VIRGINIA DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

ANNUAL REPORT ON THE STATUS AND PROGRESS OF THE INDUSTRIAL HEMP RESEARCH PROGRAM

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Commissioner

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Annual Report on the Status and Progress of the Industrial Hemp Research Program

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Annual Report on the Status and Progress of the Industrial Hemp Research Program

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Executive Summary
The 2015 Session of the Virginia General Assembly enacted the Industrial Hemp Law (Law) (Va. Code § 3.2-4112 *et seq.*), which authorizes the Virginia Department of Agriculture and Consumer Services (VDACS) to establish and oversee an industrial hemp research program that will be directly managed by public institutions of higher education. In 2018, the four public universities with VDACS-approved industrial hemp research programs planted a total of approximately 135 acres in industrial hemp. Following amendments to the Law enacted by the General Assembly in 2018, VDACS established a new industrial hemp research program that is directly managed by VDACS.

BACKGROUND

The U.S. Congress, through Section 7606 of the Agricultural Act of 2014, allowed state departments of agriculture to grow industrial hemp for research purposes, under certain conditions. The 2015 Session of the Virginia General Assembly enacted the Industrial Hemp Law (Law), which authorized the Virginia Department of Agriculture and Consumer Services (VDACS) to establish and oversee an industrial hemp research program that was directly managed by public institutions of higher education.

In August 2015, VDACS entered into a memorandum of understanding with James Madison University (JMU), Virginia State University (VSU), and Virginia Polytechnic Institute and State University (Virginia Tech) to conduct industrial hemp research. In 2016, these three research universities planted a total of approximately 37 acres in industrial hemp. In September 2016, VDACS entered into a memorandum of understanding with a fourth public institution of higher education, the University of Virginia (UVA), to conduct industrial hemp research. In 2017, the four research universities planted a total of approximately 78 acres in industrial hemp. In 2018, the four research universities planted a total of approximately 135 acres in industrial hemp.

Following a review of the Law with stakeholders and interested parties during the summer of 2017, VDACS received approval from the McAuliffe Administration in late 2017 and, subsequently, the Northam Administration in 2018 to pursue amendments to the Law (i) to expand the opportunities available to individuals who are interested in growing or processing industrial hemp by creating a research program managed by VDACS that does not require the individual to partner with a public institution of higher education and (ii) to reduce the regulatory burden on individuals interested in participating in one of these research programs. The 2018 Session of the General Assembly amended the Law to create a new industrial hemp research program, in addition to the existing higher education industrial hemp research program, that is directly managed by VDACS and eliminated the fingerprint-based criminal history background check required in order to obtain an Industrial Hemp Grower License. The amendments also replaced the previous industrial hemp grower licensure program with a registration program for industrial hemp growers and processors.

UNIVERSITIES CONDUCTING RESEARCH

In June 2018, VDACS renewed its memorandum of understanding (MOU) with JMU, UVA, VSU, and Virginia Tech to conduct industrial hemp research.

All four research universities worked with select farmers to grow industrial hemp on privately-owned land. UVA, VSU, and Virginia Tech also grew industrial hemp on university-owned or university-managed property. In 2018, the industrial hemp research universities expected to plant a total of approximately 250 acres in industrial hemp in 31 counties. Due to delays in acquiring some of the industrial hemp planting seed as well as the rain received throughout the growing season, the research universities ultimately planted approximately 135 acres in industrial hemp in 2018.

As the universities' MOUs establish the option to renew the research agreement annually for up to five years, at the time of this report, none of the universities have definitive findings to report. Each university submitted a progress report on its research to VDACS. A summary of each report is provided below, and the reports are included in the appendices of this report.

James Madison University

JMU is researching how effectively industrial hemp grows in Virginia's Ridge and Valley region and is testing whether industrial hemp seed can be planted and harvested with conventional agricultural equipment. JMU is also investigating the use of industrial hemp seed oil in the production of biofuels.

In 2018, JMU partnered with private farmers to grow industrial hemp in Albemarle, Loudoun, Louisa, Middlesex, Rockingham, and Stafford counties. JMU studied four dual purpose (grown for both grain and fiber) hemp varieties. JMU is studying the fiber and grain yield of these varieties in response to seeding rate and planting date. JMU reports that, while late May through late June plantings resulted in high weed pressure for most varieties, most of JMU's early July plantings experience little to no weed pressure.

JMU's Engineering Department is overseeing additional projects studying the chemical composition changes across the growth cycle of select industrial hemp varieties, the market potential of industrial hemp products in Virginia's poultry industry, and industrial hemp seed's nutritional quality for animal feedstock.

See Appendix A for the complete report submitted by Dr. Michael Renfroe and Dr. Samuel Morton, the principal co-investigators for JMU's industrial hemp research, and Dr. Shelly Thomas, JMU's Industrial Hemp Research Program Project Manager.

University of Virginia

UVA is conducting a combination of field-based agronomic experiments, greenhouse-based molecular breeding and plant propagation experiments, and laboratory-based plant cell and tissue culture work with the long-term goal of developing regionally-adapted low or no tetrahydrocannabinol (THC) containing industrial hemp cultivars.

In 2018, UVA partnered with private farmers to grow industrial hemp in Albemarle, Augusta, Fluvanna, Lee, Northampton, Scott, and Wythe counties to test five varieties of industrial hemp, comparing different planting schemes and seeding rates.

UVA continued its greenhouse and laboratory studies into best practices for the growth of high cannabidiol (CBD) varieties under greenhouse conditions and the development of expertise in traditional and molecular breeding to create new industrial hemp varieties.

UVA also worked with JMU's industrial hemp researchers to test 10 industrial hemp varieties in Rockingham and Middlesex counties under different seeding rates. Another component of UVA's industrial hemp research program included a "Founding Fathers" initiative to grow a fiber variety of industrial hemp on the grounds of George Washington's Mount Vernon Estate and James Madison's Montpelier Estate to raise public awareness of Commonwealth's history as a hemp-growing state.

See Appendix B for the complete report submitted by Dr. Michael Timko, the principal investigator for UVA's industrial hemp research, with collaboration by Dr. Ryan Huish at UVA-Wise.

Virginia State University

VSU is researching and analyzing required soils, growing conditions, and harvest methods related to various varieties of industrial hemp; conducting industrial hemp seed research; and studying the use of industrial hemp in new energy technologies.

In 2018, VSU conducted a variety trial at its Research and Demonstration Farm (Randolph Farm) in Chesterfield County as well as three collaborating farms located in Powhatan, Cumberland, and Augusta counties. VSU evaluated a total of seven varieties of industrial hemp at Randolph Farm, while the collaborating farms grew three fiber varieties and one seed variety of industrial hemp. VSU noted that its plots suffered as a result of excessive rainfall and summer grass weed infestation.

See Appendix C for the complete report submitted by Dr. Maru Kering, the principal investigator for VSU's industrial hemp research.

Virginia Polytechnic Institute and State University

Since the inception of its industrial hemp research, Virginia Tech has conducted agronomic trials to identify industrial hemp varieties that are well-suited to the soils and climate of Virginia and to compare yield responses to various agronomic treatments. Virginia Tech is conducting its research at the following Virginia Tech-owned or managed properties: Kentland Farm in Montgomery County, the Northern Piedmont Center in Orange County, the Southern Piedmont Agricultural Research and Extension Center in Nottoway County, and the Tidewater Agricultural Research and Extension Center in the City of Suffolk. In 2018, Virginia Tech also collaborated with private farmers in Augusta, Buckingham, Caroline, Clarke, Franklin, Halifax, Pittsylvania, Prince William, Pulaski, and Russell counties.

In addition to its evaluation of fiber and grain varieties in 2018, Virginia Tech conducted the following studies: herbicide tolerance; germination temperatures; tillage versus no-till establishment; establishment method and seeding rate studies; entomological assessments including the effects of simulated insect defoliation on hemp grain yield, the effects of selective insecticide applications on hemp grain yield, and determining the quality of hemp as a host plant for corn earworm and brown marmorated stink bug development; and an evaluation of floral varieties of hemp.

See Appendix D for the complete report submitted by Dr. John Fike, the principal investigator for Virginia Tech's hemp research, with collaboration from Dr. Michael Flessner, Dr. Thomas Kuhar, Dr. Sally Taylor, Dr. Carol Wilkinson, Kadie Britt, and Jabari Byrd.

Controlled Substance Importer Registration

In order for VDACS to import industrial hemp planting seed, the agency must obtain from the U.S. Drug Enforcement Administration (DEA) (i) an importer registration under the federal Controlled Substance Act and (ii) a separate permit for each shipment that the agency imports.

On September 14, 2015, VDACS received its initial Controlled Substance Importer Registration from DEA. Since this date, VDACS has maintained this registration, with DEA most recently renewing VDACS's Controlled Substance Importer Registration on June 15, 2018, following a site inspection of VDACS's Seed Laboratory, where VDACS stores the seed it imports, and a review of VDACS's industrial hemp seed custody records.

Hemp Seed for Planting

In 2017, some of the research universities expressed interest in obtaining industrial hemp planting seed from domestic sources. Upon VDACS's inquiry, DEA explained to VDACS that its Controlled Substance Importer Registration does not authorize VDACS to receive industrial hemp planting seed from a domestic source, even if the source has its own DEA Controlled Substance Registration. As such, VDACS sought and received informal advice from its Assistant Attorney General who, upon review of relevant federal and state law, offered that, with significant caveats, the interstate shipment of industrial hemp planting seed is permissible. VDACS shared this informal advice with the research universities, encouraged the principal investigators to seek advice from university counsel, and explained that, should the university elect to obtain industrial hemp planting seed from a domestic source, neither the university's MOU with VDACS regarding industrial hemp research nor the principal investigator's Industrial Hemp Grower License would be in jeopardy.

In 2018, at the request of VSU and Virginia Tech, VDACS applied for and received five import permits from DEA to assist these two universities in importing industrial hemp planting seed from international sources. With these import permits, VDACS imported 11 varieties of industrial hemp planting seed, totaling approximately 1,188 pounds. JMU and UVA elected to procure their own industrial hemp planting seed for the 2018 growing season.

Tetrahydrocannabinol (THC) Testing

The Commissioner of Agriculture and Consumer Services is responsible for providing random testing of industrial hemp for compliance with THC levels. Section 7606 of the Agricultural Act of 2014 establishes that industrial hemp grown for research purposes pursuant to this section shall have a THC concentration not more than 0.3 percent on a dry weight basis. At VDACS's request, the Department of General Services' Division of Consolidated Laboratory Services (DCLS) identified and validated a test method it is using to determine the THC concentration of industrial hemp samples collected by VDACS inspectors.

In 2017, VDACS collected a sample of each industrial hemp variety grown at each of the universities' production fields and submitted these samples to DCLS for testing. At the time that last year's progress report was published, test results were pending for all of these samples. This report will summarize the THC testing conducted on the industrial hemp grown in 2017.

VDACS's sample collection protocol required VDACS inspectors to collect a "Bag A" sample and a "Bag B" sample of each industrial hemp variety grown at each of the universities' production fields. DCLS tested the "Bag B" as necessary to confirm a test result from "Bag A" that indicated the sample had a THC concentration over 0.3 percent. DCLS tested 41 "Bag A" samples, and the THC concentration of the majority of the samples collected was less than 0.10 percent. Four "Bag A" samples had a THC concentration over 0.3 percent. The THC concentration of all four of these samples was less than 0.80 percent. VDACS inspectors were unable to collect a "Bag B" for two of the industrial hemp varieties that had a THC concentration over 0.3 percent due to the poor condition of the hemp in the production field at the time the inspector sampled the field. VDACS requested that DCLS test the "Bag B" of the two remaining industrial hemp varieties that had a THC concentration over 0.3 percent to confirm the results of the "Bag A" tests. The THC concentration of one of these confirmation tests was less than 0.3 percent, while one was 1.86 percent. As the industrial hemp variety whose "Bag A" and "Bag B" samples both had a THC concentration over 0.3 percent was in the possession of a principal investigator who has a DEA Controlled Substance Researcher Registration, allowing the principal investigator to possess marijuana, VDACS did not require the principal investigator to destroy the plant material from this industrial hemp variety.

INDUSTRIAL HEMP GROWER LICENSE

Prior to the 2018 amendments to the Law, before growing industrial hemp as part of the industrial hemp research program, an individual was required to (i) have an agreement with a public institution of higher education that documented that the individual would be a participant in that institution's industrial hemp research program and (ii) obtain a grower license from VDACS. The Law also required that a state and national fingerprint-based criminal history background check be a component of the application process for this license. As of June 30, 2018, 85 individuals had an active Industrial Hemp Grower License and were growing industrial hemp in collaboration with one or more of the research universities.

INDUSTRIAL HEMP GROWER AND PROCESSOR REGISTRATIONS

The 2018 Session of the General Assembly amended the Law to create a new industrial hemp research program, in addition to the existing higher education industrial hemp research program, that is directly managed by VDACS and allows Virginians to grow or process industrial hemp without being a participant in a research program managed by an institution of higher education.

The amendments also replaced the previous industrial hemp grower licensure program with a registration program for industrial hemp growers and processors.

On July 2, 2018, VDACS began accepting applications for Industrial Hemp Grower and Processor Registrations from individuals interested in participating in the new VDACS-managed industrial hemp research program. As of November 1, 2018, VDACS had issued 75 Industrial Hemp Grower Registrations and 15 Industrial Hemp Processor Registrations for participants in the VDACS-managed industrial hemp research program. Under these Industrial Hemp Grower Registrations, industrial hemp will be grown in 55 localities throughout Virginia.

The Industrial Hemp Grower Registration applications indicate that many applicants are interested in growing varieties of industrial hemp known to produce higher levels of cannabidiol (CBD), one of the cannabinoids produced by the Cannabis plant. In the years since the enactment of Section 7606 of the federal Agricultural Act of 2014, the U.S. industrial hemp industry's interest in growing hemp for its grain and fiber has shifted to an interest in growing those varieties of industrial hemp known to produce higher levels of CBD for CBD product production. While VDACS is issuing Industrial Hemp Grower Registrations to applicants who present a research plan that includes the cultivation of industrial hemp known to have higher levels of CBD, VDACS has elected to refrain from engaging in market research of any industrial hemp extract containing CBD or hemp-derived CBD product due to questions regarding the permissibility of the distribution of such extract or product to someone who is not a participant in an industrial hemp research program in Virginia. Until such time that VDACS receives guidance that this activity constitutes a lawful purpose, as required by the Virginia Industrial Hemp Law, VDACS will not be issuing a registration to any person who indicates an intention to sell or distribute any industrial hemp extract containing CBD to someone who is not registered to participate in an industrial hemp research program in Virginia.

Section 3.2-4116 of the Virginia Industrial Hemp Law requires a participant in the Virginia Industrial Hemp Research Program managed by VDACS to submit a report by October 1 to the Commissioner regarding his growing or processing activities for the previous year. The reports received in October 2018 indicate that a majority of the registered industrial hemp growers did not plant any industrial hemp in the limited time between their receipt of their registrations and the report deadline. Some growers reported challenges in identifying reliable, domestic industrial hemp planting seed sources.

Appendix A

INVESTIGATION OF INDUSTRIAL HEMP FOR OIL AND BIOFUEL PRODUCTION IN VIRGINIA

Annual Report to
Virginia Department of Agriculture and Consumer Services

by

Michael H. Renfroe, Ph.D.

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August 30, 2018

Research on the growth of industrial hemp was conducted by James Madison University in cooperation with contract farmers as permitted by the federal Agricultural Act of 2014 and the Virginia Industrial Hemp Farming Act of 2015. Experiments were designed to address the following objectives:

Field based research (Dr. Renfroe and contract growers)

1. To determine how effectively hemp will grow in Virginia in the Ridge and Valley Province, examining growing conditions and analyzing soil properties
2. To analyze harvest methods and determine if conventional agricultural equipment (seed drillers and combines) can plant and harvest industrial hemp without major problems
3. To investigate the use of hemp seed oil in the production of fuels (biodiesel) and the use of press cake for livestock feed

University based research (Dr. Morton)

1. To explore the potential for the chemical conversion of hemp oil to produce a qualified quality biodiesel
2. To determine the potential for lignocellulosic derived biofuels
3. To develop a strong and extensive life-cycle systems overview

Site Selection

This year JMU expanded its Industrial Hemp Research Program to include eight field sites, including locations in Rockingham, Augusta, Stafford, Louisa, Middlesex, and Loudon counties. These locations represent a variety of soil types and geographic provinces across the Commonwealth.

Field Trials

We planned to investigate planting rates, planting dates and effects of hemp cultivars. We planted three seed cultivars from Canadian sources and a fiber cultivar from a European source. Additional cultivars were grown on two sites in collaboration with Dr. Michael Timko at the University of Virginia.

Seeding rates were varied from 30-60 pounds per acre. To continue testing the use of conventional agricultural equipment on hemp production and harvesting, six 1.5 acre plots were planted with three oilseed cultivars (Fig 1-2) at one farm location. Seeds were planted using a conventional drill seed planter and will be harvested with a combine outfitted with a grain head. Approximately seven acres of oilseed hemp was planted at another location. For cultivar comparisons, smaller plots were seeded at different rates and different planting dates (Fig 3) at different locations. Planting dates ranged from June 14 to July 22.

Sampling of the field trials is underway. Following data collection, data will be analyzed to determine seed and fiber yields. Oilseed cultivars will be assessed for oil production and ability to convert the oil into biodiesel. The fiber cultivar will be used in retting experiments to determine the nature of fiber production and isolation from hemp. Harvesting is expected to be complete by the middle of September.

To date, our preliminary data support the importance of proper field preparation and adherence to the basic principles of agricultural production. Individuals that think any field or site can be converted to hemp production are likely to be disappointed. Best yields can be expected from fields that have been in agricultural use and are properly prepared for planting. Fields with extensive seed banks from prior years will not produce quality crops of hemp. Hemp is susceptible to drought which can put it at a competitive disadvantage with weeds. Early moisture is extremely important to get prompt germination and seedling establishment. On the other hand, too much water is deleterious to hemp production. Hemp performs best in well-drained soils. There is still a need to determine the best cultivars for Virginia and an even greater need to develop the markets for raw inputs of industrial hemp.

Fig. 1. Early (mid-June) field planting with mature stand of industrial hemp in late August.

Fig. 2. Late (mid-July) field planting of industrial hemp in late August.

Fig. 3. Small plot trial ready for sampling in late August.

INVESTIGATION OF INDUSTRIAL HEMP FOR OIL AND BIOFUEL PRODUCTION IN VIRGINIA

Addendum to the Annual Report to
Virginia Department of Agriculture and Consumer Services

by

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Office of Research and Scholarship
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October 19, 2018

Site Selection
In 2018, JMU expanded its Industrial Hemp Research Program to include eight field sites in six counties (Augusta, Loudon, Louisa, Middlesex, Rockingham, and Stafford) representing various soil types and plant hardiness zones (Table 1).

Field Trials: Large Plots
Objective: To determine fiber and grain yield for four different hemp cultivars in response to seeding rate and planting date in different soil types across Virginia using conventional farming equipment.

We used three Canadian cultivars (CFX-1, CRS-1, and Joey) and one European cultivar (Felina 32); all of these are considered dual cultivars (grown for both grain and fiber). Seeding rates varied from 30 to 70 pounds per acre. At each site (see Table 1), growers used conventional farming equipment for seed bed prep and planting.

Table 1. Site locations including county, soil type, and plant hardiness zones.

County	Soil Type	Plant Hardiness Zone	Cultivars	Seeding Rates (lbs/acre)	Planting Dates
Augusta	Loam	6b	Felina 32	35, 45, 60, 70	mid July
Loudon	Loam	7a	Felina 32	45	early August
Louisa	Loam	7a	CRS-1	45	late June
Middlesex A	Sandy Clay Loam	7b	Felina 32	45	mid June, early July
Middlesex B	Sandy Loam	7b	Felina 32	45, 60	mid July
Rockingham A	Sandy Loam	6b	Joey, CFX-1, CRS-1	45	mid June, early July
Rockingham B	Clay Loam	6b	Joey	30, 45	early July
Stafford	Silt Loam	7a	Felina 32	45, 60, 70	late May

The Augusta County site burndown herbicide was applied to existing vegetation; as a no-till site, Felina 32 was planted in mid-July with a no-till drill at four seeding rates (35, 45, 60, 70). It rained shortly after planting, and hemp in areas of the field that were slightly lower in elevation did not emerge, presumably because clay in the soil formed a hard crust when the water dried. However, the other areas of the field grew very well (Figure 4a), with good emergence (delayed in some areas by wetter soil) and height, outcompeting most weeds. Unfortunately, just before harvest, the rainstorms blew in, making it impossible to harvest (Figure 4b) and creating a great deal of moisture on the dense seed heads. The majority of the seeds left on the seed heads after the storms germinated on the plants (Figure 4c).

Figure 4. Field site in Augusta county. A. Strong growth for all seeding rates. B. Flooding of the site after storms. C. Seeds germinating on seed head after rain.

Due to the extreme weather this summer (too much rain too frequently), a number of sites failed because hemp was not able to compete with weeds in the wet conditions. The Loudon County site was a hay field, and the grower waited until after hay harvest to plant in early August without a burndown herbicide. The hemp did not grow quickly enough to outcompete the grasses. Similarly, Rockingham County Site B was planted no-till without burndown herbicide. Early on it was evident that the 30 lbs/acre plot was not competing with weeds as well as the 45 lbs/acre plot, but by harvest hemp was overtopped by grasses and weeds in most parts of the field. In Louisa county, herbicide was applied two times, two weeks apart before planting, which provided a window for the hemp to emerge. However, by the end of the season the hemp was overtopped by a lush crop of millet, which had been planted four years before and not seen in the field again until this year. No herbicide was used at the Stafford County site, and the three plots were disked then planted via hand broadcasting. Although there was strong emergence, most of the hemp was overtopped by weeds by mid-July.

The mid-June planting for Middlesex County Site A had three large plots. Plot 1 (an agricultural field) and Plot 2 (a grassy field) both used a burndown herbicide then tilling before planting; however, they were overwhelmed by weeds by the end of July. Plot 3 was a no-till site that followed a wheat harvest. Although no herbicide was used, there was little weed pressure (other than morning glories) on the no-till Felina 32. The mid-July planting at Middlesex County Site B had two large plots at two seeding rates. The higher seeding rate (60 lbs/acre) better out-competed weeds than the 45 lbs/acre, although ivyleaf morning glories (mostly *Ipomoea hederacea*, with few *I. purpurea*) persisted at all Middlesex County plots. There was also a great deal of caterpillar pest pressure on all Middlesex County plots. The vast majority of seeds had small holes drilled into them and the hearts were eaten. Although caterpillars clearly focused on the seeds, leaves were also eaten to some extent.

Rockingham County Site A had six large plots. CFX-1, CRS-1, and Joey cultivars were planted in ~1.5 acre plots in mid-June and again in early July. The field was ripped after barley harvest, then tilled and rolled before planting. No herbicide was applied. The mid-June plots grew well; however, there was high weed pressure (Figure 5A), especially from lambsquarters (*Chenopodium album*), spiny pigweed (*Amaranthus spinosus*), and redroot pigweed (*Amaranthus retroflexus*). The amount of weeds meant that the fiber would be unlikely to be useful, and seeds would need to be cleaned well to remove weed seeds. The early July plots also grew well, catching up to the mid-June plots by harvest time. However, there was very little weed pressure on the July planting; although there were some patches of the weeds, most of the ground was bare under the hemp. Although population densities of pest caterpillars did eventually increase, this was after seed development and generally after seeds should have been harvested. We put off harvest for a week so we could harvest at the JMU Industrial Hemp Field Day (Figure 5B), but unfortunately rainstorms storms pummeled our plots in the interim. As with the Augusta site, the seeds that were left on the plants germinated on the seed head.

Figure 5. Rockingham County Site A on September 21, 2018. A. The large plots from above. Note the dramatic difference between the foreground (mostly brown hemp seed heads) showing the early July planting with few weeds and the background in front of the tent; the brighter green of the weeds shows severe weed pressure in the mid-June planting. B. Hemp harvest with conventional equipment.

Field Trials: Small Plots

1. A senior Integrated Science and Technology major planted Felina 32 and harvested throughout the life cyle to analyze the growth rate, biomass, and tensile strength of industrial hemp with the addition of inoculated biochar to the soil.

2. Comparing hemp yields in Rockingham and Middlesex counties.

Objective: To determine fiber and grain yield of ten different hemp cultivars in response to seeding rate and planting date in different soil types in two locations in Virginia.

We planted ten cultivars (our four plus six experimental cultivars in collaboration with UVa) in 8.5 x 10.2 foot plots at three seeding rates (30, 45, and 60 lbs per acre) on two planting dates (mid-June and early July) at two locations (Rockingham County Site A and Middlesex County Site A). No herbicide was used at either site; sites were tilled shortly before planting.

As with the large plots, the mid-June small plots at Middlesex County were overwhelmed by weeds by the end of July; these plots were destroyed. The mid-June Rockingham County small plots also had tremendous weed pressure (Figure 6A & B), but the hemp was taller and survived better than in Middlesex, so we harvested from these plots. The late planting at both sites (Figure 6C & D) had much less weed pressure, although the Middlesex plots had severe pest pressure (see above). Many cultivars were a foot or more shorter at the Middlesex County site compared to the Rockingham County Site.

Field Trials Summary

1. The late May through late-June plantings resulting in high weed pressure for most cultivars, excluding no-till Felina 32 at the Augusta and Middlesex County sites. However, the Early July plantings had little to no weed pressure for all cultivars except the short experimental variety from UVa. This has occurred in other years as well; this may be a window of time for growers to plant hemp, although the late season might mean less height than an earlier planting.

2. Almost all cultivars were much shorter in Middlesex County compared to Rockingham County, despite being planted only 1-2 days apart.

3. In Middlesex County, the hemp growth cycle coincided with pest caterpillar growth, so the majority of hemp seeds were drilled into and eaten by caterpillars; however, in Rockingham County the maturation of these same hemp cultivars (planted at the same time) did not coincide with high caterpillar density, so pests had little effect on hemp growth.

4. Cultivars vary widely in their ability to quickly form a canopy to outcompete weeds, withstand harsh weather conditions, continue to grow after the photoperiod shortens, and yield product. Canadian varieties flower (and stop vegetative growth) much more quickly in response to photoperiod change compared to the French variety. Therefore, Canadian varieties planted later in the summer likely will not grow as tall as European varieties at a similar latitude to Virginia.

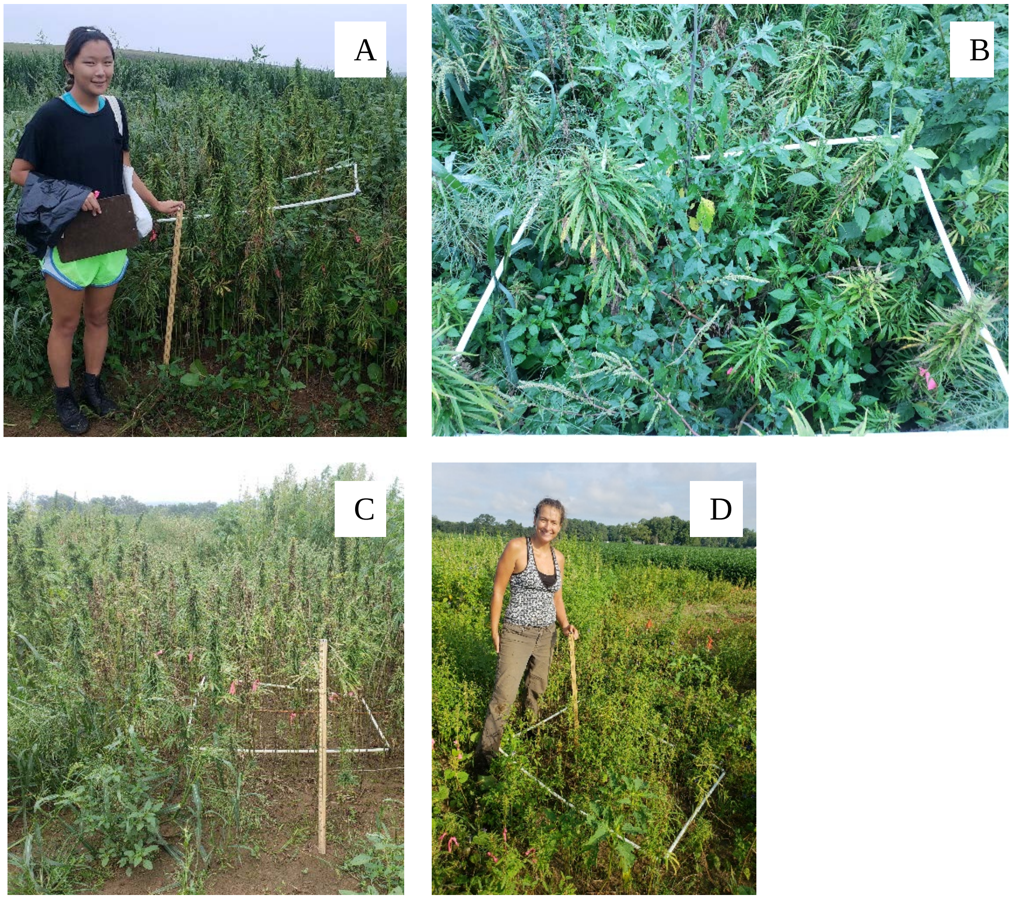

Figure 6. Small Plot Field Trials of CRS-1 planted at 45 lbs per acre. A & B. Mid-June planting at Rockingham County Site A, note high weed pressure. C. Early July planting at Rockingham County Site A with much less weed pressure. D. Early July planting at Middlsex County Site A, note how much shorter the hemp plants are, despite being planted only two days apart.

Lab Studies

Three undergraduate projects are overseen by Dr. Samuel Morton (Engineering Department).

1. A senior engineer Research Assistant is studying the chemical composition (especially the various cannabidiols) changes across the growth cycle of three industrial hemp cultivars (Joey, CFX-1, and CRS-1).

2. An engineering senior is conducting Honors Research on the market potential for hemp products in the poultry industry of Virginia, focusing on fiber for bedding and seed as a feed additive.

3. A biotechnology Research Assistant is investigating hemp seed nutritional quality for Virginia animal feedstock. A conservative interpretation of the 2017 AAFCO guidelines indicates that cannabidiols cannot be added to animal feedstock, which limits the use of hemp seed use in this industry. This goal of this study is to determine the change in nutritional quality of hemp seed once cannabidiols are extracted from hemp seed.

Annual Report

Title of Project: The University of Virginia Industrial Hemp Research Program

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Permits and Registrations: The Virginia Department of Agriculture and Consumer Services (VDACS) and University of Virginia (UVA) have a Memorandum of Understanding (MOU) that allows the University to conduct industrial hemp research. This MOU was first signed on September 26, 2016, was renewed on July 26, 2017, and is current through December 31, 2018. Two additional years are allowed on renewal. The University of Virginia Industrial Hemp Research Program holds a grower's permit from VDACS, and is a registered Schedule 1 research site with the Drug Enforcement Agency (DEA) and the Virginia Board of Pharmacy (VBP).

Industrial Hemp Growers License Number: 2018-03-UVA-031 [exp. 3/5/2019]
DEA Registration Number: RT0519201 [exp. 11/30/2018]
VA Board of Pharmacy Controlled Substance Registration: 0220001838 [exp. 02/28/2019]

Executive Summary

Industrial hemp research conducted by the University of Virginia (UVA) and its partner growers throughout the Commonwealth is comprised of field-based agronomic experiments, greenhouse-based plant growth studies, molecular breeding experiments, and laboratory-based plant cell/ tissue culture and genetic engineering work with a long-term goal of developing regionally-adapted, high-value hemp cultivars which can fulfill multiple purposes/uses across the agricultural, manufacturing, energy, and medical fields. The primary components of this work are the identification of quality germplasm for use and improvement and the specific modification of the biological properties of the hemp plant to provide fiber, seed, and other derivative materials to support the development and economic growth of a new vertically integrated hemp industry. This work also aims to establish the foundation for the development of processing and manufacturing technologies designed to utilize these newly developed cultivars for the production of high value products. Testing of these plant materials is therefore a necessary requirement moving forward.

The work at the University of Virginia is currently funded by a grant from 22nd Century Group, Inc., a plant biotechnology company with a long-term focus on research, development, licensing, manufacturing, and worldwide sales and distribution of agricultural products, the Claude Moore Charitable Trust, the 4VA Collaborative Research Program, and the VDACS Specialty Crops Funding Program. These sources of support have helped to defray the costs of obtaining seed for agronomic work and experimental development and to support activities conducted by growers working with the UVA hemp research program.

SUMMARY OF EXPERIMENTAL RESEARCH ACTIVITIES

I. Agronomic evaluation of industrial hemp varieties

Building upon research activities conducted during the 2017 growing season, the overarching goals of our research studies were (i) to further determine the agronomic performance of various industrial hemp cultivars/varieties/breeding stocks in various agro-ecological zones as (ii) the starting point of a focused genetic improvement program aimed at developing high-performing, regionally-adapted varieties for the Commonwealth of Virginia. The target is the development of high yielding (e.g., grain, hurd, fiber, seed oil, floral extracts) cultivars with low or ultralow-THC levels (0.3 % or lower) and the provision of acceptable [certified] seed to farmers of the Commonwealth.

A component of this work is the determination of best practices for growers based upon regionally needs and requirements. At the present time there are no clearly established agronomic practices for hemp and how hemp growing as an industry fits into the current crop rotation schemes used by farmers throughout the state. Thus, our experimental approach to some extent was minimal and direct as we worked with growers to define needed foundational information.

This current report is being submitted prior to the completion of the growing season and, therefore, any information contained within should be considered as preliminary and not final. As experimental data are accumulated and interpreted, findings of relevance will be made available to interested parties upon request. The results of this work are solely the responsibility of the investigators and have not been influenced by the source of support for the studies.

Notes on field trial site selection.

The climate in Virginia differs largely across the Commonwealth and as such the state has identified five different climate regions based upon average winter and summer temperatures and annual precipitation. Soil composition also varies across the Commonwealth. To ensure that a diversity of growing environments and soil conditions were evaluated as part of our 2018 growing activities a variety of field locations were targeted for planting trials of our selected industrial hemp varieties. The sites where planting by UVA contracted growers occurred are as follows (with exact GPS locations placed on file with VDACS).

(i) Coastal Areas: Bundy Farm, Cape Charles, VA (Northhampton County) Approx. 10 acres
(ii) Central Areas: Morven Farms, Charlottesville, VA (Albemarle County) Approx. 8 acres; Bremo Plantation, Bremo Bluff, VA (Fluvanna County) Approx. 12 acres; Waynesboro Nurseries, Waynesboro, VA (Augusta County) Approx. 10 acres
(iii) Southwestern Areas: Broadwater Farm, Nickelsville, VA (Scott County) Approx. 2 acres; Burke Farm, Jonesville, VA (Lee County) Approx. 2 acres; Etherton Farm, Nickelsville VA (Scott County) Approx. 2 acres; Johnson Farm, Ft. Blackmore (Scott County) Approx. 2 acres; Moore Farm, Rural Retreat, VA (Wythe County) Approx. 10 acres

Comparison of till versus no-till planting schemes.

A major part of our studies in 2018 was a comparison of different planting schemes and seeding rates. No-till agriculture involves planting of crops from year to year without disturbing the soil to decrease soil erosion and increase the amount of water in the soil, the soil's ability to retain organic matter and nutrient cycling. Our studies examined whether no-till practices versus conventional tilling (clearing current crops and disking to remove vegetative debris) are suitable for hemp production and assist the grower in keeping the production costs (i.e., fuel, labor, and machinery) as low as possible. No-tillage production generally does not use herbicides to control weeds but may require the use of a heavy seed drill capable of penetrating vegetative residue and placing seed at a constant depth. If hemp were to be grown organically, the use of herbicides/pesticides would obviously be excluded from any practice. Based upon our experience in the 2017 growing season we know that weed control is very important in tilled fields, especially if there are persistent perennial weeds. As such a broad range of herbicides rated for hemp production may need to be identified and best practices for application and weed control will need to be developed. In all cases, we want to take into account the planting history of each site. In each of our sites the planting history is known and all fields were currently in crop production and used primarily for either hay, corn, soybean or tobacco.

Defining the soil fertility requirements for hemp production.

Hemp is not unlike other commercial crops and despite claims to the contrary soil fertility and application of suitable levels of fertility inputs are essential for good growth and yield. To the extent possible where prior information was not available, soil analysis was conducted at the site to determine levels of soil fertility. If prior application of fertility treatments were known testing was not done. In most cases experimental fields received basic fertilization with nitrogen (urea), phosphorus (DAP, diammonium phosphate) and potassium (potash). NPK was applied as recommended following soil testing and in general involved application of 100 -150 lb / acre of nitrogen, 50 lb / acre DAP, and 50 lb / acre potash. Depending on the application and individual contracted to provide the fertilizer additional micronutrients were also included (e.g., sulfur, Mg, Mn, etc).

Sourcing appropriate germplasm for testing and improvement.

The seed material used in our studies were a combination of cultivars/varieties/breeding lines obtained either by our sponsors or from plants grown in the 2017 growing season in Virginia from which seed as part of the UVA breeding program was collected and stored for replanting in 2018. In some cases, seed materials were purchased from domestic sources or from certified seed vendors / distributers in Europe. In all cases importation protocols consistent with State and Federal guidelines were followed and proper permits were obtained. Varieties were selected based upon their reported use as either types, hurd types, oil /seed types and dual purpose lines. Plantings at some sites consisted of single variety plantings (for seed production) with comparisons of planting rates (densities) being evaluated and at other sites studies were designed to compare performance of specific varieties under different planting strategies (till versus no-till; plant density). In all cases the germination ability of all varieties were tested under greenhouse conditions prior to test plantings and germination rates of all varieties had a minimum of 85% with the majority of the varieties being significantly greater.

The following breeder's seeds were conserved from 2017 season and used for replanting: hemp varieties used are as follows:

UVA Test 1 (a Finola type) VA2017
UVA Test 2 (a fiber/grain type similar to Samuri – Virginia 2017)
UVA Test 3 (a fiber/grain type Samuri-Vermont 2016/2017)
UVA Test 4 (multipurpose line Oregon Wilde 2017)
UVA Test 5 (a commercially available Ukrainian high fiber/hurd variety - Hlukhivskii 51)

Basic Planting Schemes and experimental design by site.

1. Bundy Farm, Cape Charles, VA (Northhampton County)

Fields were prepared prior to planting by Turbo tilling (vertical tillage tool) twice and the field were sprayed with 28 oz/acre Power Max liquid herbicide (Re. No. 32209 Pest Control Products Act). Spray contains glyphosate, 540 grams acid equivalent per liter, present as potassium salt. Spraying occurred on May 2, 2018 and the first planting was 23 days later on May 25, 2018. Seeds were planted using a Case III conventional drill with cultiplanter (field cultivator) set at 7 inch row spacing with a 1/2 to 3/4 inch depth of planting. The planting rate was 40 to 50 lb / acre. Two varieties were tested at this site: UVA Test 2 and UVA Test 4.

Both varieties showed good germination rates and growth despite the wetter than normal growing conditions with UVA Test 2 showing almost twice the growth rate of UVA Test 4 through early June. In early June UVA Test 4 began to flower and growth arrested at about 18 inches to 2 feet at which time weeds began to overtake the field. Clearly the day length of Virginia is not suitable for this variety since flowering was too early to allow sufficient growth. Given the severe weed pressure on July 20, 2018 the field was bush hogged and the trial terminated. UVA Test 2 continued to grow and develop and had reached heights of between 6-10 ft. Growth across the field was uneven and it appeared that the growth was influenced heavily by soil moisture, fertilizer application (indications of slight unevenness in application) and weed pressure. The performance of UVA Test 2 at Cape Charles was consistent with its performance at other locations. A small section of the field is planned to be harvested for testing.

2. Bremo Plantation, Bremo Bluff, VA (Fluvanna County)

The studies at Bremo Plantation consisted of analysis of varieties and planting rates. In particular, we were comparing the performance of seed that is part of a breeding and selection scheme for multiyear performance. In this case the field was previously grown in barley and we used direct drilling into the flattened straw as a weed control cover. Soil tests that were taken in March of 2018.The field was fertilized on July 5, 2018 with the recommendation for N, P, and K of 159, 50 and 60 lb/acre, respectively. The field was planted on July 9, 2018. We used two varieties (UVA Test 2 and UVA Test 3) and three planting rates across the 12 acres. Planting rate comparisons consisted of two 3 acre plots at 80 and 45 lb / acre, respectively, and sowing of the remaining 6 acres at 60 lb / acre. At the end of each planting cycle, the remaining seed in the drill was dispensed with the flutes wide open to empty the seed box in the field.

Both varieties showed good germination rates and growth despite the wetter than normal growing conditions. UVA Test 2 showing a bushier growth habit than UVA Test 3; flowering of UVA Test 2 was later than UVA Test 3. Through early July and August the crop did well but a tornado or downburst on September 6, 2018 leveled about half of the crop, and heavy rain from hurricane Florence blew down much that was remaining. As of the submission of this report we have maturing seed and expect to harvest in two to three weeks what remains.

3. Waynesboro Nurseries, Waynesboro, VA (Augusta County)

Trials at Waynesboro Nursery were aimed to examine the performance of a high fiber/hurd variety UVA Test 5 (Hlukhivskii 51) under different planting densities and fertilizer application conditions. All of the fields used for planting were disked (conventional tilling). Cherry Tree Hill fields were disked and rolled and the field was fertilized after planting with N, P, and K of 25, 20, 40 lb / acre, respectively, and 10 lb / acre sulphur and boron. A later planting at Hartman Farm Field was disked and rolled with no fertilizer treatment. Cherry Tree Hill was planted on June 19, 2018; Hartman Farm was planted on July 19 – 20, 2018. Planting was done with a Haybuster 107C Drill. The drill was set at a row spacing of 7 inches and a planting depth of ¼ inch. The planting rates (lb / acre) among the fields were as follows: CTH1 (0.37 acres) - 45 lb / acre; CTH2 (1.4 acres) - 45 lb/acre; CTH3 (0.5 acres) - 45 lb; CTH4 (0.85 acres) - 30 lb/acre; CTH5 (2.07 acres) - 30 lb/acre; CTH6 (2.14 acres) - 30 lb / acre; CTH7 (0.6 Acres) - 70 lb/acre; CTH8 (0.66 Acres) - 45 lb / acre; CTH9 (1.12 acres) - 70 lb/acre; HF1 (2.2 acres) - 45 lb/acre; HF2 (2.8 acres) - 70 lb / acre. [Note that this field was disked and not rolled; seeds were planted after disking.]; HF3 (1.7 acres) - 50 lb / acre; HF4 (3.0 acres) - 50 lb/acre; and HF5 (1.4 acres) - 45 lb /acre.

The lateness of planting and the slow growth of UVA Test 5 resulted in extreme weed pressure. After the weeds started to overtake the field, we examined whether treatment with a post planting herbicide would assist in allowing the hemp to better establish itself. In this case, a portion of the fields were sprayed with clethodin 2E (a post emergent herbicide that is specially formulated to control a wide range of annual and perennial grasses and has been used in a variety of crops including cotton, soybeans, sunflowers, etc). It was applied as a top dressing at a rate of 11 oz / acre. At this point all fields remain growing and we are awaiting analysis. It appears as though hemp to a large extent tolerated the clethodin treatment, but this did not appear to have substantially altered the weed pressure. If possible we will take measurements on small subplots to record plant density, plant height, stalk diameter, fiber yield, and grain yield at the conclusion of the growing season. At the time of this report the field are still growing and we are still in the process of evaluation.

4. Morven Farms, Charlottesville, VA (Albemarle County)

Trials at Morven Farms were aimed to examine the performance of a high fiber/hurd variety UVA Test 5 (Hlukhivskii 51) under different planting densities. All of the fields used for planting were disked prior to planting (conventional tilling) and fertilizer application was according to recommendation for corn. (i.e., N, P, and K of 159, 50 and 60 lb / acre, respectively). A simple planting scheme was used, in the variety was planted using drilled in 7” rows at a depth of ½ - ¾ inch. The seed drill was set to plant seeds at a rate of 45 lb and 65 lb / acre split evenly over the total acreage.

Plant density, plant height, stalk diameter, fiber yield, and grain yield will be measured at the conclusion of the growing season on small subplots. Since at the time of this report we are still in the process of evaluation, the data presented are not complete.

The Morven farm field has a moderate slope and during the course of the 2018 season we have had several major rainfall events and significant erosion of parts of the field.

5. Industrial Hemp in Southwest Virginia

This experimental work was carried out in collaboration with Ryan Huish, PhD at the University of Virginia-Wise and is focused on the development of industrial hemp cultivars that are capable of growing in the Southwest regions of the Commonwealth where years of poor management practices and industrial mining have devastated soil quality and fertility. In this work we were comparing different varieties and different planting schemes to access the agronomic performance of various industrial hemp germplasms best practices suited for growing in the Southwest Region.

In the southwestern areas we grew on five sites: Broadwater Farm, Nickelsville, VA (Scott County) Burke Farm, Jonesville, VA (Lee County); Etherton Farm, Nickelsville VA (Scott County); Johnson Farm, Ft. Blackmore (Scott County; Moore Farm, Rural Retreat, VA (Wythe County). The fields at Burke Farm were planted on May 15 and 17, 2018; those at the Broadwater and Etherton farm on June 8, 2018, and at the Johnson farm on June 9, 2018.

The growers in Southwest Virginia were testing two treatments: no-till and conventional-till. They were each growing 3 hemp cultivars UVA Test 1, UVA Test 2 and UVA Test 4. These cultivars were randomly assigned six plots at each site, three of these randomly assigned as no-till treatment, and three of these randomly assigned as conventional-till. Each plot was approximately 60 ft x 40 ft. At one site, the Broadwater Farm, only conventional-tilling was tested due to prior preparation of the fields by the grower. For no till, we controlled for other variables by burning all vegetation off each plot with Glyphosate beforehand, and fertilizing them (based on the soil report results) to similar fertility levels. These fields have had different recent uses in the recent past: some were hay fields, some corn fields, some tobacco fields, some pumpkin fields, and some were tilled using conventional methods, and some were no-till in previous years. These are variables we will have to consider as we analyze the results.

During the growing season, growth parameters were quantified using drone aerial remote imaging. At the end of the experiment, hemp yield samples were collected from 5 randomly selected one-square-meter sections within each treatment plot for statistical analyses. These samples were not collected within 2 meters from the edge of the treatment plot to avoid edge effect. Data collection began late August 2018 and as of September 30th, the hemp has not been harvested (besides the small subplots taken for data collection late August through September). The fields on the Burke farm were not collected because of severe weed pressure and an inability to do any effective harvesting. The field was clear cut and the harvested biomass materials burned on site. As of September 30, 2018, we have not yet completed the analyses and thus do not have results yet. We will determine whether there is any significant difference in the performance of the hemp between the no-till vs. conventional till, and between the varieties selected.

On the Moore Farm (Rural Retreat, Wythe County, VA) we examined conventional no-till using one hemp cultivar, UVA Test 4 with a goal of being able to harvest fiber, hurd, and grain from the site at different times in order to compare the quality of this material with grows occurring at other locations in Virginia. UVA Test 4 was planted in mid-May and showed good germination rates and growth rates through early June. In early June it began to flower and growth arrested at about 18 to 24 inches at which time weeds began to overtake the field. Clearly the day length of Virginia is not suitable for this variety since flowering was too early to allow sufficient growth. Given the severe weed pressure on the field was bush hogged and the trial terminated.

Overall conclusions.

Overall conclusions are that UVA Test 4 is not highly suited for Virginia unless planting can occur in early March. This may be possible but one needs to try next year on a limited basis. This variety flowered very early and only got one or two feet tall. UVA Test 1 harvested from Virginia fields (Morven Farm) appeared to perform better than UVA Test 4, but not as well as UVA Test 2. Locally adapted UVA Test 2 performed slightly better than material grown in other locations. Overall, UVA Test 2 and UVA Test 3, are the better choices for across Virginia; with mid-to late season planting they grew easily 8 - 10 feet tall. UVA Test 2 also provided a better canopy closure, which lead to superior weed control. What we learned was that with conventional tilling approaches it is important to plant quickly after burn-off of weeds, or to use a second burn-off if there is a significant lag between preparation and planting to prevent weed regrowth. If not, you are faced with severe competition to the hemp plants. With no till planting, the use of a cover crop (such as clover, barley, or spring wheat straw) could be beneficial in keeping weeds down.

II. Greenhouse and laboratory experiments for hemp genetic improvement

In cooperation with Kingsland Nursery, Scottsville, VA (Seth and Lisa Richardson, growers) UVA conducted greenhouse based studies beginning in early November 2017 that primarily focused on two experimental outcomes: (1) best practices for the growth of high CBD strains under greenhouse conditions for the production of flowers for cannabinoid extraction and feminized seed for propagation; and (2) development of expertise in traditional and molecular breeding to create new varieties.

Experimental cultivars of various high cannabinoid strains were grown using different growing protocols and propagated under various fertilizer, lighting, container sizes and phytohormone/supplement regimes to determine the best conditions for growth of plants and for the direct selection of plant phenotypes and chemotypes for downstream breeding and propagation work. Plants were grown to maturity and floral parts collected for measurement of total cannabinoid levels and levels of 10-12 individual components (CBD, CBC, CBG, THC, etc.) and compositional differences among the various cannabinoids and terpenes present in the plant cataloged. All growing was done using biological control methods to produce nontoxic harvest material.

Trials were done to determine which plants could be selected and used as a source for generating either cuttings or feminized seed. Application of different treatments to generate feminized seed were evaluated.

In the laboratory, we are focused on the development of *in vitro* culture conditions for the growth, regeneration, and vegetative propagation of elite lines of high CBD strains. We are also interested in developing new gene transfer (plant genetic engineering/ transformation technologies) for hemp. At the present time little is known about the requirements for *in vitro* culture of hemp and even less information is available of the variability of responses among different hemp genotypes.

We have initiated basic studies to determine the response of the various germplasm to general in vitro culture conditions that test which plant growth medium works best and which balance of plant phytohormones are most effective in the establishment of callus, root, and shoot generation drive plant embryogenesis leading to regenerated growth. We are also determining the optimal experimental conditions for plant genetic transformation based upon the use of one of several gene transfer technologies: biolistic gene transfer, *Agrobacterium*-mediated gene transfer, and DNA-free genome editing with preassembled CRISPR-Cas9 ribonucleoproteins. The long term aim is the development of molecular genetic tools for Cannabis, with an eye towards the generation of hemp varieties that have unique agronomic characteristics or biochemical compositions of agricultural, nutritional, or medicinal value

III. UVA - JMU 4 VA Cooperative Project

The University of Virginia worked with Drs. Shelly Thomas and Mike Renfroe (JMU) to conduct comparisons of different cultivars to determine performance quality under different growing parameters. The goal of this work is to identify the best performing hemp varieties in the Grower's location, response to varied field conditions, response to seeding rate, and response to planting date.

Two sites were selected for analysis (1) Rockingham County and (2) Middlesex County. At each site small plots of 8.5' x 10.14'were used six UVA test cultivars were planted along with imported varieties (Felina 32, Joey, CRS-1, and CFX-2). The various cultivars were at three different seeding rates (30, 45, and 60 lb/acre) at two different locations (Rockingham and Middlesex counties) with four replications. Seeds are to be drilled in 6" rows at a depth of ½ - ¾ inch using a Carter Manufacturing plot seeder. For each small plots, the following information was collected: (i) emergence data every other day for 2 weeks (ii) flowering stages; (iii) harvesting date. A 1 m^2 area from the center of each plot was collected and the following phenological data was measured: plant height, length of seed head, diameter at base of plant, weight of dried stalk; weight of dried grain after seed cleaning. Information was also collected on the invading weeds and measured heights of weeds to determine weed coverage for each plot.

IV. Public Awareness and Outreach Activities.

The University of Virginia partnered with Brian Walden, a local farmer in Albemarle County, in outreach activities aimed at raising public awareness of the Commonwealth's history as a hemp growing state and the potential for industrial hemp as part of current farming activities. As part of the "Founding Fathers" initiative, UVA provided seed of a typical industrial hemp cultivar that was used for fiber production to be grown in a small scale plot on the grounds of George Washington's Mount Vernon estate in Alexandria, VA. Working with Dean Norton, Director of Horticulture, at George Washington's Mount Vernon, an ~200 ft^2 demonstration plot was planted on its Pioneer Farm site in May. The field was allowed to grow throughout the season and was used as part of an educational exercise to teach the public about industrial hemp in colonial and modern times. In late August the site was harvested and demonstrations of how the hemp fibers would have been prepared for use on the Mt Vernon estate were carried out by the staff. The harvest was covered by the Washington Post and NPR and has resulted in significant visibility for hemp and Mt. Vernon.

Similar outreach activities were also carried out at James Madison's Montpelier Estate in Orange, VA, where working with Sean O'Brien, PhD, the Executive Vice President and Chief Operating Officer we planted an approximately 1.5-acre demonstration plot. The field was planted in May and allowed to grow throughout the season. The field was used as part of an educational exercise to teach the public about industrial hemp. As of this present time, the field has not yet been cut, although we have been periodically taking samples of the plants for analysis.

Appendix C

Evaluating growth and productivity of several industrial hemp (*Cannabis sativa* L.) varieties in Virginia

Annual Report to
Virginia Department of Agriculture and Consumer Services

By

Maru Kipleting Kering, Ph.D.

Agricultural Research Station
Virginia State University
Petersburg, VA

September, 2018

Non-Technical Summary

During the 2018 production years, work was done at the Virginia State University (VSU) Research and Demonstration Farm (Randolph Farm), and at three other locations. The collaborating producer farms were in Powhatan, Cumberland, and Augusta Counties. At all four locations, grain-type variety Felina 32 and fiber-type varieties Carmagnola and Fetura 75 were planted. In addition, at Waynesboro Nurseries and VSU sites, grain-type variety Fedora 17 was planted. Also planted at VSU, was grain-type variety USO32 and Canadian grain-type varieties; Joey and Canda. At the four locations, planting was done within two weeks between July 1 and July 15. The abnormally high summer rainfall and late planting created unfavorable growth conditions with flooding conditions killing seedlings and competitive summer grass weeds suppressing plant growth. While insects pest were high at VSU location (Randolph farm), isolation of planted sites in Powhatan and Cumberland locations let to reduction in observed pests.

Major goals of the project

The overall goal of the project is to evaluate both fiber- and grain-type hemp varieties for establishments and growth performance in Virginia. The project seeks to determine; 1) Industrial hemp varieties that are suited to the southeast Virginia conditions; 2) The effect of nitrogen fertilizer on biomass, grain yield and grain quality; 3) Effect of planting date on growth and yield. However, during 2018 growing season, variety trial was the only one carried out at all locations. Also at VSU study site, planting date study with first planting is mid-April was not implemented due to delay in seed acquisition from European-based seed suppliers.

Expected Outcome

Overall outcome expected from this project includes; 1) Information on fresh/dry biomass of fiber- and seed yield of grain-type hemp varieties under different nitrogen fertilizer levels; 2) Information on growth and seed yield of different grain-type industrial hemp varieties at what would be considered optimal nutrient fertilizer levels, 3) impact of planting date on both fiber and grain type industrial hemp varieties.

Accomplishment

During 2018, a total of seven varieties were evaluated (Table 1). Due to delay in arrival of European-sourced seeds, all studies previously done in 2017 were not implemented. Only variety trial study was implemented with a total of seven; five grain and two fiber-type varieties being planted at VSU Research and Demonstration (Randolph) farm. At collaborating farms, all three fiber-type varieties were grown and at least one seed variety. However, late planting, and excessive rainfall, and water logging conditions that killed seedlings let to poor emergence in some locations. There was relatively good stands in two of three collaborating producer fields, while in one, poor emergence and competition from grass weeds let to poor crop performance.

Table 1. Industrial hemp varieties under study at Virginia State University in 2018

Variety-type	
Grain	***Fiber***
Canda	Carmagnola
Joey	Fetura 75
Felina 32	
Fedora 17	
USO32	

Seedling Emergence and Growth

While seedling emergence was satisfactory, excessive rainfall killed some of the seedlings and resulted in sparsely populated crop stands. This was especially evident in plots at VSU Research and Demonstration (Randolph) farm as shown in Figure 1a and Figure 1b. The fiber-type looks better in the photos and is likely a result of greater seeding rate compared to grain-type varieties. At the collaborators farms, unlike at VSU where small plot experiments were laid out, plot sizes were larger and there were uneven emergence of seedling even within a plot. Some areas had greater seedling density and resulted in greater plant populations while other had none to sparse populations (Figures 2a & 2b). And even for area with an initial greater seedling emergence, excessive rainfall in mid-summer let to flooding condition that killed some of the emerged plants, and created non-optimal soil conditions for plant growth. In fact continued rains prevented access to some the plots especially those on the river bottom as the case was for plots in Waynesboro Nursery, Waynesboro VA. Summer grass weed infestation was a problem in collaborators farms especially in Cumberland and Powhatan counties (Figure 2 and Figure 3). While some infestation by insect pests and birds occurred in some locations, low pest infestations were observed in Powhatan and Cumberland counties, which may be due to isolation of sites which were located in wooded areas and away from previously cropped fields. Up to the time of submitting this report, no attempt has been made to obtain grain yield and crop biomass due to poor stands and water-logging conditions in some of the plots.

Figure 1a

Figure 1b

Figure 1. Fiber-type (Fig. 1a) and grain-type (Fig. 1b) varieties stands for a crop established at VSU Research and Demonstration (Randolph) Farm

Figure 2a

Figure 2b

Figure 2. A good (Fig. 2a) and a poorly established (Fig. 2b) stand of same variety of hemp in Cumberland County VA. In poorly established section of the field, summer weed grasses outcompeted the crop.

Figure 3a

Figure 3b

Figure 3c

Figure 3. In Powhatan County, good seedling emergence with acceptable population density (Fig. 3a) but accompanied by aggressive summer grass weed (Fig. 3b). The warm season grasses easily outcompeted the crop (Fig. 3c).

Figure 4. In Augusta County, there was a good crop with relatively low grass weed population compared to other collaborating farms.

Future Plans

In 2019, VSU will continue varietal evaluation, planting date and fertilizer studies. We intend on using the same varieties as before and possibly others in 2019 and VSU will continue to work with current collaborating producers. Virginia State University will continue to participate in industrial hemp research and continue seeking new participants besides working with other institution of higher learning in the Commonwealth of Virginia. To address production challenges that have been observed/encountered during these pilot studies, researchers at VSU will expands its research objectives in the future. Future research may look into pest and pathogen control strategies and may include breeding to come up with Virginia-developed varieties.

Appendix D

Annual Report to the Virginia Department of Agriculture and Consumer Services

John Fike
Associate Professor
School of Plant and Environmental Sciences (SPES)
Virginia Tech

October 18, 2018

University collaborators and students on this project include:

Jabari Byrd, Michael Flessner, Sally Taylor and Carol Wilkinson, School of Plant and Environmental Sciences

Thomas Kuhar and Kadie Britt, Entomology

Seed procurement

Seed for grain and fiber studies were obtained from Canadian, European, and US seed suppliers. It is important that the State understand some of the challenges with getting seed into the US from out of country, so the following is a brief synopsis of most of the challenges we faced this year. Seed shipments from Canada and Europe were held up due to paperwork lost by the shipping company (on two occasions) and in one case, the shipping company was going to return the seed to its point of origin because it didn't have paperwork – which they (the shipping company) had lost. Customs officials also let our shipment sit at the port of entry because they could (or would) not read the English words within a label on seed shipped from Lithuania. Later, services from a Customs broker were needed to help move the seed on arrival (despite our having paid a brokerage fee to the seed supplier). A seed company's shipment from Canada was damaged and the paperwork lost, resulting in need for the shipper to reapply for all the appropriate permits. Orders for these seed were placed in February with intent to have on hand and plant in May. Most of our experimental plantings were delayed as we waited on some of these varieties to arrive. Through all of these experiences, staff at VDACS worked diligently to help move the process forward, including getting new permitting paperwork for lost shipments.

Seed shipped internally for grain, fiber and flower studies were delivered without issue. Easing the import of seed from abroad or getting a supply of seed in country should be priorities for the industry and policy makers alike.

2018 Research studies

Herbicide tolerance

Hemp tolerance to herbicide screening studies were conducted in 2017 and 2018. This included 3 three experimental repetitions of both preemergence and postemergence herbicide screenings in the greenhouse and two experimental repetitions (2017 and 2018) of both preemergence and postemergence herbicide screenings in the field. Data were collected routinely as a part of all experiments and data analysis is on-going. A full summary of the data is expected by Jan. 1, 2019 and we anticipate journal submission and publication. At least four herbicides (both pre- and post-emergence) have been identified as potential candidates given low (<30%) injury rates.

Germination temperatures

Germination of northern and southern European and Canadian seed varieties was tested on a temperature gradient table to determine lower and upper thresholds for germination and potential differences by source of origin. Seed were germinated across a temperature range of 5 to 40°C. Preliminary data suggest most northern-derived lines will have less tolerance to heat than the southern-derived lines, and germination begins to fall in the low to mid 30°C range, as might be expected. However, the theoretical minimum temperature for germination (extrapolated from the data) was less than 1°C for all varieties.

Tillage vs. Not-till establishment

Research at Virginia Tech's Kentland farm explored tillage and no-till establishment with both grain and fiber varieties. A count was scored if a plant was observed within a 6" x 6" cell inside a 4-cell x 5-cell grid and four measures were taken in each plot. Percent stand (Table 1) based on counts were similar for fiber types (seeded at 60 lb/acre). However, percent stand for grain (seeded at 30 lb/acre) were about 36% greater with conventional tillage. Although counts were lower for grain plots in no-till, this was largely driven by the very poor stand and high weed pressure in a single plot. Standard deviation of stand counts (a measure of stand variability) was much greater for grain under no-till establishment (23%) than under conventional tillage (2%). Variation was low and similar for both planting methods in no-till (5%) and conventionally tilled (3%) plots.

Biomass was hand harvested from each plot at the end of season. Grain plots with no-till establishment had about 83% the biomass of the tillage plots (Table 1). However, when the one poorly-established plot was not used in the estimate, the biomass yield of the no-till plots was 98% of the conventional plots – essentially not different. Grains have not yet been separated from stems to determine grain yields, but we expect similar yield results. With an assumed harvest index of 33% (which is low), grain yield will likely be about 1470 and 1220 lb/acre, respectively.

For fiber plots, the difference between establishment methods was minimal (about 96% of conventional tillage). Estimated biomass was about 5 tons/acre for each method. Average stem heights and stem diameters were similar for both establishment methods.

Table 1. Stand and yield parameters for hemp grain and fiber using tillage and no-tillage establishment methods.

Grain	Percent stand*	Stems/m^2†	Biomass, tons/acre‡
Tillage	90	100	2.2
No-till	66	63	1.8
Fiber			
Tillage	98	210	5.1
No-till	91	202	4.9

*Determined 10 days after planting

†Determined end of season

‡Calculated from fresh weight and an estimated dry matter percentage of 25%

Data from this study suggests that no-till establishment can be successful, although it may be more difficult with grain plots. The one failed in the grain plot had poor establishment and later was challenged by weeds.

Fiber and grain variety evaluation

Eleven grain and six fiber cultivars were planted in small plots in Blacksburg and Orange, VA. Planting occurred in late June at each site. Data were not collected at the Orange site due to change in management at the research station and heavy weed pressure.

For grain cultivars, data from the study indicate good establishment success for all varieties except Wojko (Table 2). Prior to the study, germination percent was tested and seed planted were adjusted to a seeding rate of 30 lb/acre of *germinable* seed. Despite a higher planting rate (due to low germ) that strategy clearly was ineffective for this cultivar, suggesting that seed vigor may be an issue to consider in achieving successful stands. Wojko aside, percent stand ranged from 81% (Canda) to 100% (Ferimon).

The correlation between estimated biomass yields ranged from 0.94 tons/acre (CFX 2) to 2.48 tons/acre (Futura) for all varieties planted at 30 lb/acre. French monoecious varieties Futura, Ferimon and Felina appeared most promising in this test. For all cultivars, percent stand was positively correlated (71%) to end of season stem count, but much less related to yield (52%), thus the stem to yield relationship was intermediate (67%) to those values.

We also added a seeding rate test within the grain cultivar study, planting CFX 1 and Joey at 20, 30, and 40 lb/acre. Interestingly, stand percents differed little between 30 and 40 lb/acre seeding rates, and were strongly (>97%) correlated to stem count for each cultivar. However, end of season stem counts were not well correlated with biomass yield (30% for CFX 1 and 45% for Joey), because yields declined at the higher seeding rate.

In contrast to grain varieties, total stem numbers were strongly negatively correlated (-97%) with estimated yield. Italian lines (Carmagnola, Compana Elleta, Fibranova) had the greatest yields (>3 tons/acre) over this shortened season. North European fiber lines go to flower earlier at our latitude and likely will be insufficient biomass producers unless they can be both planted and harvested early enough to support a late season crop. Fiber separation has not been possible to date, so a better understanding of actual fiber yield remains to be addressed.

Table 2. Percent stand, stem count, biomass yield, and cultivar rank by stem and biomass yield for hemp grain and fiber cultivars. Grain varieties were planted at 30 lb germinable seed/acre and fiber at 60 lb germinable seed/acre. CFX 1 and Joey also were planted across a range of seeding rates (20 to 40 lb/acre; highlighted bands).

Grain	Percent stand*	Stems/m^2†	Biomass, tons/acre‡	Rank, stem	Rank, biomass
Bialobreszkie	94	112	1.53	5	3
Canda	81	64	0.99	10	11
CFX 1 (20 lb)	84	45	0.61	14	14
CFX 1 (30 lb)	91	72	1.06	9	10
CFX 1 (40 lb)	90	83	0.75	13	9
CFX 2	83	52	0.94	11	13
Fedora	90	164	1.60	4	1
Felina	91	112	1.81	3	3
Ferimon	100	152	2.26	2	2
Futura	86	91	2.48	1	6
Joey (20 lb)	80	61	0.91	12	12
Joey (30 lb)	92	85	1.42	7	7
Joey (40 lb)	92	95	1.14	8	5
Tygra	91	85	1.50	6	7
Wojko	3	5	0.00	15	15
Fiber					
Bialobreszkie	98	126	1.90	2	6
C. Elletta	100	73	3.33	5	2
Carmag	75	75	3.12	4	3
Fibranova	84	52	3.71	6	1
Tygra	97	102	2.61	3	4
Ukraine	99	138	2.15	1	5

*Determined 15 days after planting

†Determined end of season

‡Calculated from fresh weight and an estimated dry matter percentage of 25%

Establishment method and seeding rate studies – Southern Piedmont AREC

Field studies evaluating the effect of fertility on industrial hemp production were conducted in 2018 at the Virginia Tech Southern Piedmont Agricultural Research and Extension Center (SPAREC). These trials were planted late in the growing season; about six weeks later than what would be considered optimal. The 2018 growing season was wetter than normal with 6.1, 6.3, 4.6, and 4.6 inches of rain in June, July, August, and September, respectively. The late planting and high rain levels probably reduced fiber and grain yields compared to other studies. There was some bird pressure this year but not as much as in preceding years. Despite these caveats, these tests were successful and provide very useful information. The information in this report is from two years of trials and is not intended as an immediate recommendations for growers. Conclusions will be adjusted based on data obtained from subsequent growing seasons.

Felina 32, a monoecious variety from France, was used in all studies. The experimental design for each study was a randomized complete block with four replications. Plot size was 6' x 20'. The seeding rate was 40, 60, and 80 lbs/A drilled for the grain, dual, and fiber tests, respectively. Row spacing was 16" in the grain test and 8" in the fiber and dual tests. The soil at the site is an Appling fine sandy loam. Conventional tillage was used to prepare the site and 200 lb/A of K_2O (0-0-60) was applied. A second dual purpose test was conducted by broadcasting seed by hand and then cultipacking the seed.

Plots were seeded on 15 June 2018 with a Truax Flex II drill at an average planting depth of 0.25" or less. Nitrogen was applied by hand to each plot as ammonium nitrogen (34-0-0) prior to seeding. The nitrogen rates for the fiber test were 0, 40, 80, and 120 lb N/A. The nitrogen rates for the grain test were 0, 80, 160, and 240 lb N/A. The nitrogen rates for the dual purpose tests were 0, 40, 80, and 160 lb N/A. Two dual purpose tests were conducted; one test was seeded with the drill on conventionally prepared land and for the second test, seed was broadcast by hand on conventionally prepared land and then cultipacked. Plots were sprayed on 5 July 2018 (20 days after seeding (DAS)) with Assure II (300 mL/A) with a surfactant (Meherrin 80-20 at 1 pint/gal) for crabgrass control. American goldfinches and doves were observed beginning in mid to late August. The birds are light enough they can perch on the plant and eat the seed. Fishing line will be strung across the top of the plots in a crosswise pattern to deter birds in future tests.

Plant density, plant height, stalk diameter, fiber yield, and grain yield were measured. Plant density was determined by counting the number of plants per square foot at 10 DAS and number of plant stems per square foot after harvest. Five counts were made per plot. Plant height (cm) was determined by measuring 10 randomly selected plants per plot the day of harvest. Stalk diameter (mm) of 10 randomly selected stalks was measured with a caliper 10 cm above the soil surface the day after harvest. A 5' x 15' section of each plot in the fiber test was harvested with a Wintersteiger self-propelled forage harvester and total plant material weight recorded (lbs) as an estimate of fiber yield. Grain yield was determined by manually harvesting all heads from a randomly selected 16 square foot area avoiding plot edges. Grain was thrashed and cleaned by hand, the number of seed counted and weighed (lbs/A). Dual test plots were harvested first for grain and then for fiber. All tests were harvested on 26 September (103 DAS). Harvest was later than normal, especially for the fiber test, due to excess rain.

<u>2018 Results</u>

Seed in the fiber, grain, and dual purpose tests started germinating in about three to four days. In contrast, seed from the broadcast dual purpose test did not begin germinating until about eight to nine days which coincided with a 1.17" rain. Broadcast seed was closer to the soil surface and may have needed increased soil moisture from the rain before it could germinate. Assure II provided affective crabgrass control and did not negatively impact the young hemp plants. Assure II is labeled as a single post-emergent spray for weed control in industrial hemp in Canada. No significant differences were observed among nitrogen rates for plant density at 10 DAS, plant density at harvest, stem diameter, plant height, and plant weight for the fiber (Table 3), dual purpose (Table 4), and broadcast dual purpose (Table 5) tests. The lack of significant differences was probably primarily due to the excess rainfall throughout the growing season. Average monthly rainfall for May, June, July, August, and September is

3.9, 3.9, 4.7, 4.1, and 4.0”, respectively. In contrast, rainfall in 2018 was 9.5, 6.1, 6.3, 4.6, and 4.6” in May, June, July, August, and September, respectively. Plant weight, plant height, and stalk diameter did increase with increasing nitrogen rates in the fiber test, but the increase was not significant. Significant differences were observed among nitrogen rates for stem diameter in the grain test (Table 6). Stem

Table 3. Data from fiber test conducted in 2018.

	Plant Density		Stem	Plant	Plant
N rate	10 DAS	Harvest	Diameter	Height	Yield
lb/A	plants/ft^2		mm	cm	lb/A
0	10.15	7.20	3.40	67	4004
40	9.15	10.45	3.94	73	4731
80	8.95	7.80	4.20	71	5228
120	9.35	8.60	4.27	82	5973
LSD (*P*=0.05)	ns	ns	ns	ns	ns
CV (%)	18.34	21.56	11.76	11	20

Table 4. Data from dual purpose test conducted in 2018.

	Plant Density		Stem	Plant	Plant
N rate	10 DAS	Harvest	Diameter	Height	Yield
lb/A	plants/ft^2		mm	cm	lb/A
0	7.55	5.95	3.44	68	4459
40	7.75	7.05	3.20	84	5455
80	8.35	6.25	4.13	76	5609
160	9.20	6.40	3.91	80	5937
LSD (P=0.05)	ns	ns	ns	ns	ns
CV (%)	26.36	38.59	15.12	21	14

Table 5. Data from dual purpose broadcast test conducted in 2018.

	Plant Density		Stem	Plant	Plant
N rate	10 DAS	Harvest	Diameter	Height	Yield
lb/A	plants/ft^2		mm	cm	lb/A
0	5.50	6.25	4.46	85	6065
40	5.05	4.90	4.57	94	6082
80	3.55	4.00	4.83	86	4797
160	2.60	3.35	5.51	93	6587
LSD (P=0.05)	ns	ns	ns	ns	ns
CV (%)	33.92	37.92	13.25	13	19

Table 6. Data from grain test conducted in 2018.

	Plant Density		Stem	Plant
N rate	10 DAS	Harvest	Diameter	Height
lb/A	plants/ft^2		mm	cm
0	4.25	3.05	4.06	68
80	3.55	3.20	5.56	91
160	3.15	4.40	6.18	89
240	2.35	3.00	5.32	82
LSD (P=0.05)	ns	ns	0.79	ns
CV (%)	46.41	27.35	9.43	13

diameters at 0 lb N/A were significantly smaller compared to stem diameters at 80, 160, and 240 lb N/A. No significant differences were observed among nitrogen rates for plant density at 10 DAS, plant density at harvest, and plant height for the broadcast dual purpose test. Grain is being thrashed and cleaned.

Entomological studies in fiber and grain crops

Industrial hemp variety Felina 32 was grown at Virginia Tech's Kentland Farm in Whitethorne, VA for entomology research, including 1) assessing effects of simulated insect defoliation on hemp grain yield, 2) assessing effects of selective insecticide applications on hemp grain yield, and 3) determining the quality of hemp as a host plant for corn earworm (*Helicoverpa zea*) and brown marmorated stink bug (*Halyomorpha halys*) development.

To assess the effects of defoliation on grain yield, hemp plants were manually defoliated at four levels (0%, 25%, 50%, and 75%) and at three times (20, 40, and 60 days post planting). Preliminary analysis revealed no effect of defoliation on grain yield.

To assess effects of selective insecticide applications on pest presence and damage, three different active ingredients 1) *Bacillus thuringiensis* to control for Lepidopteran larvae (chewing worms), 2) sulfoxaflor to control for piercing-sucking hemipteran pests (aphids, stink bugs, plant bugs, etc.), and 3) a combination of the pyrethroid lambda-cyhalothrin + the diamide chlorantraniliprole to control for all insects, and an untreated control. There was no effect of treatment on grain yield of hemp, although more work is needed on grain analysis. Observations from several of the grain trials is that shells of hemp achenes often do not contain a viable seed.

Lastly, preliminary lab studies revealed that both corn earworm (*Helicoverpa zea*) and brown marmorated stink bug (*Halyomorpha halys*) successfully developed from neonates to adults on industrial hemp seed heads. Development rate and survival of both insects was equal to or similar to sweet corn as a host plant.

Dr. Sally Taylor's hemp plot at the Tidewater AREC in Suffolk, VA was completely lost to unknown causes. In early September, a few remaining plants were collected and taken to the Plant Disease Clinic on campus at Virginia Tech. Upon examination, Anthracnose (*Collectotrichum dematium*) was found on the majority of plant samples, although it is not clear that this was the agent that decimated the stand.

Flower trials

Several varieties of flower hemp were grown at Virginia Tech research facilities in the region. Data have been gathered on timing of maturity and harvest, disease presence and flower development (based on bud thickness and resinousness) and are being processed. *Septoria* (leaf spot and *Botrytis* (girdling of the plants) were common fungal pathogens identified on the flowers in the field, and mold has been an issue for some of the plants during the drying process, although this has been tied to storage conditions rather than a specific variety, *per se*.

Data collection on flower yields have not been completed as we are waiting for plants to dry in order to get dry matter values on samples we have harvested. (Plant wet weights generally averaged around 10 lb, but the range was from a few lb to over 20 lb/plant). Data on field observations also have not been completely processed, and we have some limitations on describing those due to material transfer agreement limitations, although there were clear varietal differences with respect to size, date of maturity, plant shape, and resin load. Replicates for each cultivar generally were established with 6 (feminized) or 12 (non-feminized) plants per block, and some cultivars displayed high variability among plants within varieties. This low uniformity may present some issues for some producers.

In addition to research farm studies, several growers experimented with hemp this season. Maturity ratings were gathered at two farms and followed similar patterns within those same varieties grown in the university system. Flower varieties were challenged by the soils at one site and lepidopteran caterpillars were a problem for all growers. Use of Bt or other pesticides will need further investigation.

Preliminary information from some private lab analyses suggest that available cultivars may be above threshold for THC when the sample evaluated is taken from the most prominent cola. This sampling method and the current mandate that producers have material below 0.3%THC places significant burden of risk to producers given that the sampling method may overestimate total THC concentration – other buds lower down in the plant canopy will likely have lower THC values – and that processors can blend cannabinoids to keep TCH levels at or below 0.3% (as we have been informed by industry).