 - 10:50am
Ali Cala	Exploration of the host range of hemp powdery mildew	10:50 - 11:00am
Ivy Thweatt	Evaluating nitrogen rates on plant growth and cannabinoid content in outdoor hemp in Alabama	11:00 - 11:10am
Morgan Goodnight	Disease firsts in the first year of hemp productionin Missouri	11:10 - 11:20am
Henry Smith	Identification and characterization of Fusariumspp. affecting Kentucky Hemp	11:20 - 11:30am
Alejandra Velez	Managment strategies for corn earworm,Helicoverpa zea, in Alabama Hemp	11:30 - 11:40am
Gary Wayne Morgan	Effect of different drought intensity and timing onfloral hemp photosynthesis and cannabinoid profiles	11:40 - 11:50am
Rufus Akinrinlola	Numerous fungicides suppressed hemp powderymildew in the greenhouse in Tennessee	11:50 - 12:00pm

LUNCH AND LEARN

Presenter	Title	Time (ET)
Kaylee Hirsch	Creating Infographics	12:15 - 12:35pm
Katelyn Kesheimer	Livestreaming to Social Media	12:15 - 12:35 pm
Kim Leonberger	Teaching via Zoom	12:15 - 12:35 pm
Move between Zoom rooms		12:35 - 12:40 pm
Kaylee Hirsch	Creating Infographics	12:40 - 1:00 pm
Katelyn Kesheimer	Livestreaming to Social Media	12:40 - 1:00 pm
Kim Leonberger	Teaching via Zoom	12:40 - 1:00 pm

AGRONOMY 1

Presenter	Title	Time (ET)
James DeDecker	Midwestern Hemp Collaboration	1:00 - 1:15 pm
Eric Linder	Assessment of Floral Hemp Planting Date and Density for Optimized Biomass	1:15 - 1:30pm
Hsuan Chen	Cannabinoid Yield, Fertility, Grain Size of the Diploid, Triploid, and Tetraploid version of a Cannabigerol-Dominant Cultivar	1:30 - 1:45pm
Bob Pierce	Cannabinoid accumulation in floral hemp cultivars; Implications for harvest management.	1:45 - 2:00pm
Tom Keene	Summary of national grain/fiber cultivar trials.	2:00 - 2:15pm
Patrick Veazie	Magnesium’s Impact on Cannabis sativa ‘BaOx’Growth and Cannabinoid Production	2:15 - 2:30pm
Calvin Trostle	The Texas A&M Two-Step with Hemp: Backward on CBD, Forward on Fiber	2:30 - 2:45pm
Tyler Mark	Economics of Hemp Production and Demand	2:45 - 3:00pm

AGRONOMY 2

Presenter	Title	Time (ET)
Faith Hatt	Genetic Transformation and Tissue Culture of Cannabis sativa L.	1:00 - 1:15 pm
David Suchoff	Evaluation of Chinese and Australian fiber hempvarieties and planting dates in North Carolina	1:15 - 1:30pm
Mitchell Richmond	Hemp Agronomic Field Trial Updates from Tennessee	1:30 - 1:45pm
Tara Valentine	Impact of planting date and seed depth on establishment, growth, and grain yield of hemp inKentucky.	1:45 - 2:00pm
Kristin Hicks	Reference Plant Tissue Nutrient Ranges for Cannabis sativa in the Southeast	2:00 - 2:15pm
Margaret Bloomquist	Floral Hemp Variety Selection for North CarolinaOutdoor Production	2:15 - 2:30pm
Nicole Gauthier	Scouting for Disease: Pathology for Non-Pathologists	2:30 - 2:45pm
David Cornett	Welcome to the National Hemp Growers Cooperative	2:45 - 3:00pm

PEST MANAGEMENT 1

Presenter	Title	Time (ET)
Clement Akotsen-Mensah	Industrial Hemp IPM updates in Missouri	1:00 - 1:15 pm
Raul Villanueva	Approaches to Conduct Balanced Studies on Hemp Russet Mites	1:15 - 1:30pm
Armando Falcon	Parasitism of Corn Earworm by Tachinid Flies inIndustrial Hemp	1:30 - 1:45pm
Louis Bengyella	Impact of Septoria species in CBD hemp	1:45 - 2:00pm
Shilpi Chawla	Flower and Head Blight caused by Fusarium sp.detected on Hemp Varieties Grown in Virginia	2:00 - 2:15pm
Raj Singh	New Diseases of Industrial Hemp in Louisiana	2:15 - 2:30pm
Karla Gage	Hemp-Weed Interactions	2:30 - 2:45pm

PEST MANAGEMENT 2

Presenter	Title	Time (ET)
Nicole Gauthier	Time of Infection and Host Susceptibility in Kentucky Hemp	1:00 - 1:15 pm
Kadie Britt	Beginning an integrated pest management program in California hemp	1:15 - 1:30pm
Jonathan Cale	The utility of two parasitoid wasps for managingcannabis aphid (Phorodon cannabis) infestations on indoor-grown cannabis.	1:30 - 1:45pm
Julian Cosner	Investigating Tactics to Manage Corn Earworm on *Cannabis*	1:45 - 2:00pm
Kimberly Gwinn	A Review of Diseases of Cannabis sativa causedby Fusarium	2:00 - 2:15pm
Kimberly Gwinn	Weed Control Study in Hemp Grown for Fiber inMichigan	2:15 - 2:30pm
Heather Darby	Mechanical Weed Control in Hemp Grain	2:30 - 2:45pm

Posters

First Name	Last Name	Title
Toni	Adedokun	Evaluation of the Susceptibility of Hemp (Cannabis sativa) to Black Shank Disease of Tobacco (Phytophthora nicotianae) (Adedokun, O., Smith, H., Anthony, N., Szarka, D., Barnes, J., Dixon, E., and Gauthier, N.)
Nicole	Barboza	The effects of Fusarium on Hemp plants (Barboza, N., Akinrinlola, R., Gwinn, K., Kelly, H., and Hansen, Z.)
Alyssa	Collins	Fiber and grain hemp production in Pennsylvania (Collins, A., Graybill, J., Clark, B., and Butler, B.)
Kaylee	Hirsch	Herbicide efficacy for weed control in CBD hemp (Hirsch, K., Kelton, J., and Kesheimer, K.A.)
Hoyeon	Jeong	An Analysis of Kentucky Hemp THC (Jeong, H., Patalee, B., and Mark, T)
Kelly	Jones	Relationships Between Cannabis sativa and Epicoccum nigrum (Jones, K., Lee, M., Hatagan, R., Villalobos, J., Ownley, B.H., and Gwinn, K.D.)
Tyson	Knight	Insect Seasonality & Guild Composition on Industrial Hemp (Cannabis sativa L.) Grown In High Tunnels in Alabama
Megan	Lee	Relationships Between Cannabis sativa and Epicoccum nigrum (Jones, K., Lee, M., Hatagan, R., Villalobos, J., Ownley, B.H., and Gwinn, K.D.)
Eric	Linder	Exploration of Temporal Cannabinoid and Biomass Production in Floral Hemp (Linder, E., Young, S., Li, X., Whipker, B., and Suchoff, D.)
Gary	Lopez	Denisifaction of Hemp Flower and Seed Hulls: Determination of Pellet Physical Characteristics (Lopez, G. and Jackson, J.)
Kyle	Owsley	Phytotoxicity of Tolerant Exempt Pesticides on Hemp Production (Owsley, K., Pickens, J., Kesheimer, K.A., and Olive, J.)
Magdalena	Ricciardi	Observations of insect and disease pests on field grown hemp in Kentucky

Zachary	Serber	Insect communities on outdoor CBD hemp change throughout the season and include pest and beneficial insects
Zenaida	Viloria	Evaluation of Biopesticides for the Management of Helicoverpa zea in Hemp (Viloria, Z., Falcon-Brindis, A., Bradley, C., and Villanueva, R.T.)

Meeting Proceedings

Following are 47 meeting abstracts, organized alphabetically by author. Oral and poster presentation abstracts are included herein.

Evaluation of the Susceptibility of Hemp (*Cannabis sativa*) to Black Shank Disease of Tobacco (*Phytophthora nicotianae*)

Oluwatoni Adedokun, Henry Smith, Noah Anthony, Desiree Szarka, Jessica Barnes, Ed Dixon, and Nicole Gauthier
Department of Plant Pathology, University of Kentucky, Lexington, Kentucky

Phytophthora nicotianae is the primary causal agent of black shank, a devastating root and crown rot disease that can lead to 100% losses in tobacco. Once infection occurs, *P. nicotianae* causes crown rot in roots, the wilting of leaves, chlorosis of leaves, development of stem lesions, and eventually leads to plant death. Tobacco is no longer a major cash crop in the United States due to federal restrictions and regulations. Growers in Kentucky, North Carolina, and Virginia are looking for an alternative crop. Hemp has the potential to become the next cash crop for the Commonwealth of Kentucky and other tobacco- producing states. Hence, farmers need to know whether hemp serves as a good rotational or replacement crop for tobacco, particularly for fields with a history of *P. nicotianae*. We conducted 3 on- farm trials in confirmed "hot fields," fields with a history of an established *P. nicotianae* population.

Next, we conducted two greenhouse trials to test pathogenicity of two isolates of *P. nicotianae* race 1 to two cultivars of hemp ('HK' a proprietary CBD cultivar and 'Felina' a grain and fiber cultivar), and two cultivars of tobacco (KY14 which is susceptible to race 1 and KT-212 which is partially tolerant to races 1 and 2). Roots and crowns from all trials were examined for symptoms of *P. nicotianae* infection, plated onto media to isolate the pathogen, and analyzed by nested PCR for molecular confirmation of the presence of pathogen genomic DNA. In both the field and greenhouse trials, hemp was asymptomatic and no *P. nicotianae* was recovered from roots or stems. As expected, tobacco became infected and died shortly after symptoms developed. PCR amplification of the COX 1 gene was negative for *P. nicotianae* in all hemp samples, while results were positive for tobacco, both in the field and the greenhouse experiments. Thus, hemp appears to be a non- host or resistant to *P. nicotianae* race 1 and is recommended as a good rotational or replacement crop for tobacco fields with a history of *P. nicotianae* race 1. Rotation with hemp may help break the disease cycle of black shank.

Numerous Fungicides Suppressed Hemp Powdery Mildew in the Greenhouse in Tennessee

Rufus Akinrinlola, Kimberly Gwinn, Toni Wang, and Zachariah Hansen
University of Tennessee, Knoxville, TN, USA

Hemp powdery mildew (PM), caused by the fungus Golovinomyces sp., is a common disease of hemp in greenhouses and high tunnels. In a series of greenhouse trials at the University of Tennessee, a total of 52 fungicide treatments were tested against powdery mildew on 'BaOx2' or 'Sweetened' hemp cultivars. Forty-two of the treatments were experimental products, and 10 were commercial products. Experimental units consisted of one hemp plant per pot with four replicates. Treatments were inoculated with a spore suspension containing $2x10^5$ spores/ml one day after or before the first fungicide application. Non-treated controls were only sprayed with water. During each trial, three fungicide applications were made at 7-day intervals by thoroughly covering plants using a hand-held sprayer. Disease incidence and severity were rated three times at 7-day intervals, and disease index (DI) and the area under disease progress curve were calculated. Ninety-two percent (48) of the treatments significantly controlled PM in at least one trial, and 8% (4) failed to control PM. Compared to the control plants, the effective treatments reduced DI by 51% to 100%. Fourteen treatments had "excellent" efficacy, reducing DI by 100%. Twelve treatments had "very good" efficacy, reducing DI by 90% to 99%. Seventeen treatments had "good" efficacy, reducing DI by 71% to 89%, and five treatments had "fair" efficacy, reducing DI by 55% to 70% compared to the control. Among the commercial treatments, Milstop and Sulfur were excellent; Cinnerate, Exile, Guarda, and Regalia were very good; and Defguard, PerCarb, Sil-Matrix, and Stargus were good.

Industrial Hemp IPM updates in Missouri

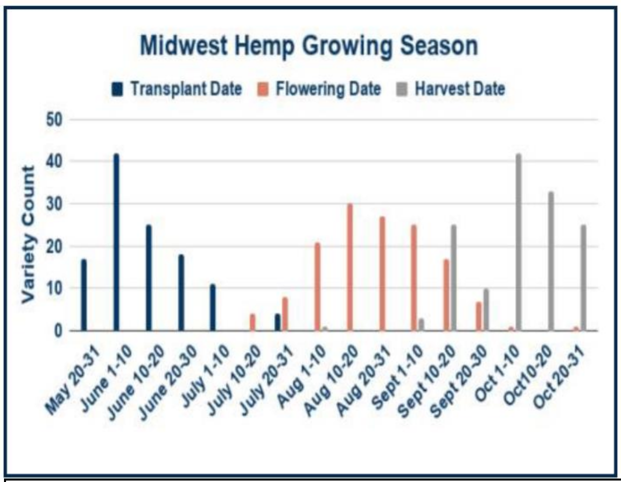
Clement Akotsen-Mensah
Lincoln University Cooperative Extension and Research, Jefferson City, MO 65101

Legalization of hemp in Missouri has brought about a growing interest for industrial hemp production. However, as a new crop, there is a high probability of insects and other arthropods switching to feed on hemp and cause significant crop damage when planted as monocrop. During the 2020 and 2021 cropping seasons, studies were conducted to determine the importance of key insect pests in industrial hemp production. Several sampling methods were deployed in variety trial plots at Lincoln University and other parts of the state. Sampling methods used include bucket traps, TRÉCÉ Pherocon stink bug st**ic**ky dual panel trap**s**, dual sticky traps, and visual sampling. The results showed that corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), yellowstriped armyworm, *Spodoptera ornithigalli* (Guenée) (Lepidoptera: Noctuidae), green stink bug, *Chinavia hilaris* (Say), southern green stink bug, *Nezara viridula* (Linnaeus), and brown stink bugs (mainly *Euschistus* spp) are the most common pests currently found on hemp and that their activities could potentially cause significant crop injury to seed, cannabinoid and dual hemp varieties. The results are discussed in terms of the importance of these insects in the development of Integrated Pest Management (IPM) for industrial hemp in Missouri.

Midwestern Hemp Research Collaboration: Participatory Cultivar Testing to Grow the Hemp Industry

Phillip Alberti[1], Marguerite Bolt[2], James DeDecker[3], Shelby Ellison[4], Esther Shekinah, D.[5]
[1]University of Illinois Extension, Freeport, Illinois, USA
[2]Purdue University, West Lafayette, Indiana, USA
[3]Michigan State University, Chatham, Michigan, USA
[4]University of Wisconsin, Madison, Wisconsin, USA
[5]Michael Fields Agricultural Institute, East Troy, Wisconsin, USA

Beginning in 2020, our team representing four land-grant Universities and one non-profit embarked on a partnership with Native Nations, hemp growers and private laboratories across the Midwest to study hemp cultivar performance in our region. With support from USDA-NIFA, NCR-SARE and hemp seed companies we have collected data on over 150 cultivars for CBD, grain and fiber from 70+ suppliers. Participating researchers manage replicated cultivar trials with agreed-upon protocols at university and partner locations. Commercial hemp growers participate by submitting agronomic information via an online survey and flower samples to our laboratory partners for analysis at a discounted cost. Observations have included phenology, height, yield and cannabinoid profiles, as well as applied agronomic practices. Data on cannabinoid cultivars is aggregated in the Midwestern Hemp Database (MHD), a public online resource where users can filter, sort, and visualize the dataset with ease to answer practical hemp performance questions. This work has resulted in a growing list of cultivars with "Good Potential" to meet the needs of Midwestern hemp growers. In 2020, "Good Potential" cultivars were defined as those that 1) Had at least five distinct samples submitted to the MHD, 2) Initiated flowering prior to Aug. 30, 3) Yielded more than 0.5lbs/plant of stripped biomass, 4) Averaged less than 0.39% total THC, and 5) Averaged ≥5% CBD. Moving forward, we hope that our work will inform grower decision-making and regulatory policy, such as performance-based testing, to reduce the burden on hemp growers, regulatory agencies and the industry at-large.



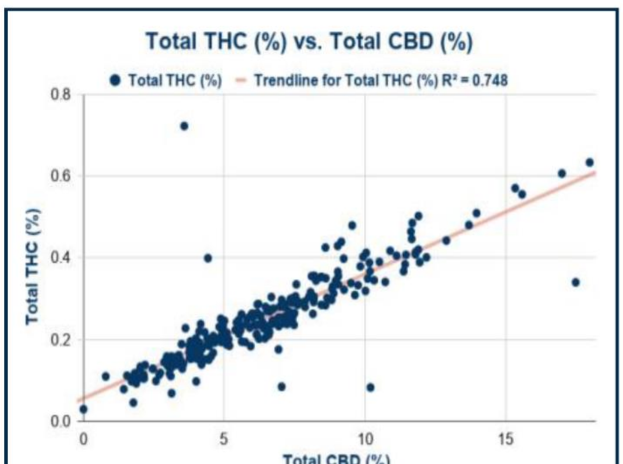


Fig. 1. Histogram illustrating various production milestones of cannabinoid hemp cultivars entered into the MHD.	Fig. 2. Scatter plot comparing Total CBD (%) and Total THC (%) for qualifying "Good Potential" CBD dominant cultivars entered into

Weed Control Study in Hemp Grown for Fiber in Michigan

Eric Anderson[1], Brook Wilke[1] and Erin Burns[1]
[1]Michigan State University, East Lansing, MI, USA

Weed control has been reported as a primary challenge in establishing hemp (*Cannabis sativa* L.) grown for grain or fiber. Knowing that no herbicides are currently labeled for use in hemp in the U.S., cultural weed management options such as the use of cover crops need to be tested for their effectiveness. A field located in southern Michigan at the Kellogg Biological Station was planted to cereal rye (*Secale cereale* L.) in the fall of 2020. Individual plots (3.0 m x 12.2 m) were managed in the spring of 2021 with one of 10 treatments including the timing and method of cover crop termination followed by the use or lack of in-season herbicide weed control. A burndown application (glyphosate + saflufenacil) was applied 38 days before planting to simulate no cover crop while glyphosate alone was applied six days before planting for early termination. Field cultivation was conducted on 20 April and 20 May in "no cover, tilled" plots. A Polish fiber hemp variety, Bialobrzeskie, was planted at 53.2 kg ha^{-1} on 20 May in all plots. Hemp and weed stand counts were taken in-season and at harvest, and hemp subplots (0.25 m^2) were harvested by hand to determine yield estimates.

Termination timing	**Termination method**	**In-season weed control**
Early termination	Herbicide	Herbicide
Early termination	Herbicide	None
Termination at plant	Crimper	Herbicide
Termination at plant	Crimper	None
Termination at plant	Herbicide	Herbicide
Termination at plant	Herbicide	None
No cover	No-till	Herbicide
No cover	No-till	None
No cover	Tilled	Herbicide
No cover	Tilled	None

The cereal rye was at heading (approximately Feekes 10.3) at the time of hemp planting. Herbicide termination was effective but the roller-crimper did not successfully terminate the rye just prior to planting. Few hemp plants were found in plots where the rye had been crimped while weed pressure was very high, and those plots were considered a stand failure. Hemp dry matter yields were higher with in-season herbicide weed control compared with no herbicide in all treatment combinations except with no cover, tilled plots. Although in-season weed control numerically reduced both weed density and biomass when measured at harvest, both were highly variable and no differences were detected among treatments. except the treatment combination of cover crop termination at plant via herbicide and no in season weed control had significantly more weeds than the treatment combination of no cover, no-till, and received in season weed control. The results of this single-year study showed that a cereal rye cover crop did not appear to suppress weeds without an in-season herbicide application regardless of termination timing.

Fusarium Species Associated with Hemp in Tennessee

Nicole Barboza[1], Rufus Akinrinlola[1], Kimberly Gwinn[1], Heather Kelly[2], and Zachariah Hansen[1]
[1]University of Tennessee, Knoxville, Tennessee, [2]University of Tennessee, Jackson, Tennessee, USA

The increased cultivation of hemp (*Cannabis sativa)* in Tennessee has raised awareness of diseases associated with this crop. Eleven *Fusarium* isolates associated with foliar hemp diseases were recovered from field-grown hemp in Jackson, Tennessee. Little is known about which species of *Fusarium* are pathogenic on hemp in TN and their impact on hemp quality and yield. Two of the *Fusarium* isolates demonstrated pathogenicity when tested using hemp detached leaf assay. These isolates were identified as *Fusarium sporotrichioides* based on internal transcribed spacer (ITS) sequence data. Research is ongoing to identify the species of each *Fusarium* isolate by sequencing the RNA polymerase second largest subunit (RPB2) and translation elongation factor 1-alpha (TEF1), and to determine their pathogenicity using whole-plant Koch's Postulates assays.

Development of Septoria disease in outdoor CBD-hemp production system

Louis Bengyella[1], Francesco Di Gioina[1], Alyssa Anne Collins[2], and John E. Kaminski[1]
[1]Department of Plant Sciences, Pennsylvania State University, State College, PA, USA
[2]Department of Plant Sciences, Pennsylvania State University, Manheim, PA, USA

Abstract: The introduction of *Cannabis sativa* L (THC < 0.3%, hemp) into new ecosystems such as Pennsylvania for the primary production of grains, fiber, and cannabinoid oil has met new challenges. Grown cannabinol (CBD) strains produce several branches and a dense canopy at late vegetative and flowering stages making it an ideal host for the spread of invasive pathogens. Among these challenges is the resurgence of *Septoria* species, ascomycetes pycnidia-producing which causes leaf spot diseases on Cannabaceae. We investigated *Septoria* infection timing, the variations in weather parameters during infection, and severity on day sensitive cannabinol (CBD) strain farmed outdoor at the center county, Pennsylvania from 7.24.2021 to 9.11.2021. For a given CBD strain, 8 plants were randomly and visually rated as follows: (i) 0 - 35% for localized infection on bottom fan leaves, (ii) 36 – 80% for localized infection at the bottom - middle fan leaves, and (iii) 81 – 100% for whole plant infection including sugar leaves. We compared 2 m and 10 m air temperature and relative humidity. We found that the onset of Septoria leafspot by the 7/24/2021 was associated with a persistent temperature inversion notably 70.67 °F and 71.36 °F for 2 m and 10 m air temperature, respectively (**Figure 1**). Maximum temperature inversion was observed between 8.14.2021 to 8.28.2021 while no inversion was observed with relative humidity. We found without any management strategy, the mean disease severity varied from 7.5% - 100% leading to the dead of petioles, fan, and sugar leaves of the plant. Outdoor CBD growers might need to adopt early control strategies when Septoria leaf spots coincide with a temperature inversion.

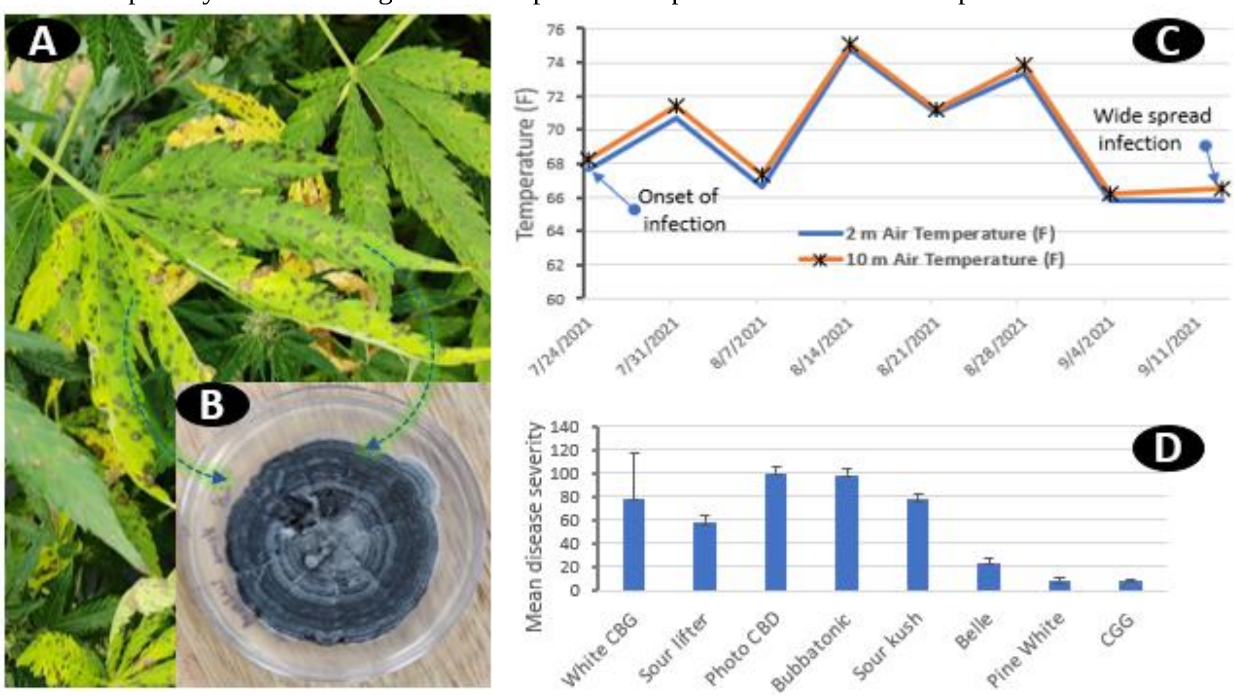


Figure 1: (**A**) Diseased hemp-CBD strain caused by *Septoria* species with characteristic leafspot, (**B**) Closeup of pure isolate, (**C**) Persistent mean weekly temperature inversion during the infection process, and (**C**) Septoria leafspot severity on varieties of day sensitive hemp-CBD strains.

Beginning an integrated pest management program in California hemp

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Hemp and cannabis (both Cannabis sativa L.) are becoming increasingly common crops to California agriculture but information regarding pest management is scant. As such, grower ability to produce a viable crop free of pest injury can be challenging. In July 2018, a team of University of California Agriculture and Natural Resources (UCANR) personnel surveyed cannabis growers to obtain information concerning current production practices. Responses from approximately 100 growers informed that most cannabis crops are either produced outdoors or in greenhouses and pest management strategies were primarily reliant upon biologically based inputs. This study was the first of its kind and has aided work thus far to begin an integrated pest management program in California cannabis and hemp. As a next step, work began in summer 2021 to catalogue arthropod species present in hemp. Four sites each in both the San Joaquin Valley and Central Coast regions of California were sampled from August through October. Sampling methods/techniques included 1) bucket traps, 2) yellow sticky traps, 3) D-vac sampling, 4) leaf collections, and 5) visual observations. Data generated thus far indicate a variety of species are present in crops and as sample processing continues, more comprehensive species identification will aid in determining species of concern. Survey and sampling work are important first steps to establish a sustainable integrated pest management program in hemp and cannabis. Outcomes will lead to a more targeted approach in the development of future research questions.

Exploration of the Host Range of Hemp Powdery Mildew

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Powdery mildew of hemp was first identified in New York in 2019, and isolates were identified as *Golovinomyces spadiceus* (Weldon et al. 2019) which is now known as *G. ambrosiae* (Qiu et al. 2020). While many powdery mildew species have a narrow host range, *G. spadiceus* has been reported on several other crops species including sunflower (Félix-Gastélum et al. 2019; Moparthi, Bradshaw, and Grove 2018), okra (Moparthi et al. 2018), and the ornamental flower Green and Gold (Trigiano, Boggess, and Bernard 2018). Further, another species of powdery mildew, *G. cichoracearum* has been reported on hemp in other locations (Pépin, Punja, and Joly 2018) and is a causal agent of cucurbit powdery mildew. In this study, the host range of an isolate of *G. ambrosiae* isolated from hemp was evaluated in both an indoor walk-in growth chamber and a field trial. *Golovinomyces ambrosiae* was able to infect many of the crops that were inoculated. There were also differences in the disease severity within specific crop cultivars in the field environment. Understanding the host range of hemp powdery mildew will determine best practices for rotation for disease management.

Fusarium Head and Bud Blight Detected on Hemp Varieties in Virginia

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Sixteen varieties, grown for evaluating agronomic traits under Virginia State University hemp breeding program, were scouted for diseases in October 2020 and August 2021. In both years, hemp flower heads and buds with initial bleaching and later necrotic discoloration symptoms were collected for the study (Fig. 1). Seeds from symptomatic heads were harvested manually and examined under the stereo binocular scope. Pinkish-white-fuzzy growth was observed on bracts of hemp seeds. Slides were prepared directly from seed samples and examined under the compound microscope. Macro- (4-6 µm x 25-45 µm) and micro-conidia (4-6 µm x 8-12 µm) were present. Ten seeds from varieties ‘Jinma’ and ‘Tisza’ with three replications were placed aseptically on Petri dishes containing acidified potato dextrose agar (APDA) and incubated at 25°C for 3-days. Fungal colonies grown were examined under the compound microscope. Majority (84.2%) of plated seeds showed white to pink growth on media (Fig. 1), but there were a few gray, dark gray and fast-growing-white aerial mycelial bearing fungi as well. A single mycelia from one of the pinkish colored colonies was isolated and grown on APDA for further molecular confirmation. For molecular characterization, DNA was extracted using Prepman™ Ultra and conserved regions were amplified using internal transcribed spacer (ITS), translation elongation factor 1-α (ef1-α), and β-tubulin (βt) primers. *Fusarium fujikuroi* is confirmed using the three primers and submissions are underway with GenBank. Pathogenicity was tested on 10-week old hemp varieties in a humid chamber. Seeds harvested at the end of the season and also from inoculated female plants showed significantly reduced germination. For instance, original seed lot to harvested seed lot germination percentages of varieties were 44.4 to 33.3 for Jinma, 66.7 to 77.8 for KY Plume, 77.8 to 0.0 for Tisza and 100.0 to 0.0 for Futura 75. Microscopic observations made in 2021 revealed a composite of pathogenic and saprophytic fungi inhabiting various parts of hemp seed. The study emphasizes the critical need for future research in documenting direct and indirect (mycotoxin production) impacts of pathogens on hemp flower and seed.

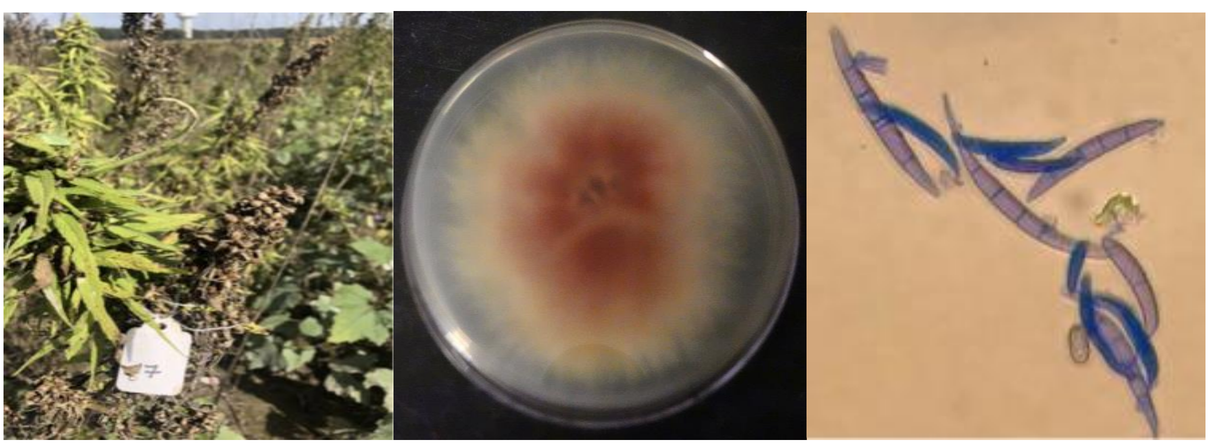

Fig. 1. Hemp heads and buds showing initial bleaching and later necrotic discoloration on hemp varieties grown at Virginia State University’s Randolph Farm, Fungal isolate of *Fusarium fujikuroi* on acidified potato dextrose agar, micro and macro-conidia of *F. fujikuroi* under compound microscope (40x).

The Impacts of Manganese (Mn) on the Growth, Leaf Tissue Mn Concentration, and Cannabinoid Accumulation of *Cannabis sativa* L. (cv: 'BaOx') from Vegetative to Flowering

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This study utilized a modified Hoagland's solution in which manganese (Mn) was altered at increasing concentrations of a full-strength Hoagland's solution with all other elements held constant. Plants were destructively harvested at the end of each of three distinct life stages of development (vegetative, pre-flowering, and flowering) to elucidate the impacts Mn has on *Cannabis sativa* L. 'BaOx' growth and development. Stages were defined as follows: the vegetative stage was grown for eight weeks under long day conditions (16 hr. photoperiod), the pre-flowering stage was terminated 4 weeks after initiation of a critical night length (CNL, 8 hours of darkness), and the flowering stage was terminated 8-weeks after initiation of CNL. The nutrient concentration of most recently mature leaves (MRML) and total plant above ground biomass (vegetative biomass) was measured at the end of each life stage. Eight weeks after the induction of the (CNL) a sub-sample of floral material was harvested and analyzed for cannabinoid concentration. Regression analysis was conducted to evaluate the impacts of Mn on the dependent variables (biomass production, leaf tissue mineral concentration, and cannabinoids), and means were analyzed using general linear model (proc GLM in SAS 9.12). Suggested nutrient ranges were selected from the lower and upper means which were statistically similar at the higher concentrations of Mn fertility. These values provide the upper and lower means after which increasing Mn fertility did not result in statistically greater dependent variable response. These ranges and regression equations will help growers target Mn fertility based on production goals and target markets. Hemp biomass production was reduced when less than 13.5 $\mu mol \cdot L^{-1}$ Mn was supplied in the nutrient solution at the vegetative and pre-flowering stages. At the flowering stage there appeared to be a slightly higher Mn requirement with biomass production being reduced when less than 15.75 $\mu mol \cdot L^{-1}$ was supplied. Leaf tissue Mn concentrations also started to plateau at the same fertility concentrations where biomass accumulation leveled off. This suggests that these leaf tissue Mn concentrations may represent a sufficiency range for Mn fertility which correlates to optimal biomass production. The Mn sufficiency ranges for the MRML were 49 to 75 $mg \cdot kg^{-1}$ for the vegetative stage, 57 to 77 $mg \cdot kg^{-1}$ for the pre-flowering stage, and 42 to 103 $mg \cdot kg^{-1}$ for the flowering stage. Cannabinoid accumulation started to plateau at lower Mn nutrient solution concentrations (4.5 to 9.0 $\mu mol \cdot L^{-1}$) suggesting that cannabinoid metabolism may have a lower Mn requirement than other growth processes. Additional research is necessary to further establish the Mn sufficiency range in greenhouse and field grown hemp and to explore the upper limits of Mn supply to avoid potential Mn toxicity responses.

Building Extension for Fiber and Grain Hemp Production in Pennsylvania

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Hemp production restarted in Pennsylvania beginning in 2017 with a research pilot program initiated by the PA Department of Agriculture. Beginning with only 16 total permit holders and approximately 50 acres in that year, hemp production in Pennsylvania has now expanded to approximately 1000 acres and over 500 farmers in 2020. During this time, the hemp marketplace has undergone drastic changes, which in turn influenced the motivations and desires of users of Penn State Extension resources focused on hemp production. In order to better understand the needs of this audience, feedback was solicited from potential Penn State Extension users in summer of 2021. Responses showed that the extension audience is comprised of not only existing and potential growers, but also 18% industry or agency members who provide services to hemp growers. Further, most of these farmers are new to growing crops of any kind, and were largely unaware of the services, events, and products extension commonly provides to the agricultural and business communities. While variety testing, specific crop management guidance, and other traditional topics of extension education continue to be extremely important to this audience, respondents make it clear that subjects ranging from the basics of agronomy to the intricacies of navigating the legal and economic landscape of hemp are critical to their perceived success in the industry. Novel approaches to extension education will likely be required to meet the needs of this unique audience in the still-developing industry of agronomic hemp production in Pennsylvania.

Welcome to the National Hemp Growers Cooperative

J. David Cornett, PhD
Chief Agronomist
National Hemp Growers Cooperative, LLC

A brief introduction to the National Hemp Growers Cooperative (NHGC); including summaries of the services available to our members, and what we are doing to provide sound, science-based leadership and guidance to our member/growers in an effort to establish the credibility of industrial (or fiber/grain) hemp as a legitimate and viable agricultural species. We discuss preliminary 2021 seed trials in the Southeast, plans for subsequent, partnered 2022 seed trials to be conducted over a much larger geographical footprint, education and training, and descriptions of other on-going projects and technologies that employ industrial hemp in a wide variety of applications and localities.

Investigating Tactics to Manage Corn Earworm on *Cannabis*

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Production of industrial hemp, *Cannabis sativa* L., has increased tremendously in the U.S. after its legalization through the Agricultural Improvement Act of 2018, known as the 2018 Farm Bill, which allowed commercial hemp production. By grower number, in 2020, Tennessee was the nation's largest hemp program with over 1,800 producers licensed to grow up to 6,500 hectares (16,000 acres) according to the Tennessee Department of Agriculture. Though fiber and seed have a role in the industry, most growers (ca. 98%) concentrate on cannabidiol production because of the expected higher cash value potential per hectare. Introducing hemp as a monocrop system in this temperate region while researchers scramble to provide pest management strategies seems to be brewing a perfect storm for hemp. This emerging industry has been negatively impacted by larvae of corn earworm, *Helicoverpa zea* (Boddie), which feed on developing inflorescences. Unfortunately, few synthetic chemical pesticides are labeled for use on hemp which provides a unique opportunity to investigate alternative control methods.

Hemp varietal research was conducted at the Greeneville Research and Education Center and at the Clyde Austin 4-H Center in Greeneville, TN (both locations in eastern Tennessee) in 2019 and 2020, respectively. The results of this study have revealed that variety and plant maturity are highly correlated to larval damage ($p \leq 0.05$). No correlation between fertilizer or cannabinoid concentrations and larval damage was found ($p > 0.05$). Findings from this research allow hemp growers to make informed agronomic decisions before planting to improve hemp production in Tennessee. Further research on floral processing requirements, pesticide efficacy, olfactory cues for corn earworm moths, parasitoid species as a means of biological control, and varietal selection may lessen the impact of corn earworm larval damage on hemp.

Mechanical Weed Control in Hemp Grain

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Weed control in hemp is a challenge as herbicides have not been registered for this crop. Cultural methods may be a primary means to control weeds in this crop. A trial was conducted in Alburgh, Vermont to evaluate the effectiveness of row spacing on weed control and yield in industrial hemp. The experimental design was a randomized complete block with four replications. Treatments consisted of three types of row spacing: STANDARD at 7.0" between rows, WIDE at 9.0" between rows, and BANDED with a 5.0" seed spread in a row and 6.0" between rows (Figure 1). A dual-purpose industrial hemp variety, 'Anka' (Valley Bio Limited, Ontario, Canada), was planted into 10' x 50' plots on 24-May. The WIDE row treatment was planted with a Kverneland grain drill. The STANDARD treatment was planted with a Sunflower 9412 no-till grain drill. The BANDED treatment was planted with a custom-built seeder that was made from a 12 row International row crop cultivator and converted to an air seeder using a Gandy and a 6212-air box. Parallel linkage units were mounted 12" apart and mounted with precision Dutch openers that created 5" banded seed rows and 6" between rows. The WIDE and BAND treatments were cultivated with a Schmotzer hoe on the 16-Jun. The Schmotzer hoe, imported from Germany, is a manually guided, rear-mounted implement that can be used to cultivate in-between wide rows of hemp. This allows weed control to take place later in the growing season, after plants are well established. Weed cover was assessed as a percent of total plant cover using the web-based IMAGING crop response analyzer. Plant height and populations were measured prior to harvest. Hemp grain yield, test weight, and moisture were measured at harvest. Data were analyzed using mixed model analysis using the mixed procedure of SAS. Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

Weed cover in the treatments ranged from 7.03 to 17.1 percent and there was no significant difference between treatments. Row spacing did not significantly impact hemp yields. The WIDE row treatment yielded the highest, at 1150 lbs ac^{1}, although it was not significantly different from the STANDARD or BANDED treatments. The BANDED row treatment had the highest test weight, at 43.4 lbs bu^{-1}, however this was comparable to the STANDARD row treatment. The STANDARD row treatment had an average height of 177 cm, which was significantly lower than other treatments.

Hence, row spacing did not appear to impact weed biomass and cultivation did not appear to improve weed control. During the early growth stages of hemp, weed pressure appeared to be problematic. The hemp plants were small, weak, and had poor root development while weeds seemed to be growing much quicker. On 16-Jun plots were cultivated, which appeared to reduce weed cover or plant populations. It was certainly plausible to think that cultivating would help with weed control, however the cultivation also seemed to pull-out the tiny hemp seedlings. When the hemp was 8-10" tall, it grew rapidly past the weeds and became far more competitive and clearly could grow past the weed pressure. Future research needs to be focused on practices and management systems that create conditions that allow for maximum seed germination and plant stands that suppress weed pressure.

Floral Hemp Variety Selection for North Carolina Outdoor Production
2018-2021 Statewide variety evaluations

Authors: Davis, Jeanine[1]; Suchoff, David[2]; Post, Angela[2]; Bloomquist, Margaret[1]; Katherine Learn[1] and Shannon Henriquez Inoa[2]
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Four years of floral hemp variety evaluations across the state of North Carolina were completed in October 2021. Our objective was to evaluate popular and breeder submitted floral hemp varieties for cannabinoid biomass production and regulatory compliance. Variety selection and development are integral to successful production of floral hemp in North Carolina. North Carolina hemp producers' most important considerations have been optimizing best practices for yield, passing compliance testing, and addressing factors affecting post-harvest handling in a humid environment. Outdoor trials were completed at three locations per year from 2018 – 2021. Planting dates were early June, with 12 to 29 varieties per year, each replicated three times at all sites. Varieties were evaluated for: days to flowering and maturity, size, shape, yield, cannabinoid analyses, and tetrahydrocannabidiol (THC) compliance. In 2021, a fee structure was incorporated to the NC State floral hemp variety trials, and triploid hemp varieties were added. Nineteen entries were grown and evaluated in 2021 in the coastal, piedmont, and mountain regions of the state.

Observations over the trial years include increased uniformity within strains and uniformity across varieties suggesting favorable advanced trait selection for the state. Data supporting marketable yields and cannabidiol (CBD) content varied across years, sites, and varieties. In 2021, all varieties at the mountain site had compliant THC testing with the North Carolina Industrial Hemp Pilot Program and were sampled at appropriate timing for USDA hemp program compliance. This information supports the evolving industry and provides a view of the evolving pool of varieties available and in development for the North Carolina floral hemp industry. Information from these studies is available by year and location for producers. Thanks to the NC Agricultural Foundation for funding these studies. Additional resources can be found on the NC State Extension Hemp webportal.

Parasitism of Corn Earworm by Tachinid Flies in Industrial Hemp

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Fig 1. Tachinid fly ready to attack a defensive CEW larva.

The corn earworm (CEW), *Helicoverpa zea* Boddie, is one of the major pests attacking hemp (*Cannabis sativa* L.) in the United States. However, its economic impact is still unknown. Larvae of this moth feed on hemp flower buds, seeds, and leaves, especially affecting hemp grown for CBD production. Since Kentucky is one of the top hemp producers in the US, protecting the emerging outdoor production is critical. Little is known regarding CEW interactions with natural enemies, -specifically parasitoids- in this system. Tachinids are endoparasitoids of several insects including moths, butterflies, beetles, stink bugs and many other pests of economic importance. Still, detailed studies of the role of tachinids in the biological control of hemp pests are lacking (Fig 1).

Fig 2. CEW larva with tachinid eggs.

The objectives of this study were to quantify and model the parasitism rates by tachinid flies upon CEW affecting field grown hemp, and to identify the tachinid species in this system. The study took place at three locations of western KY (two sites in Caldwell and one in Calloway counties). The number of CEW larvae, proportions of parasitized larvae (tachinid eggs attached to the body, Fig 2.), and healthy larvae (undetected eggs) per plant (N=390) were recorded. In the lab, we reared both healthy and parasitized larvae under controlled conditions, recording the weight and number of eggs per individual larva.

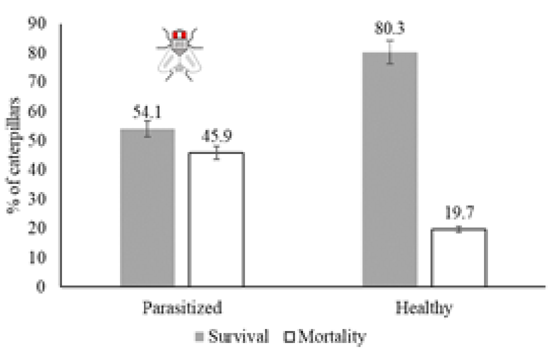

Fig 3. Survival and mortality on parasitized and healthy CEW.

Tachinid eggs observed in single CEW larva ranged from 1 to 22. The number of eggs was not correlated with the weight of CEW larvae. Mean (±SEM) percentage of parasitized CEW larvae per plant was 42.7±4.2. Tachinid flies induced 45.9% mortality on parasitized CEW (Fig 3). The difference in survival proportion between healthy and parasitized larvae was highly significant ($\chi^2 = 25.9$, df = 1, $p<0.001$). In healthy larva the mortality reached to 19.1%. The mortality of healthy larva maybe due to natural causes, handling, pathogens, or other unknown reasons. Both the number of eggs and weight of the caterpillars explained the mortality ($\chi^2 = 14.9$, df = 2, $p<0.001$). The number of eggs is positively related to mortality, whereas the larval weight showed a positive effect on the survival of everyone. The identification of tachinid species is still in progress.

Hemp-Weed Interactions

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Information regarding the interspecific interactions between hemp and weeds is limited. Some limited studies suggest that hemp is a competitive crop, once established. Hemp produces a diverse array of secondary metabolites, the most abundant of which are terpenes and cannabinoids. These compounds are not known to be related directly to plant growth and may serve other functions instead, perhaps acting as allelopathic compounds which promote the competitive success of hemp. Two studies were conducted to assess hemp-weed interactions. The first tested the ability of hemp to compete with a highly competitive and economically damaging weed in agricultural systems, waterhemp (*Amaranthus tuberculatus* (Moq.) Sauer). High cannabidiol (CBD) hemp plants were placed in competition with varying densities of waterhemp, at 0, 1, 3, and 5 plants per planting hole in a plasticulture system in Carbondale, IL in 2019 and 2020. Hemp floral yield, total biomass, and phytochemical profile were tested for differences in response to competition. The second study assessed the potential allelopathic properties of hemp residue in greenhouse pots with the equivalent residue to 3,781 kg ha^{-1}, either incorporated into soil or placed on the soil surface, and compared to a corn residue (*Zea mays* L.) control. Five species were tested for sensitivity to hemp residue, as well as hemp itself, including soybean (*Glycine max* L.), wheat (*Triticum aestivum* L.), velvetleaf (*Abutilon theophrasti* Medik.), yellow foxtail (*Setaria pumila* [Poir.] Roem. & Schult), and waterhemp. While there was no effect of waterhemp competition on hemp yield or phytochemistry at any waterhemp density, yield and phytochemistry profiles were different by year. There was, however, an effect of hemp residue on the germination and growth of some species. While incorporated hemp residue had little effect, hemp residue placed on the soil surface reduced the germination of waterhemp. Hemp residue also reduced the biomass accumulation of all species except soybean and hemp. While this study suggests hemp residue may affect germination and growth of other plants, it does not suggest which components of hemp residue are responsible. There may be potential in the future to use the weed suppressive abilities of hemp residue in rotation with other crops in an integrated weed management approach.

Time of Infection and Host Susceptibility of Common Leaf Spots in Kentucky Hemp

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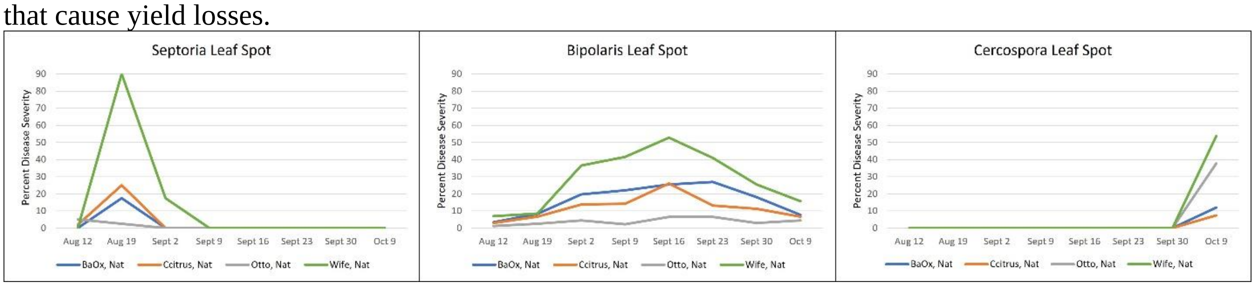
Leaf spot diseases have been the most prominent disease challenge of hemp since the crop was reintroduced in 2014. Since then, those diseases have shifted in importance. Hemp cultivars with different susceptibilities have come and gone. Thus, understanding disease cycles has been challenging. The most prominent foliar diseases of field hemp in Kentucky in the past eight years were Bipolaris leaf spot (*Bipolaris gigantea*), Cercospora leaf spot (*Cercospora flagellaris*), and Septoria leaf spot (*Septoria cannabis*). These diseases have consistently caused plant losses as a result of severe blighting, failure of flowers to mature, or processors rejecting entire shipments. Because modern hemp is a "new" crop, little is known about production systems and pathosystems. In order to properly manage diseases in hemp, we need to better understand fundamental concepts. This study addressed some basic questions regarding host susceptibility and time of infection for the most prominent diseases of hemp.

Experimental cultivars from four different relatedness groups (Baox, Cherry, Otto II, Trump) were planted at two locations in Kentucky in 2020 and 2021. Fields were planted in mid to late June and harvested in early October. Disease was rated weekly beginning 4 weeks after planting and through harvest. Septoria leaf spot was the first disease to appear in fields: mid-July in production fields and late-April in volunteer seedlings in Year 2. Septoria leaf spot was most severe in lower to mid-canopies, causing defoliation in the most severe cases. Disease peaked in late-August. Bipolaris leaf spot developed in late-July and became more severe in the most susceptible cultivars and in upper canopies. Cercospora leaf spot developed in late-September and became more severe in both upper and lower canopies. Sugar leaves curled and became necrotic. The Trump group (cv T1, cv Wife) were the most susceptible to all three leaf spot diseases (higher disease severity). The Otto II group (cv Otto II, cv Endurance) was the least susceptible to the diseases.

Even in the most severely diseased plots, yield loss was not affected by disease. Both biomass and cannabinoid (CBD) yields were similar to fungicide-treated and non-inoculated plots. However, our observations confirmed that commercial fields across Kentucky were inconsistently affected by the diseases. Wet fields and those with more humid microclimates were consistently more affected by leaf diseases, and sometimes crops suffered complete losses by whole plant blighting or rejection by processing facilities.

This research is but one step toward understanding the common leaf spot disease of hemp. A better understanding of the pathogens and their interactions with hemp can bring us to better manage diseases that cause yield losses.



Scouting for Disease: Pathology for Non-Pathologists

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Plant diseases cannot be identified by symptoms, alone. In fact, diseases are simply reactions by the plant; these symptoms are not pathogen specific. Different disease agents can produce symptoms identical to one another. Likewise, symptoms from a single causal agent can be inconsistent or unpredictable based on host or environmental conditions. Confirmation of disease agents requires examination of the pathogen itself (for example fungal spores) or sequencing of genetic material. For the non-pathologist, this is often left to a specialist.

Field scouting focuses on collection of observations and information that either narrows the problem down to a particular disease or group of diseases or provides a pathologist with information needed for a confirmation. Regardless, field observations are critical for accurate diagnoses. Therefore, the responsibility of scouting may fall on agronomists, entomologists, county agents, or growers who can spend sufficient time in the field.

This 5-step approach to field scouting can serve as a reliable method for data collection and preliminary diagnoses.

<u>A checklist for field scouting:</u>

1. Begin with an overview of the field (or greenhouse): drainage, soil, compaction, grade change, surrounding plants, weeds, etc. Examine and/or photograph the field in its entirety. Look for patterns across the planting. Take note of scattered symptoms or hot spots where problems are concentrated. Photos are always helpful.
   Document details like fertility (including soil test results), field history, hemp cultivar, planting date, and any other information about the planting.
2. Examine affected plants at soil or crown level. Take note of wounds or damage. Look for fungal signs such as mycelial mats or sclerotia near the soil. Check for plant stability and anchoring of roots/stems. Take whole plant samples, including roots, if possible.
3. Examine individual plant canopies or single branches. Trace dieback to the point of origin. Sample whole branches by cutting as far back from the canker or wound as possible.
4. If entire plants are affected, examine roots. Dig (don't pull) entire root systems. Leave some soil intact for further examination in the lab.
5. Lastly, consider leaf and flower symptoms. Distinguish leaf spots from abiotic symptoms like marginal leaf scorch. Document any patterns within the plant (upper or lower canopy, new or old leaves, etc). Photographs are always helpful. Press leaf samples in paper; do not store diseased leaves in plastic bags; put flower or seed heads in paper bags.

Disease Firsts in the First Year of Hemp Production in Missouri

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Hemp production, both CBD and industrial hemp, was a new addition to Missouri fields in the 2020-2021 growing season. The number of permits requested across the state increased from 2020 to 2021 making the need for timely, accurate information regarding the spread and impact of hemp diseases in Missouri production systems of critical concern. In the 2021 growing season, numerous hemp samples were received at the MU Plant Diagnostic Clinic from throughout Missouri. Potential pathogens were plated on media and disease-causing organisms were identified (**Table 1**). Diseases observed included foliar and vascular diseases, some of which had been reported in earlier decades. Of note were new diseases to hemp production in the state which caused significant damage in some production fields. One such disease was charcoal rot, a relatively common disease of corn and soybean, which has not been reported on hemp in Missouri until this season. Understanding the types of disease challenges of hemp in Missouri will allow for implementation of integrated disease management strategies in the future, including crop rotation.

Table 1. Diseases of hemp observed and number of diagnoses from samples received at the MU Plant Diagnostic Clinic during the 2021 growing season, the first year of commercial hemp production in Missouri.

Disease	**Pathogen**	**Number of Diagnoses**
Pythium Crown and/or Root Rot	*Pythium* spp.	8
Charcoal Rot	*Macrophomina phaseolina*	6
Fusarium Crown and/or Root Rot	*Fusarium* spp.	5
Yellow Leaf Spot	*Septoria cannabis*	2
Stemphylium leaf and stem spot	*Stemphylium* spp.	2
Olive leaf spot	*Cercospora* spp.	2
Brown leaf spot and stem canker	*Phoma* spp.	2
Anthracnose	*Colletotrichum* spp.	2
Alternaria Leaf Blight	*Alternaria* spp.	2
Cercospora leaf spot	*Cercospora* spp.	1
Dieback; Canker; Twig Blight	*Botryosphaeria* spp.	1
Abiotic (Herbicide Drift)		1
Total		**34**

Fusarium diseases of *Cannabis sativa*: a review

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Losses due to species of *Fusarium* associated with hemp range from minor to total crop loss, but impacts also includes mycotoxin production and the ability to be opportunistic human and animal pathogens. Sixteen species associated with hemp are classified into six species complexes: *Fusarium oxysporum*, *F. solani, F. incarnatum-equiseti, F. sambucinum*, *F. tricinctum*, and *F. fujikuroi*. Control strategies for fusarium diseases of hemp rely mostly on those developed for other crops. Based on historical observations, it is likely that there is disease tolerance in *C. sativa*. Fifty-eight biopesticides and one conventional pesticide have been labelled for use on hemp in the US, but multiple products share the same active ingredients. Of the 23 products with stated fungicidal activity, only fourteen mention *Fusarium*. Chemical structures of the mycotoxins produced by these species of *Fusarium* vary from very simple chemicals (butanolide and butanolide) to structurally complex molecules such as depsipeptides (beauvericin and enniatin B) and trichothecenes (deoxynivalenol and its acetylated derivatives, diacetoxyscirpenol, and T-2-toxin). Control of these fungi is essential to prevent crop loss and to exclude these fungi and their associated mycotoxins from consumer products.

Genetic Transformation in Cannabis

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Genetic transformation has been used for decades to elucidate the functional genomics of crop species helping to determine genes' roles in plant phenotypic development and subsequently contribute to informed decisions in sustainable breeding programs. For example, in Arabidopsis, the discovery of the AGO mutant paved the way for the development of siRNA-mediated gene silencing technology which silences a gene's protein products post-transcriptionally resulting in developmental abnormalities as seen in this image of an Arabidopsis from Bohmert et al. 1998. Transformation can also be used to develop pest and pathogen resistant varieties, decrease grain yield loss by interrupting shattering genes, improve fiber quality by reducing the accumulation of lignin in the xylem, enhance plant architecture by identifying deleterious mutations in potential parental breeding stock, and even maybe even improve cannabinoid content by down regulating undesirable enzymatic function, plus much more. In this presentation I will share a theorized step-by-step protocol for the genetic transformation of *Cannabis sativa L.* and highlight areas in which the scientific community may contribute to the development of this valuable tool for the future of sustainable *Cannabis sativa L.* breeding programs.

Reference Plant Tissue Nutrient Ranges for *Cannabis sativa*

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Foliar plant tissue surveys of both field and greenhouse crops are frequently conducted in order to estimate the sufficiency levels of individual plant nutrients in crops. These reference values are used to detect fertility problems in the crop by plant tissue analysis. As an emerging crop in commercial production, little published data exists documenting nutrient levels in *Cannabis sativa* and no field survey levels have been published. In this study, 6119 hemp (*Cannabis sativa* L.) foliar plant tissue samples collected from 76 North Carolina counties and submitted to the NCDA&CS Agronomic Division between 2017 -2020 were analyzed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and Mo. The >100 *Cannabis* cultivars included in this survey were grown for cannabidiol (CBD) production in both field and greenhouse systems. Reference ranges for each element were calculated using a quartiles approach on the population distribution of the sample set. Comparison of elemental concentrations in field and greenhouse samples showed similar distributions and medians and thus were combined into one survey to produce a single set of recommended sufficiency ranges for *Cannabis*, regardless of production system. The 1st (Q1; 25th percentile) and 3rd (Q3; 75th percentile) quartiles of the population distribution for each element were calculated and used to approximate the lower (Q1) and upper (Q1) levels of the sufficiency range. To validate the approach, the predictive Q1 critical level was tested against published deficiency levels for *Cannabis* and the predicted sufficiency range (Q1--Q3) was compared to published greenhouse surveys. For macronutrients (%), the suggested sufficiency ranges for CBD cultivars are: N (3.3-5.0); P (0.27-0.48); K (1.8-2.7); Ca (1.5 -2.9); Mg (0.30-0.65); S (0.25-0.36). For micronutrients (mg kg^{-1}), the suggested sufficiency ranges are: Fe (70-150); Mn (40-158); Zn (33-60); Cu (5-11); B (30-90); Mo (0.3-1.5). These ranges serve as an acceptable estimate of expected nutrient levels in hemp grown in the Southeastern U.S. until additional information from sufficiency ranges studies become available.

Herbicide Efficacy for Weed Control in CBD Hemp

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Due to the short amount of time we have been growing hemp in the modern era, we have limited research on the pests that destroy hemp in the United States. Therefore, the purpose of this study was to evaluate existing herbicides in CBD hemp fields to determine effectiveness against weeds. We measured weed coverage using a quadrat and assessed total weed coverage. Treatments included five herbicides, an untreated control, and mechanical removal with a hoe. Harvested hemp samples were sent for potency testing. We found that herbicides resulted in significantly lower weed counts and coverage than the untreated control. Regarding the effect of herbicides on CBD and THC levels, only one herbicide resulted in a potency level higher than the legal limit. The other herbicides did not affect the level of either chemical. Regardless of product used, the herbicides significantly suppressed weed presence compared to the untreated control, but none provided complete control.

An Analysis of Industrial Hemp THC in Kentucky

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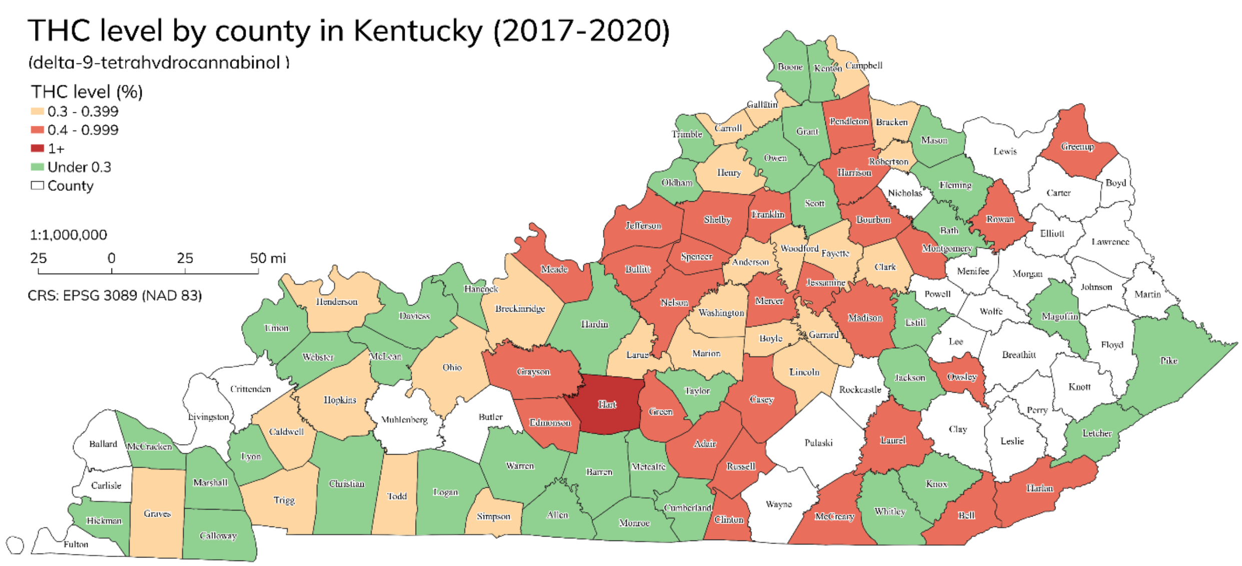
Since the inclusion of industrial hemp into the 2014 & 2018 Farm Bills, interest in grain, fiber and floral hemp production has been going through growing pains. Producers have been seeking opportunities to diversify their operations and to increase profits. The present problem that farmers growing industrial hemp have had is the THC content, which is the psychoactive chemical component that cannabis plants (e.g., marijuana, hemp, and hashish) commonly have as well as, which is the only criterion to distinguish industrial hemp from other cannabis plants.

Farmers who want to cultivate industrial hemp with the license issued by State government must observe the regulation where the level of THC of industrial hemp products must be under 0.399% (3,999 ppm) in Kentucky. Because the THC sample test is performed during the harvest season, farmers never know the level during the growing season. Thus, they might fail to crop and get lost all investment on industrial hemp if the level of THC tested is over the threshold. It implies that the level of THC is the risk (or uncertainty) for farmers to operate their farms. Moreover, the crop failure may affect the farming plan of the next year and discourage cultivating industrial hemp, causing the increase of farm exists.

In this poster and research, we want to describe statistics on THC level and to explore the geographical relationship of the level of THC in Kentucky. We will display the change of THC level by year and by county in Kentucky. Using the histogram and quantile statistics, we draw the distribution of THC level and compare the mean by year. In addition, we will draw the choropleth map on the level of THC by county, displaying the spatial correlation between counties in Kentucky.



Relationships Between *Cannabis sativa* and *Epicoccum nigrum*

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Epicoccum species that are biologically active against phytopathogens can act as antagonists, produce antifungal chemicals, or induce resistance and enhance growth of host plants. *Epicoccum nigrum* is a ubiquitous fungus that can cause plant diseases and act as a biological control against a range of plant pathogens. Leaves of industrial hemp 'Katani' seedlings grown in the greenhouse with foliar symptoms of disease were surface sterilized and plated on water agar to isolate endophytic fungi. Fungi were identified based on cultural morphology and sequencing of the internal transcriber spacer region of the rDNA operon. Both *E. nigrum* and known fungal pathogens (*Bipolaris, Fusarium,* or *Alternaria*) were commonly co-isolated from these tissues. Disease symptoms did not develop when plants were inoculated with *E. nigrum* spore suspensions (10^8 spores/mL) spread on leaves (wounded or not wounded) or applied as a root drench. However, in detached leaf assay, tissue degraded in areas of fungal growth but not in no-pathogen controls. When 'Katani' seedlings (3-4 weeks after planting) were inoculated with *E. nigrum* spore suspension, then challenged with spores of *Bipolaris*, disease severity caused by *Bipolari*s was reduced. All hemp isolates of *E. nigrum* produced a yellow-orange pigment on the underside of the colony and in culture medium in advance of fungal growth. Dual cultures of pathogens and *E. nigrum* were grown on potato dextrose agar (PDA) with streptomycin. A mycelial plug of the pathogen was placed in the middle of a Petri dish containing PDA. Four agar plugs (two from *E. nigrum* cultures and two from PDA without pathogen) were placed equidistant from the pathogen. In dual culture, *E. nigrum* inhibited growth of all tested phytopathogens (*Fusarium* sp., *Bipolaris* sp., and *Alternaria alternata*). Width of the zone of inhibition (two per plate) was measured from photographs at ten points using ImageJ software and averaged for each plate. The experiment was repeated. *Bipolaris* and *Fusarium* were more sensitive to the presence of *E. nigrum* than *A. alternata*. Many of the secondary metabolites of *E. nigrum* are volatile. To test for the presence of inhibitory *E. nigrum* volatiles, *E. nigrum* was grown for six days on PDA, and the pathogens were grown for five days on PDA. Lids of the plates were removed, and bottoms of the Petri plates with pathogen above were sealed together with Parafilm. Colony diameter was calculated from photographs using ImageJ software. In preliminary tests, pathogen growth was not inhibited when grown above *E. nigrum* cultures, suggesting that pathogen inhibition by *E. nigrum* was not due to volatiles. These results showed competition between *E. nigrum* and other pathogens of hemp, supporting our hypothesis that *E. nigrum* has potential to reduce diseases in hemp. Additional research to support the nature of pathogen suppression will be performed.

Summary of National Grain/Fiber Cultivar Trials

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With the passage of the 2014 Farm Bill, States were permitted to begin research on the production of hemp (*cannabis sativa L.* with less than 0.3% THC). There was intense interest among growers in cultivating hemp for grain, fiber, and floral material, however most of the plant genetics that had been grown in the U.S. had been lost over the years in which hemp could not be cultivated. Cultivars for fiber and grain production were sourced from Canada, Europe, China, and Australia. The suitability and adaptability of these cultivars to US growing areas (particularly at Southern latitudes) was unknown. In support of the objectives of the USDA S-1084 Multi-State Hemp Project, several institutions worked to put together a national program to examine growth and yield of grain and fiber cultivars across different latitudes of the United States. The program has expanded each of the last three years with 11 institutions participating in 2019, 14 in 2020, and 15 in 2021. Each participating site grows a common collection of 10 to 15 cultivars provided by the breeder or an authorized seed distributor. All seeds are sent to common location at the University of Kentucky to be germination tested and shipped to the participating institutions. This ensures that all sites are using the same lot of seed for each cultivar. Participating institutions plant, care for and harvest cultivars in a randomized complete block design, following a generally agreed upon protocol modified to fit local equipment and conditions. This trial experience was the first attempt at growing hemp for many of the institutions. Each year several sites have struggled with stand establishment, weed encroachment, weather damage, and bird predation. Despite these challenges, the program has managed to collect performance data from several sites each season in order to begin to inform decisions about cultivar selection. Summary data for 2019 and 2020 will be presented. Thus far, it seems that many of the genetic resources currently available for grain and fiber production are better suited to Northern latitudes. When grown in the South, these cultivars are often smaller in stature with lower straw and grain yields due to flowering earlier in their growth period. Additional work is needed to find or develop cultivars adapted to different regions and to establish optimum management conditions and optimum planting dates for each region. As we have learned more about hemp production, the protocol and data collection procedures have improved with each iteration of the trial. In 2021, a common data collection template was provided for each participant to record their data to make data analysis easier and speed the dissemination of the information to stakeholders. For the future, we plan to continue this program as long as there is interest among the core group of institutional partners.

Effect of Different Drought Intensity and Timing on Floral Hemp Photosynthesis and Cannabinoid Profiles

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Drought is a common abiotic stress that can negatively affect plants at the organismal and cellular level. Hemp production was legalized at the federal level in 2018, however, there is a lack of information available about how to grow their crop while maintaining THC compliance. Prior research conducted with marijuana has demonstrated significant increases in cannabinoid production during drought stress with mixed results on the effects of yield. Little information is known about the effects of drought intensity and timing on hemp yields and cannabinoid profiles in drought stressed hemp, therefore the objective of this study was to use two hemp (*Cannabis sativa*) cultivars to demonstrate the effects of different intensities and timings of drought stress on water use, yield, and cannabinoid profile. Greenhouse trials were conducted in Zirconia, NC in 2021. Water use, cannabinoid profile, and yields were analyzed for each cultivar and a two-way ANOVA was performed. We found that there were significant differences between the two cultivars used in the study. Throughout the study Baox used more water than Cherry Mom. Drought intensity effects on yield depended on variety, with Baox having significant differences among drought intensities, with early stress showing the largest loss. However, the cultivar Cherry Mom had no significant differences between drought intensities implying that this cultivar could be drought tolerant. Cherry Mom demonstrated higher THC and total cannabinoid content earlier in the season due to faster maturity, however; Baox tended to have similar levels of Cherry Mom close to harvest. Drought resulted in significant decreases in THC content solely in extreme situations, however total cannabinoids for both strains differed significantly depending on drought intensity and timing. This study is important because it shows abiotic stress factors, such as drought, can have a profound impact on overall yields, cannabinoid content and health of different hemp cultivars.

Assessment of Floral Hemp Planting Date and Density for Optimized Biomass Production

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Floral hemp (*Cannabis sativa* L.) grown for CBD extraction is relatively new for North Carolina's agricultural landscape. In order to address the current lack of farmer guidance the aim of this study is to produce best agronomic practices for floral hemp. The goal of this research was to assess how transplant date and transplant density affect floral hemp biomass production. Two trials were conducted in 2020 (Kinston and Salisbury, NC) and three in 2021 (Salisbury, Kinston and Jackson Spring, NC). The CBD hemp cultivar BaOx was used at all locations. This trial utilized a split-plot design with planting date as the main-plot and planting density as the split-plot. There were a total of 5 planting dates which occurred every two weeks, spanning from mid-May to early July. Four planting densities were investigated: 0.91, 1.12, 1.52, and 1.82m between plants. Height and width measurements were taken weekly until the plants transitioned into the reproductive phase. Two plants per plot were harvested at floral maturation (approximately 25% amber trichomes). After harvest, plants were dried, and floral and leaf material was stripped from the stems and weighed. Results indicated that the main effect of transplant date and plant spacing were significant for biomass production. Biomass yield followed a linear regression, with the crop losing approximately 0.009 kg per plant or 45 kg ha^{-1}. The effect of plant spacing on a per plant basis showed a higher yield with a 1.82 meter spacing however, the 0.91 and 1.12 meter spacing yielded more on a per-hectare basis. These trials suggest that, while spacing can affect yield on a per-plant basis, yield on a per-hectare basis is driven by the number of plants per hectare and the time of transplant.

Exploration of Temporal Cannabinoid and Biomass Production in Floral Hemp

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The production of compliant hemp requires total THC to not exceed 0.3%. Exceeding this legal threshold would result in a non-compliant crop and economic loss to the grower. With limited available information, growers must test their crop regularly to determine when to harvest. Insufficient data exists on temporal biomass and cannabinoid production in hemp for CBD extraction. This research was conducted to elucidate how biomass, CBD, THC production develops during floral development with the goal of creating grower recommendations for optimum harvest timing. Field trials were conducted in 2020 and 2021 growing seasons in Kinston and Salisbury, North Carolina as well as in a greenhouse during the fall of 2020 in Raleigh, NC. Field trials included the CBD hemp cultivars BaOx and Cherry Wine. The cultivars were planted with 1.52 meters spacing in 20 plant plots. Three plants were harvested at 2, 4, 6, 8, 10 and 12 weeks after flower initiation. Harvested plants were dried at temperatures below 48.9 °C. Leaf and floral material were removed from the stalk, weighed, then submitted for cannabinoid analysis. The greenhouse portion of this study included the cultivars BaOx, Cherry Wine, First Light 58, First Light 70, and TJ's. This portion of the study utilized a similar protocol. Three plants from each cultivar were harvested at 2, 4, 6, 8, and 10 weeks after flower initiation. During each harvest event fresh samples were collected for cannabinoid analysis. Biomass and cannabinoid data were collected in a similar fashion to field trials. Additionally, at the time of harvest hyperspectral imaging was used to image floral and leaf material. We plan to use machine learning modeling to determine if the hyperspectral imaging data could be a tool for non-destructive measurement of cannabinoid concentrations.

Characterization of Hemp Hull Pellets

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As the landscape of the next generation of agriculture takes shape, renewable bioproducts will be a factor for a sustainable future. Like any other product, sustainable products should aim to be profitable, but they also need to have a net neutral or positive effect on the environment. These effects can be measured in their direct or indirect impact by means of competing or displacing current products in the market. Hemp is a promising crop for the future as it creates unique biomass for novel products and provides alternatives in areas like plant based proteins and natural fibers. To reach its full potential, secondary products from waste streams need to be examined for full utilization of the biomass. If hemp processing is to scale, automation and year round feedstock availability will be required for major operations to become involved. Pelleting biomass creates a dense feedstock and gelatinization (also referred to as plasticization) significantly increases pellet durability. The hulls that remain after hemp heart production are currently underutilized and provide an opportunity for bio-processors. Density can often limit the range in which bio-processors are willing to purchase materials, thus efforts in densification are often explored to expand the market for a given feedstock. Pelleting hemp hulls increases the density and produces a consistent form that is ideal for developing automated handling and provides a useful model for storage in grain bins.

This research project explored the parameters of pelleting hemp hulls for the establishment of recommended conditions for pelletization. Pretreatment included hammer milling (5mm screen) and setting the moisture content for two treated groups and a control. A total of six conditions were pelleted (five treatments groups and a control) using a pilot scale flat ring pellet mill and examined for: PDI (pellet durability index), bulk density, compressibility, angle of repose, and energy consumption of the pellet die.

Observations of Insect and Disease Pests on Field Grown Hemp in Kentucky

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Considering the recent increase of industrial hemp production in Kentucky, we provide preliminary results on the most common arthropods and diseases found on field grown hemp for cannabinoids, grain, and fiber purpose. Surveys were conducted at research sites on the University of Kentucky (UK) Spindletop Farm (Lexington, KY) and UK Robinson Center (Quicksand, KY), during the 2021 growing season. **Insects and mites:** The most common damage observed was generated by bud worms – especially by corn earworm (*Helicoverpa zea*). This pest was observed in hemp grown for grain, fiber, and cannabinoid (CBD) production. Corn earworms caused greatest damage in hemp grown for cannabinoids, probably associated to the dense bud structure. Several stink bugs: Brown marmorated stink bug (*Halyomorpha halys*)*;* brown stink bug complex (*Euchistus* spp.), and the green stink bug (*Chinavia hilaris*) were found in all hemp types, but their damage was not evident and further research is necessary. Main foliage feeders were the yellow striped armyworm (*Spodoptera ornithogalli*) and yellow woollybear (*Spilosoma virginica*). The cannabis aphid (*Phorodon cannabis*) and hemp russet mite (*Aculops cannabicola*) were found in all the hemp types. No considerable damage was observed by cannabis aphid in the field, although they are important in greenhouses. Hemp russet mites were present in the foliage and buds of all field hemp, but their damage needs further studies. In addition, scouted fields exhibit the significant presence of natural enemies such as big-eyed bugs (*Geocoris* sp.), pirate minute bug (*Orius* sp.) and several species of ladybugs (*Coccinellidae*). **Diseases:** Septoria leaf spot (*Septoria cannabis)* was documented in hemp trials for cannabinoids, grain, and fiber purpose. It was observed since vegetative stages in the lower leaves. Due to the rainy conditions of the 2021 season, the disease was also observed in leaves from the upper part of the plants beginning August 15th – September 15th among the different trials. First observations of Bipolaris leaf spot (*Bipolaris gigantea*) and Cercospora leaf spot (*Cercospora flagellaris*) in the upper leaves were also documented during the same period. In hemp cultivars for cannabinoids, at the end of September severe blighting caused by *Rhizoctonia solani* affected entire plants and plots. In addition, separate cases of Anthracnose (*Colletotrichum fioriniae.)* and Southern blight (*Athelia rolfsii*) were observed. Lastly, in hemp cultivars for fiber, grain, and cannabinoids *Fusarium graminearum* (and other *Fusarium* spp.) infestations were found. Additional research is being generated to increase our knowledge about these pests and their impact on the industrial hemp production.

Figures: a– Corn earwom (*Helicoverpa Zea*) on hemp for cannabinoid purpose; b- *Fusarium graminearum* infestation on hemp for grain and fiber purpose; c- *Rhizoctonia solani* on hemp for cannabinoid production.

Evaluation of Biological Insecticides Efficacy for Spider Mites on Greenhouse Hemp

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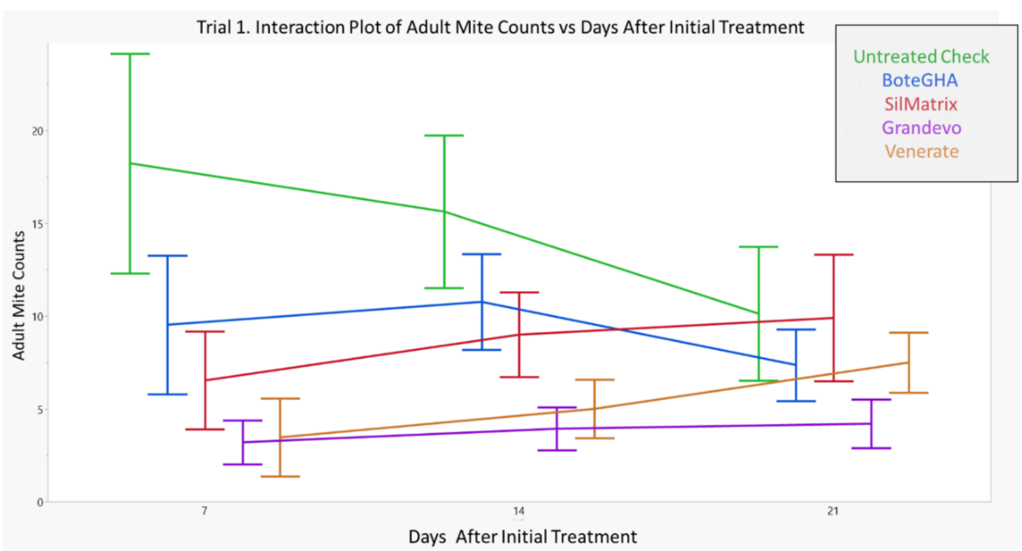
Through two trials, the following products were evaluated for efficacy of two spotted spider mites (TSSM) in greenhouse hemp: Grandevo® (*Chromobacterium subtsuge* strain PRAA4-11 and spent fermentation media), Venerate™ XC (*Burkholderai* spp. Strain A396), BoteGHA® ES (*Beauveria bassiana* strain GHA), and Sil-Matrix® (Potassium silicate) alongside an untreated control against TSSM. Products were sprayed at the label rate on 7-day intervals with the exception of 3-day intervals with Venerate™. The study was a randomized complete block design with 10 blocks. In Trial 1, adult and egg counts were conducted on 3 cm leaf segments randomly selected from a top, middle, and bottom leaf of each experimental unit. For adult counts, ANOVA indicated an interaction between treatment and time with repeated measures. Grandevo® and Venerate™ maintained lower adult TSSM counts when compared to the control in terms of adult counts at 7 and 14 days after initial treatment. Venerate was not different than the control at 28 days after initial treatment. No meaningful trends were observed with egg counts. The interaction of treatment and time were also significant for plant damage, where Grandevo® and Venerate™ had a greater level of performance than most treatments throughout the trial. Plant growth was unaffected by treatment. Trial 2 followed a similar protocol to Trial 1; however, TSSM adult and egg counts were not collected. Venerate was the only product that scored lower damage ratings when compared to the untreated control. Similar to Trial 1, plant growth was unaffected by treatment. Results of both trials demonstrated that Grandevo® and Venerate™ have potential to reduce mite populations and plant damage from an infestation of TSSM. Future work should allow for lower mite pressure and evaluation of these products as preventative treatments.



Phytotoxicity of Tolerant Exempt Pesticides on *Cannabis sativa* L. Hemp Transplants

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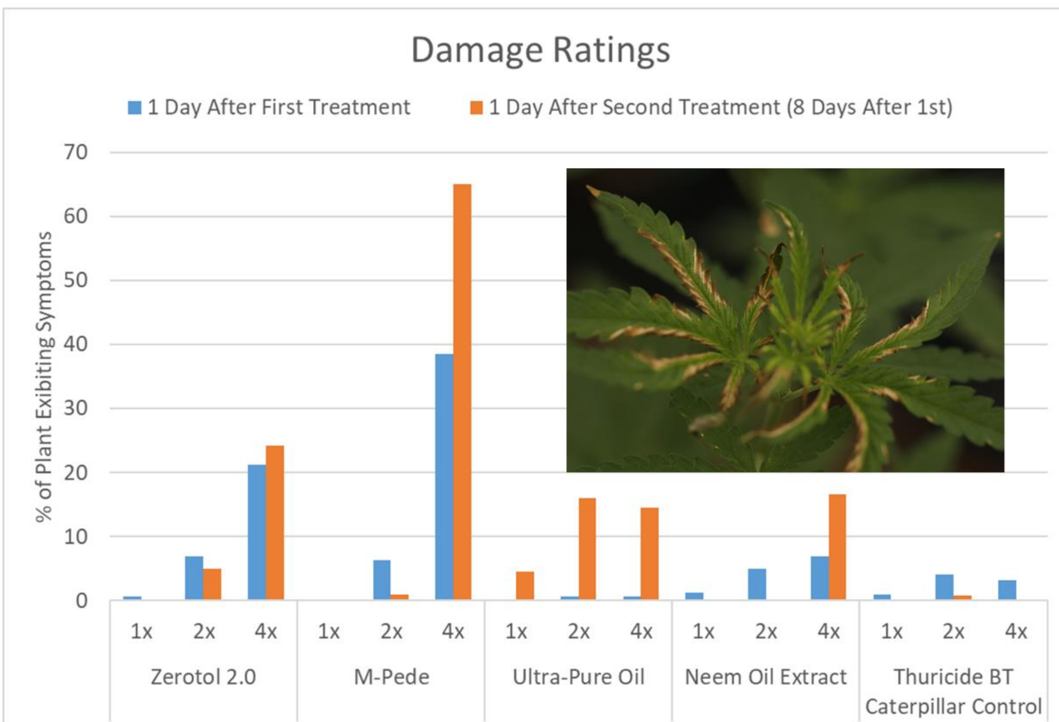
This study was performed to demonstrate the safety of five tolerance exempt pesticides that are commonly used in hemp production. Treatments of Zerotol® 2.0, M-Pede®, Ultra-Pure™ Oil, Neem Oil Extract, and Thuricide BT Caterpillar were applied a 1, 2, and 4 times the recommended label rate with a second application 7 days later. Twenty-four hours after treatments were applied, phytotoxicity damage ratings were recorded. Plant height was recorded at 7 and 14 days after initial treatment. Each treatment was compared to the control with Dunnett's Test. Zerotol® and M-Pede® at 4 times the label rate were the only treatments different than the control in phytotoxicity. M-Pede at 4 times the label rate was the only treatment that demonstrated a difference in plant height when compared to the control. Other trends may become more evident in future studies that utilize clones. All products were similar to the control at the label rate.



Economics of Hemp Production

Buddhika Patalee and Tyler Mark
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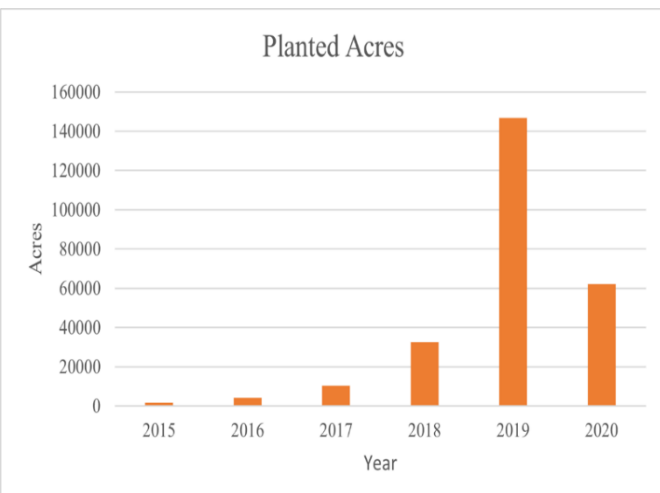
Hemp, a variety of Cannabis sativa L., is widely used as a grain, fiber, and cannabidiol (CBD) in various products, including textiles, paper, and automotive products. Although hemp production was heavily discouraged in the United States in the early 19th century, it became legal following the passage of the Agricultural Act of 2014. Industrial hemp and marijuana contain active tetrahydrocannabinol (THC), which is a psychoactive ingredient. Industrial hemp, however, is high in fiber and has low THC levels, but industrial hemp production is strictly regulated to maintain THC levels less than 0.3% (Agricultural Marketing Resource Center, 2019). Hemp oil, commonly known as CBD, is a nonintoxicating compound that has gained consumer popularity due to its use in sleep aids and pain and stress relief products. Hemp production was federally legalized in the Agriculture Improvement Act of 2018, and despite many difficulties, licensed hemp acreage surged. According to Farm Progress, as of January 2021, the U.S. cannabis industry supported 321,000 jobs across the country, with a projected increase of 250% in 2028.

While many new hemp producers are small-scale and new to hemp production, successful hemp pilot programs have revealed prevalent challenges, including marketing, legal, production, and financial risks. A holistic approach to managing the risks is fundamental in developing hemp markets. The economic viability of the hemp industry is highly dependent on the information availability of demand, supply, market prices, and future demand-supply predictions. Limited information availability regarding hemp markets and capital investment timing for farm management systems (e.g., expanding operations, processing) creates significant challenges for U.S. hemp production. Nevertheless, rapid hemp production expansion is possible as the regulatory environment becomes more stable even after the acreage crash in 2019 shown below. Although it is premature to predict economic prospects for the U.S. industrial hemp industry, influencing factors such as access to credit may determine the industry's future. Some competing traditional crops are eligible for farm program payments, such as Agriculture Risk Coverage/Price Loss Coverage programs and low-interest marketing assistance loans from the USDA-Farm Service Agency. However, hemp is not currently eligible for those programs.



Wide-scale hemp production is currently limited by existing information gaps in agronomic practices and market information and the absence of proper marketing channels. No enterprise budgets existed for hemp production until Kentucky, New York, North Dakota, Pennsylvania, and Tennessee developed enterprise budgets based on limited information. In addition, risk management tools for hemp growers are more limited compared to other agricultural sectors. This exacerbates the uncertainties in hemp production. As the market evolves, hemp will create both opportunities and risks for farm profitability.

Cannabinoid accumulation in floral hemp cultivars: Implications for harvest management

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With the implementation of the United States Department of Agriculture Final Rule on Hemp, regulators and hemp growers have a blueprint for THC compliance testing procedures. While some aspects of the sampling plan are left up to state regulators, the Final Rule established that total THC (Δ^9 THC + (0.877 x THCA) should be reported for compliance purposes. Further the rule stated that "all samples must be collected from the flowering tops of the plant by cutting the top five to eight inches from the main stem" and that "harvest shall be completed within 30 days from sample collection". Under the rule, non-compliant hemp crops may be remediated by grinding the entire plant and retesting of the homogenized biomass. It is generally known that cannabinoids (including THC) begin accumulating at the onset of flowering and increase as the flowers mature. The objective of this study was to document the accumulation of cannabinoids as measured by compliance testing procedures over time for four commonly grown hemp cultivars. Four hemp cultivars (BaOx, Cherry Citrus, Endurance, and T1) were grown from cuttings and transplanted into the field at a population of 9350 plants per hectare. Beginning at the onset of flowering, compliance samples were collected weekly by clipping 20 cm from the main terminal of three plants per plot (4 replications of each cultivar). A sufficient supply of plants was available such that each plant was only sampled once during the season. Samples were examined under a dissecting scope and were assigned a "stage" based on trichome density and secretion color. Samples were taken to the Kentucky Department of Agriculture where they were air dried overnight and then placed in a forced air drier at 70 C for 24 hours then taken to UK Regulatory Services for analysis for THC and CBD by gas chromatography. The entirety of the three 20 cm cuttings, including stems, were ground and homogenized for the composite sample. BaOx, Cherry Citrus, and T1 initiated flowering during the 1st week of September during both years of this study. Endurance did not initiate flowering until the end of September in both years. For the three earlier maturing cultivars, total THC concentration increased by 0.05 to 0.1 mg · kg^{-1} per week for six weeks. Within 3 or 4 weeks of floral initiation all three cultivars were approaching non-compliance when tested as directed under the final rule. The rate of CBD accumulation was similar and the ratio of CBD:THC remained at approximately 24:1 until very late in the growing season. The changes in trichome stage were too inconsistent to be of routine use to predict cannabinoid levels and were not a reliable indicator for scheduling of compliance testing or harvest. The floral material was harvested by stripping the flowers from the stems in the field and drying at 60 C for 5 days. Compliance samples taken near the time of harvest in 2020 indicated 3 of the 4 cultivars were non-compliant for THC based on the main stem samples, however the bulk harvested material tested after drying was compliant. A compliance sample collected for cultivar "BaOx" on October 6, 2020 was found to have 0.48% THC and 11.8% CBD. The bulk floral material was harvested on October 5 and 6, 2020 and after drying was found to have 0.21 % THC and 8.5% CBD. This example illustrates that remediation is possible for hemp that tests non-compliant in the field. Additional work is needed to better understand the relationship between compliance sample results and bulk floral harvest results to better advise growers on testing and harvest scheduling.

Industrial Hemp Research in Tennessee: Dual-Purpose Cultivar Evaluation for Fiber and Grain Production

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Industrial hemp (*Cannabis sativa L.*) has received interest from producers across the U.S. in recent years. Industrial hemp can be classified within fiber, grain, floral or dual-purpose production categories. Field-grown floral production systems typically utilize a tobacco transplanting model to target the cannabinoid market. However, in recent years the cannabinoid market has left producers with limited options for market potential and exploring alternative production methods are of interest. A field trial in 2021 at the University of Tennessee evaluated 13 cultivars in a dual-purpose hemp production system for fiber and grain. Two harvest methods were compared (hand and machine) for grain production. The range in dry grain yield was 139 to 258 lb/acre with an average of 182 lb/acre for hand-harvest. Grain yields were highest in 'Anka', 'Bialobrzeskie', and 'X-59' cultivars, regardless of harvesting method. Dry fiber yield ranged from 129 to 289 lb/acre, with an average of 207 lb/acre. Fiber yields were highest in 'Altair', 'Anka', 'Bialobrzeskie', 'H-51', 'Hlesia', and 'Lara'. Further experimentation with cultivars and production practices are warranted to maximize dual-purpose industrial hemp grain and fiber yields in Tennessee.

Two New Diseases of Industrial Hemp in Louisiana

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During 2020 growing season, Industrial Hemp (IH) growing at several outdoor farms exhibited wilting of plants along with root and crown rot symptoms similar to Phytophthora root rot. Further analysis including sequence of four isolates revealed 100% homology with a *Phytopythium* sp. In 2021, most hemp growers switched to indoor production. Mature potted 'Southern Sunset Improved' IH plants grown under a poly house at LSU AgCenter Research Center showed canker symptoms with signs of tiny black fruiting bodies on the affected stems. The pathogen was isolated and identified as *Lasiodiplodia pseudotheobromae*. Pathogenicity tests for *Phytopythium* sp. and *L. pseudotheobromae* were successfully conducted. To our knowledge, this is the first report of *Phytopythium* sp. and *L. pseudotheobromae* causing crown and root rot and stem canker on industrial hemp, respectively, in Louisiana.

Identification and Characterization of *Fusarium spp.* Affecting Kentucky Hemp

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In 2021, there were 445 licensed growers and over 12,000 acers of field hemp and 3.7 million square feet of greenhouse hemp sanctioned in Kentucky. Acreage included hemp produced for cannabinoids, fiber, and grain. A major emerging threat to profitable hemp production and yields across the Southeast are several *Fusarium* spp. causing diseases such as damping off, crown rot, vascular wilt, tip blight, and flower blight. A preliminary survey of fields from across Kentucky revealed the presence of multiple *Fusarium spp.* on hemp flowers and seed heads.

These species included *F. avenaceum*, *F. graminearum*, *F. incarnatum-equiseti*, and *F. sporotrichioides,* causing bud and flower blight (non-pollinated flowers, cannabinoid cultivars) or head blight (seed heads, grain cultivars). All isolates were recovered from symptomatic tissue. Symptoms of bud and flower blight included necrosis of flower bracts and sugar leaves coupled with visible mycelial growth; symptoms of head blight included necrosis of flower bracts and sugar leaves, in addition to dense mycelial growth on seeds. Each species was isolated from research field plots, grower samples from across the state, or from diagnostic lab submissions. The most prevalent species was *F. graminearum*, closely followed by *F. incarnatum-equiseti,* both common pathogens impacting cereal grains. In some cases, *F. graminearum* and *F. incarnatum-equiseti* were isolated from the same seed or flower head.

Differences in virulence amongst the different species are currently being addressed. Fusarium head blight has the potential to diminish yields by impeding seed development and reducing seed weight, while Fusarium bud and flower blight can cause termination of flower development and moldy buds. All species identified in this study can produce mycotoxins that may affect humans and animals: *F. graminearum* is a notable producer of the vomitoxin deoxynivanol (DON), *F. sporotrichoses* produces T-2, and *F.avenacum* and *F. incarnatum-equiseti* are producers of multiple toxic secondary metabolites.

Figure 1: Flower necrosis caused by *F. graminearum* (Credits: Henry Smith)

Figure 2: An outbreak of *Fusarium spp.* blight in a dual-purpose plot (Credits: Henry Smith)

Evaluation of Chinese and Australian fiber hemp varieties and planting dates in North Carolina

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Fiber hemp (Cannabis sativa L.) production in North Carolina and much of the Southeast has been limited due in part by a lack of regionally-appropriate varieties. When grown in the Southeast, these varieties flower too early without appreciable biomass production. Field trials were conducted in 2021 to investigate 11 fiber hemp varieties (10 Chinese and one Australian) purported to be better suited for the Southeast as well as three planting dates (mid-March, mid-April, and mid-May). Trials were planted in three locations across NC: Salisbury (Piedmont region), Kinston (Coastal Plain region), Oxford (Northern Coastal Plain region). Germination rates and stand counts were highly variable among hemp varieties. Plant height at harvest was affected by variety ($P = 0.0213$); 'Yuma-4' had the tallest plants (3.36 m) compared to 'Yuma-1' (3.00 m) and 'Yuma-2' (2.99 m). Retted stem dry weight was affected by variety ($P = 0.0294$) and planting date ($P = 0.0265$), but not the interaction ($P = 0.1213$). Yields were highest in 'Yuma-0' (24.22 MG ha^{-1}), and lowest in 'Puma' (14.168 MG ha^{-1}). Yields from the mid-April planted crop (19.904 MG ha^{-1}) were significantly higher than the mid-May crop (13.064 MG ha^{-1}), with the mid-March in between (17.674 MG ha^{-1}). Results from these trials demonstrate that high fiber hemp yields can be obtained in North Carolina with proper variety selection.

Evaluating Nitrogen Rates on Plant Growth and Cannabinoid Content in Outdoor Hemp in Alabama

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Hemp, *Cannabis sativa L*, is one of the oldest cultivated plants. However, following the most recent United States Farm Bills and an increased interest in hemp and its byproducts, hemp production has seen a major resurgence. Currently, in the U.S and Alabama, the majority of hemp is grown for its flower component, cannabidiol (CBD). However, growers still must be mindful of another plant compound, tetrahydrocannabinol (THC), which cannot legally exceed 0.3%. Growers face a lack of information on basic agronomic practices concerning growing this crop in today's environment. The insufficient data is a significant challenge for growers because of the possibility of losing their crop to the environment or going over the legal THC limit. Therefore, the study conducted examines the different nitrogen rates among hemp based on growth, CBD levels as well as THC content. BaOx variety was grown from feminized seeds and transplanted into the field. Treatments consisted of 51, 76, 109, or 164 lbs./acre of nitrogen applied at transplanting in a replicated complete block with four replications. We measured plant height and stem width weekly following transplanting. Leaf tissue and flower samples were taken to evaluate nutrient levels and potency of plant cannabinoids. The results showed no effect of nitrogen treatments on plant height and width. The potency test showed that plots that received the middle nitrogen rates (76, 109 lbs./acre) had higher CBD and THC content, but these results were not significant. Plant tissue analysis showed no effects of the treatments on nitrogen concentration in the leaves, and no deficiencies were noted in nitrogen. These results suggest that our nitrogen treatments did not affect plant growth in hemp, and even the low rates did not result in a deficiency. Severe weather conditions could have affected the results, explaining why we did not see any statistical significance in the data. The study shows the need for additional experiments because no standard nitrogen rates are recommended for hemp, and we detected a potential effect on CBD and THC levels. We should test experiments with additional varieties and nutrient rates to optimize recommendations for growers. Because the study only tested one variety, future studies will explore potential varietal differences in hemp's response to nitrogen. We will also investigate the relationship between nitrogen and insects.

The Texas Two-Step with Hemp: Backward with CBD, Forward with Fiber

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Industrial hemp production commenced in Texas in 2020. Texas objectives are: 1) discuss the potential limitations—low price—in hemp CBD production for extractable biomass, 2) outline the development of fiber production, and 3) highlight major issues at southerly Texas latitudes for grossly premature reproductive growth that precludes viable hemp production among most current fiber and grain lines. Prices for extractable biomass for CBD are now ~90% below prices available to growers in early 2019. This has greatly suppressed any possible economic return for extractable CBD biomass. In Texas in 2020 ~63% of hemp acres for CBD were planted using straight-run seed. This was to reduce costs and move to larger-scale production. Growers in this system report reducing per-acre production costs to near $3,000/acre, or about 70% less than a traditional small-acre horticultural type system. Farmers use their existing equipment and there is little hand labor involved. CBD% is about 2-3% below horticultural hand-oriented grows but no barriers have been encountered yet in getting extraction.
Fiber production has become of greater interest. Many Texas farmers are already fiber farmers—of cotton. Growers, including those using straight-run seed for CBD, view dual cropping for CBD and fiber as a possibility but with the primary focus on fiber; CBD, still at 3-5%, comes in the waste stream.
Texas A&M AgriLife's great challenge is helping identify suitable hemp fiber lines (also grain) adapted for southerly latitudes in the range of 34°N and lower. Currently nearly all fiber and grain varieties are adapted to and produced in Europe and Canada with a few from China (which test hot for THC). The result is grossly premature flowering a few weeks after emergence. A limited first-year study at Lubbock, TX (33.5°N) focused on planting dates from late March to mid-August (Table 1). New interest in Chinese 'Yu Ma' for its better germination and vigorous growth is tempered by all AgriLife sampling of Yu Ma showing %THC 0.4 to 0.8% even in vegetative growth only (no floral).

Table 1. Initial reproductive growth of hemp lines planted April 24, 2021, at Lubbock, TX (33.5N°).

Variety	Source	Origin	Initial Repro-ductive Growth
Hliana	Panda Biotech	Ukraine	May 16-18
Yuma Crossbow	Dion Oakes	Colorado	May 16-22
Anka	Canadian Hemp Alliance	Canada	May 19-22
Bialobrzeskie	Intl. Hemp	Poland	May 22
Fibranova	Italian Ministry of Ag.	Italy	June 3
SHV-1/A2	Sun House Ventures	Colorado	June 6
Eletta Campana	Italian Ministry of Ag.	Italy	June 6-12
The Joker	Black Canyon Seed	Colorado	June 10
AV-1	AcquiFlow	Iowa/CO/TX	June 20
Carmagnola Selezionata	Italian Ministry of Ag.	Italy	August 16
Jin Ma	Panda Biotech	China	August 31
MS-77	EcoFibre	Australia	September 4
Yu Ma (China)	Panda Biotech	China	September 20

Impact of planting date and seed depth on establishment, growth, and grain yield of hemp in Kentucky

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Hemp (*Cannabis sativa*) was once considered a major cash crop prior to the rise of cheaper sources of fiber and its eventual ban in the U.S. due to the use of high THC *Cannabis sativa* as a drug. Until the 2014 Farm Bill, little to no research on industrial hemp (*C. sativa* with less than 0.3% THC) production has been conducted over the past eighty years in the U.S. resulting in huge knowledge gaps for basic agronomic practices. To improve the economic potential of hemp for growers, it is essential to determine the optimum planting date and depth for hemp to produce consistent stand establishment and improve yields. The site for this trial was on a Maury-Bluegrass Silt loam soil at the University of Kentucky's Agricultural Research Farm near Lexington, KY. The site had been in burley tobacco the previous season and a winter wheat cover crop was burned down on April 16 with glyphosate. This study was a randomized split-split plot with 4 replications. Planting date (6 planting dates each 2 weeks apart) was the main plot and was longitudinally split in two randomized plots for cultivar. Each sub plot was further split latitudinally into two sub-sub plots for planting depth with a shallow (0 to 0.25 inches below soil surface) and deep (0.75 to 1.0 inch below soil surface) planting depth. Preliminary germination trials and average seed weights determined the planting rate by cultivar. Six planting dates ranged from early April to early July, planting approximately every 2 weeks. At each date, 24 pounds per acre of NWG 2730 or 27 pounds per acre of Bialobrzeskie were seeded using a Great Plains 606NT grain drill at a shallow and deep planting depth with a target of 775,000 to 800,000 pure live seed (PLS) per acre. Plants were fertilized with 150 pounds of N per acre as Urea (46-0-0)2-4 weeks after seeding, depending on emergence and growth rate. Soil moisture was determined at planting. Stand counts were calculated by recording the number of plants in one meter of one row with four repeated measures per plot, at day 7 and day 14 after planting. It has been noted that bird predation may also be playing a role in field establishment. Bird predation was observed, specifically at the time of planting and during seed set. Plant height was measured weekly throughout the growing season with ten replicates per plot. Initial flowering date was recorded and five replicates per plot of male:female flowering ratios were calculated at initial flowering and at harvest. Yield was determined by harvesting the materials from two- one square meter areas per plot. Grain yield was determined by threshing the grain heads with a LD 350 rotary lab thresher. For the April planting dates, frost and heavy rains delayed emergence and growth, took just over a month to flower and were harvested 17 weeks after planting. The May and early June planting dates emerged and flowered much faster and caught up to the first planting dates developmentally. Following the emergence of the plants seeded on June 1, there was a period of very heavy and constant rains causing portions of the field to be washed out. The last planting date took the longest to emerge due to a very hot and dry period after planting. It took the longest to flower and was harvested rather quickly and was stunted in growth. Preliminary findings show that emergence rate and development were increased in the earlier planting dates and deeper seeding depth in the grain cultivar, NWG 2730. This differs from the information found in the literature that for hemp to emerge, it should be planted in late spring at a shallow seed depth. Grain yield was increased in the shallow planting depth, except for on the June 1 planting date (possibly due to heavy rains). Grain yields for NWG 2730 averaged above 1200 lbs/acre, a notably favorable yield. There were no significant yield differences observed for Bialobrzeskie and yield fell below 400lbs/acre, a non-profitable yield. With still so many inconsistencies, planting date and depth of hemp needs to continue to be evaluated across the country to determine differences affected by changes in soil and climatic conditions.

Magnesium's Impact on *Cannabis sativa* 'BaOx' Growth and Cannabinoid Production

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Limited research exists on the fertility needs for industrial hemp (*Cannabis sativa*). Many abiotic factors contribute to the optimization of plant growth and metabolites such as the assimilation of photosynthates and adequate mineral fertility resources. Magnesium (Mg) is an essential nutrient for plant growth and plays many key roles in plant growth (photosynthesis, primary and secondary metabolite generation) and when deficient leads to suboptimal plant growth. Therefore, six Mg fertility rates (0.0, 12.5, 25.0, 50.0, 75.0, and 100.0 $mg·L^{-1}$) were evaluated to determine the optimal fertility for *C. sativa* utilizing a high CBD-type cultivar 'BaOx'. Foliar Mg concentrations increased linearly for all life stages with the greatest foliar Mg concentrations being in the highest rate of 100.0 $mg·L^{-1}$ Mg. Of the six rates, 50.0 and 75.0 $mg·L^{-1}$ Mg optimized plant height, diameter, and plant total dry weight during all three life stages. Additionally, these rates had similar cannabinoid concentrations

Management Strategies for Corn Earworm, *Helicoverpa zea*, in Alabama Hemp

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Corn earworm, *Helicoverpa zea* (Lepidotera: Noctuidae), has emerged as an injurious insect pest to hemp, (*Cannabis sativa*). One of the biggest challenges in managing corn is identifying effective management tools for control of this insect pest. Corn earworm feeds on flower buds, creating extensive crop injury and allowing the entry of pathogens that cause bud rot. Given the damage caused by this pest, we sought to explore the efficacy of different biological insecticides currently registeredfor corn earworm larvae in hemp (Spear Lep, Gemstar LC, Heligen, BotheGHA & Leprotec) and compare them to insecticides that are used against this insect pest in other crops (Dipel DF, Xentari, Coragen, Basin Flex & Cyclaniliprole 50 SL). Pheromone traps were located on two locations of the hemp field on EVS Research Station located in Shorter Alabama and assessed once a week, this tool is used for monitoring moth activity, as well as relative population sizes, helping to determine when to apply insecticides The trial took place from August 2021 to September 2021, three sprays were applied in a randomized block design with four replicates. Three days after treatment, we assessed caterpillar numbers and plant damage. Data show no difference between treatments in larval numbers and plant damage. Results and potential management strategies will be discussed.

Approaches to Conduct Balanced Studies on Hemp Russet Mites

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SUMMARY: This work deals with two topics; (1) the methodology used to conduct a study with hemp russet mites (HRM) *Aculops cannabicola* (Acari: Eriophyidae), including rearing and maintenance of a colony, and transfer of mites to healthy plants to conduct balanced design studies; and (2) the evaluation of the effects of four registered organic biopesticides to manage HRM in laboratory and field studies. The HRM laboratory colony has been held at the Research and Education Center at Princeton-KY, for more than 2 years. Active HRM colony is kept on two- to four-week-old hemp seedlings (*cv.* Felina-32) in an isolated room with a temperature of 22º (±3º) C, 16:8 (L:D) photophase, and 45% (±15%) RH. Hemp plants were irrigated three times a week and fertilized weekly with a water-soluble fertilizer (24-8-16) (2 g/liter of solution) (Scotts Miracle-Gro Products Inc). To test the organic pesticides, HRM were transferred onto 2-week-old potted hemp seedlings (same *cv.* as above) a week before the first spray. A heavily infested leaf with HRM was detached from the colony and was laid with the abaxial surface touching the adaxial surface on a third or fourth leaf, from the cotyledonary node of a seedling. Both leaves were held together with a clip made with folded twist ties (Fig. 1). Two opposite leaves were infested per plant. This method was simple and worked effectively. High and uniformly distributed HRM populations were obtained as shown by the abundance of HRM through the duration of the study.

Figure 1. Efficient transfer of hemp russet mites. Detached leaves were held with folded twist ties.

Two sprays, 7 d apart, were conducted on these plants, with each BoteGHA® ES (*Beauveria bassiana* strain GHA, 11.3% at 0.946 L), PFR-97™ 20% WDG (*Isaria fumosorosea* Apopka Strain, 97 20% at 0.907 g), Sil-Matrix® LC (Potassium silicate, 29% at 3.785 L), DeBug® Optimo (Margosa oils, 15.4% + azadirachtin 0.7% at 0.946 L); all solution calculations were based on 100 gal of water per acre. Water was used as control. Each biopesticide was sprayed on six single potted plants. Tallies of HRM were conducted taking the middle (the largest) leaflet of the compound hemp leaf from each of the six potted plants at days 3, 7, and 14 after the first spray. The most effective compound was BoteGHA®, which significantly ($p<0.05$) reduced the number of mites and kept the lowest population throughout the experiment (Fig. 2). BoteGHA® was also effective in a test conducted in an open field study. Responses of SilMatrix®, PFR-97™, and DeBug® Optimo were not different from the control, although 3 d after the second spray, SilMatrix® showed significant reduction of HRM populations. Populations of HRM were not reduced by PFR-97™.

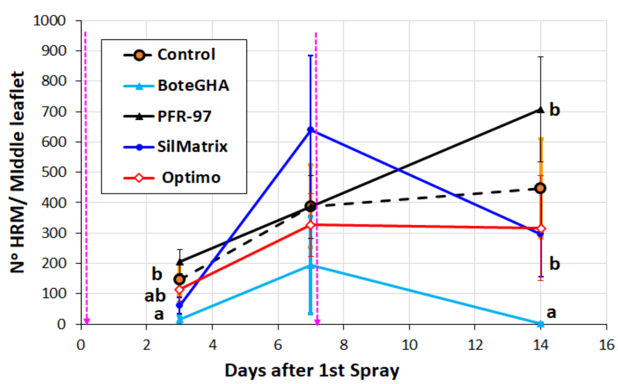

Figure 2. Means (±SEM) of hemp russet mites. Sprays are indicated by pink dashed arrows (7 d apart). Different letters on the same date indicate significant differences ($p<0.05$) after Fisher's LSD test.

Evaluation of Biopesticides for the Management of *Helicoverpa zea* in Hemp

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Figure 1. CEW larva feeding on hemp buds.

The corn earworm (CEW) *Helicoverpa zea* (Lepidoptera: Noctuidae) (Figure 1) is the most abundant and serious key pest in industrial hemp. Thus far, biopesticides make up the only available group of pesticides registered to be used in hemp. However, their efficacy in caterpillar control has not been fully tested in industrial hemp yet. The goal of this study was to assess the effectiveness of organic pesticides on CEW in a test conducted in a laboratory using foliage and flower buds from plants sprayed in the field.

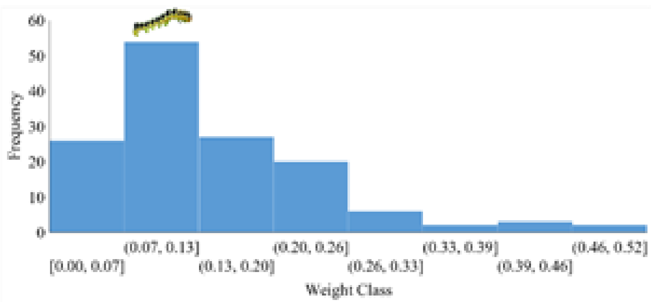

Figure 2. Histogram of caterpillar sizes.

Figure 3. Single CEW larva feeding on hemp inflorescence.

Agree® (1lb/A), DeBug® Optimo (32 fl oz/A), Heligen® (2.4 fl oz/A), and Gemstar® (10 fl oz/A) were sprayed on Baox hemp plants grown in research plots (3 rows, 8 plants/row) replicated 4 times. Each biopesticide was sprayed twice, with a seven-day interval (13 and 20 September 2021). Water was sprayed as control treatment. For the laboratory test, 140 healthy CEW larvae from assorted sizes (ranging from 0.001 g to 0.48 g) were collected from an unsprayed commercial field (Figure 2). Then, the caterpillars were weighted and placed individually in plastic cups (59.1 mL, Figure 3). To avoid size bias, larvae were distributed keeping a uniform mean weight between treatments ($p>0.5$). CEW larvae were fed *ad libitum* with hemp inflorescences collected 2 h after the second spray from each biopesticide treatment, and then fresh food was provided from sprayed plots every day. Caterpillars were monitored every two days until either 100% of individuals died or pupated. Larva mortality/treatment were recorded throughout the three-week experimental period.