II. Research Proposal

The regulations require the completion of a research proposal before your research license application can be considered. If you completed a Pre-Application and Pre-Application Research Proposal and want to certify your Pre-Application Research Proposal for use as your research proposal on this research license application, you must complete all provisions of the research license application and submit a copy of your Pre-Application Research Proposal. As the Primary Applicant, you will be given the opportunity to certify your request in the Acknowledgment Section below. **To be able to certify your Pre-Application Research Proposal, the Primary Applicant must be the same individual that completed the Pre-Application and Pre-Application Research Proposal.**

Your research proposal must explain the research you plan to conduct on behalf of the Kansas Department of Agriculture. Your research proposal will play an important role in the evaluation of your research license application and approval to participate in the Program.

Below are possible research topics that may be useful areas of study. Once you have determined the area of your research, explain in detail, on the following pages, the specific subject your research will cover.

- Agronomic research and analysis of soils, growing conditions or water usage required to successfully grow industrial hemp.
- Research on types of industrial hemp seed that are best suited to be grown in Kansas, including seed availability, creation of hybrid seed types, in-the-ground variety trials and seed production.
- Agronomic research and analysis of the most efficient types of equipment and techniques for seeding, tillage or harvest.
- Agronomic research and analysis of the most effective, economical and environmentally beneficial pest control or fertilization products or methods.
- Analysis of the management techniques and/or environmental factors that impact the delta-9 tetrahydrocannabinol (THC) concentration in industrial hemp.
- A study on the feasibility of attracting federal and private funding for industrial hemp research.
- Analysis of the economic feasibility of developing markets for the various types of industrial hemp that can be grown in Kansas.
- Research and analysis of the most efficient types of equipment and techniques for transporting industrial hemp plants, plant parts, grain or seeds.
- Analysis of the estimated value-added benefits, including environmental benefits, that Kansas businesses would reap by having an industrial hemp market of Kansas-grown industrial hemp varieties.
- Research and analysis of the most efficient types of equipment and techniques for processing industrial hemp plants, plant parts or grain.
- Analysis of the economic feasibility of developing markets for varieties of industrial hemp seed in and beyond Kansas.
- Research into the development of national and international markets for Kansas-grown industrial hemp and industrial hemp products.
- Analysis of the most efficient and economical methods for distributing and transporting Kansas-grown industrial hemp and industrial hemp products.
- Other types of research into the economic development, cultivation, market analysis, manufacturing, distribution and transportation of industrial hemp and industrial hemp products.

Research Proposal Instructions:

- **Complete the following sections**, either by utilizing the fillable form or by providing your answers on a separate page(s). *Handwritten submissions are strongly discouraged.*
- **If answering on a separate document**, please label each section (A-F).
- **Be concise**: Your research proposal should be as concise as possible; **not to exceed 2 pages total.**
- **For more information on how to write a research proposal**, please see the Technical Bulletin on How to Conduct Research on Your Farm or Ranch by visiting https://www.sare.org/Learning-Center/Bulletins/How-to-Conduct-Research-on-Your-Farm-or-Ranch.

SECTION A: Identify your research question and objective, including a statement of the type of research to be conducted and its purpose.

Q1. Which of the approved varieties are best suited for fiber, grain, or CBD production in KS?
Q2. Will different plasticulture systems grow high quality hemp?
Q3. Does fertilizer form and rate influence hemp production?
Q4. Is irrigation necessary to grow a successful hemp crop in south-central KS?
The objective of the research is to answer the above questions in field growing conditions in south-central Kansas. The purpose is to generate baseline data evaluating some basic production questions to be able to make some recommendations to new hemp growers.

SECTION B: Identify your experimental design.

All experiments will be conducted in a Randomized Complete Block Design with a minimum of four replications per treatment. Variety trials will be planted in 8ft x 20ft plots using a grain drill. Plots will be monitored for growth, weed presence, and insect presence. Plasticulture systems will use drip irrigation and different color plastic and paper to exclude weeds and moderate soil temperature. This is a more intensively managed system for higher value plants. To investigate fertilizer requirement, different rates of conventional and organic fertilizers will be applied to the soil and incorporated prior to planting. We will monitor growth and plant health throughout the growing season. To investigate irrigation, a larger field will be segregated into different irrigation regimes. We will monitor soil moisture and measure plant growth throughout the season. We will also be able to measure plant stress.

SECTION C: Explain what will be measured and what data will be collected.

We plan to measure establishment (plants/m^2), final plant height (m), biomass production (ton/acre), and grain yield (lb/acre) of the fiber and grain varieties. In the plasticulture system, we will measure final plant biomass (lbs/plant dry wt.), flower yield (inflorescense/plant), and resin content (CBD and THC content). In the fertilizer study we will measure final plant biomass, flower yield, and resin content. We will also look at chlorophyll content using a chlorophyll meter and leaf size (cm^2/leaf). In the irrigation project will will collect similar data as the fiber and grain study. Additionally, we will install soil moisture probes to monitor soil water status.

SECTION D: Explain how the project will be implemented, including location and size of your anticipated research areas (in acres or square feet), duration of your research operations and variety of industrial hemp that will be used in your research.

The fiber and grain variety trial will be conducted in field IH1. Varieties for CBD will be tested in IH2. We hope to plant in early May and harvest at the onset of pollen dispersal (fiber) or when 70% of grain has matured (grain). We don't know exactly when that will be in KS yet. The plasticulture experiment will be conducted in fields IH3 and IH4. Planting will occur in mid-May and harvest will occur when trichomes have turned tan/amber in color. We don't yet know when this will happen in KS. The fertilizer experiment will be run in fields IH3 and IH4. Planting will occur in mid-May and the study will be terminated with the trichomes on female plants have turned tan/amber in color. We don't know when that will happen. The irrigation study will be conducted in field IH6. It will be planted in early May. Harvest will occur at the onset of pollen dispersal.

SECTION E: Explain how research data will be collected, recorded and analyzed.

Data will be collected by employees of the John C. Pair Horticultural Center consistent with our procedures for collecting data from other projects. Data will be written on paper with pencil then transcribed to Excel spreadsheets. Handwritten data will then be filed and saved in case of computer failure. Data will be analyzed with a common statistical analysis software such as SAS. Data will be subjected to analysis of variance and means will be subjected to a common means separation tool when appropriate.

SECTION F: Explain how the data will be interpreted and how conclusions will be drawn, including anticipated results.

Data will be interpreted after all statistical analyses are completed. Conclusions will be based on that statistical analysis in a manner consistent with academic research ethics standards. We anticipate finding large varietal differences among our research plots. It is expected that some of the approved varieties may not be well adapted to Kansas and result in near crop failure of the variety. We anticipate large, highly productive plants, with numerous inflorescence in the plasticulture system. Based on conversations with colleagues at other institutions, we anticipate plants fertilized with organic fertilizer to outperform conventional fertilizers. They report improved plant growth in organic systems. We anticipate improved productivity in irrigated plots. However, we will wait to see if the increased productivity justifies the increased monetary and environmental expense of irrigating.

2019 K-State Industrial Hemp Dual-Purpose & Fiber Trial

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Introduction:

Hemp is a broad term used to describe the many varieties of *Cannabis sativa* L. that produce less than 0.3% tetrahydrocannabinol (THC). The crop is globally significant, but only recently was allowed to be grown once again in the United States. Varieties have been selected for improved fiber and grain production that have numerous industrial uses. However, there is no information available regarding adaptability or production of these varieties in Kansas.

In 2019 Kansans were allowed to apply for research licenses to grow industrial hemp. It was assumed the crop would grow well throughout KS since there are wild remnant populations of *C. sativa* flourishing at numerous locations across the state. However, controlled variety trials are necessary to determine which varieties are best adapted to the state. Currently, farmers must rely on information generated from other states with vastly different growing conditions than KS. Variety selection is vital in hemp production considering latitude (day length) and length of growing season influence planting time, number of days to harvest, and ultimately yield

The objective of this study was to evaluate commercially available varieties of industrial hemp in south-central KS.

Methods:

Research plots were prepared at the Kansas State University John C. Pair Horticultural Center near Wichita, KS. The location is a flat sandy loam soil (Canadian-Waldeck fine sandy loam) averaging 32 in of precipitation annually. The experimental plot had been buffalo grass for the previous 12 years. In Fall 2018, buffalo grass was terminated with glyphosate in preparation for Spring 2019 hemp planting. Prior to planting in Spring 2019, the plot was cultivated to incorporate remaining surface organic matter. On 12 June 2019 100 lbs/A of nitrogen (46-0-0) was broadcast then incorporated with a spring-tooth harrow. On 13 June 2019, 14 varieties of dual-purpose industrial hemp (Table 1) were seeded at a rate of 30 lbs live seed/A (Fig 1). On the same day three varieties of fiber hemp were seeded at a rate of 60 lbs live seed/A (Table 2). Experimental plots were 4.5 ft x 22 ft and seeded to a depth approx. 1.0 in with a Hege 1000 drill outfitted with a Zero-Max gear box on 9 in row spacing. On 15 June 2019 the plot received 2.5 in of heavy precipitation causing water to stand in portions of the plot and the soil surface to crust. No germination was observed from this planting.

Figure 1. Hege 1000 grain drill for planting hemp variety plots.

On 26 June 2019 the experimental plot was cultivated with a drag harrow to break the crust and an additional 50 lbs/A nitrogen (46-0-0) was broadcast and incorporated. The plot was re-seeded with the same varieties, at the same rates, and in the same plots as the previous planting. At this planting, seed depth was adjusted to ½ in. Additionally, because of limited seed supply, the variety 'Hliana' was not included in this second planting. On 29 June 2019 the experimental plot received 1.75 in of precipitation causing some ponding of water, however, germination was considered acceptable to continue the

Figure 2. Female inflorescence with grain ready to harvest.

evaluation. Overhead irrigation was applied as needed throughout the summer to prevent drought stress.

On 4 - 12 Sept 2019 two 1.0 m^2 sub-plots were chosen randomly for harvest in each experimental plot. For grain yield, the terminal female inflorescence (Fig 2) and primary lateral female inflorescence were removed from the plant and placed in paper bags and weighed (fresh weight). Bags were then air dried for 7 days at 75F and 45% relative humidity. Once dried, grain was manually threshed then separated from the chaff by winnowing. Plants within each sub-plot were cut at the soil surface for data collection. Data collected included: plant count per sub-plot, plant height (measured from the soil surface to the point where the female inflorescence was removed from the plant), stem caliper (measured at the soil line), stem fresh weight, and stem dry weight. Dry weight was obtained after drying samples in a forced air drying oven at 160F for four days.

Fiber varieties were harvested after the grain harvest was complete. Similarly, two 1 m^2 sub-plots were chosen randomly for harvest in each fiber experimental plot. Plants within each sub-plot were cut at the soil surface for data collection. Data collected included: plant count per sub-plot, plant height (measured from the soil surface to the end of the terminal inflorescence), stem caliper, whole plant fresh weight, and whole plant dry weight.

The experimental design for the dual-purpose varieties was a randomized complete block design with 13 varieties. Two subsamples per plot were harvested and the experiment was replicated four times. Data was subjected to ANOVA and means separated by Fishers Protected LSD. An identical experimental design and analysis was employed for the three fiber varieties.

Figure 3. Higher seeding rate of fiber varieties ensures straight stems will little branching.

To assess industrial hemp's impact on soil water content we measured the soil profile water content change over the growing season in unirrigated plots of three varieties (Canda, Joey, and Tygra). We also measured the soil profile water content change in unirrigated vs. irrigated plots of one fiber variety (SS Beta).

Soil cores were extracted to a depth of 5 ft from areas with a uniform hemp stand in each plot at early vegetative growth (23 July) and soon after biomass sampling (20 Sept). Gravimetric soil water content (θg) was calculated for each foot increment in depth at each date as follows:

$$\theta g = \frac{mass\ of\ water}{mass\ of\ dry\ soil}$$

Change in soil water (Δθg) was calculated as the difference between the soil water content after harvest less the soil water content at early vegetative stage:

$$\Delta\theta g = \theta g, harvest - \theta g, vegetative$$

Values for Δθg were subjected to analysis of variance and mean separation at $\alpha = 0.05$.

In addition to the above mentioned data, the terminal 20 cm of five plants selected at random were collected from each variety of three reps. The plant material was analyzed for THC and cannabidiol (CBD) content at the K-State Olathe Post-Harvest Physiology Laboratory using accepted laboratory techniques for such analysis.

Results & Discussion:

The growing season of 2019 can be summarized as cooler and wetter than normal (Fig 6). The first planting of dual-purpose industrial hemp failed to emerge due to a heavy rainfall shortly after planting. Water ponded on the plot and the soil crusted. Germination was near 0% across all plots. The second planting was successful and data was collected at the end of the growing season. Although a rainfall occurred 2-days after planting it did not prohibit germination and seedling emergence of most varieties. Unfortunately, germination and establishment of varieties Canda, Futura 75, Joey, and Katani were determined to be unsatisfactory to collect reliable data. Additionally, due to limited seed supply, there was insufficient seed to replant Hliana. Therefore, growth and yield data was only collected on the varieties listed in Table 3. However, samples of all varieties were collected for THC and CBD analysis and are presented in Table 5.

Growth and yield were highly influenced by variety in this experiment (Table 3). Fedora 17, Felina 32 and USO 31 had good seedling emergence and early stand development with over 100,000 plants per acre. The remaining varieties were all below 75,000 plants per acre. Helena was the tallest and produced the greatest stem dry weight, overall yield, and individual plant yield, although it had one of the lowest established stands. Felina 32 had one of the highest stand establishment rates and was also one of the highest yielding varieties. CFX1 and CRS1 both initiated flowering at approx. 18 in tall. This is likely due to the late planting date. These varieties are adapted to the long summer days of northern latitudes. It is likely that an April or May planting date would yield much taller plants that are more suitable to a dual-purpose cropping system. However, overall yield of CRS1 was comparable to several of the taller varieties.

In general, fiber varieties were more vigorous (growing faster and ultimately taller) than the dual-purpose varieties (Table 4). SS Beta had the greatest number of plants per plot and also surpassed 2-tons of dry matter per Acre. There was no difference in height among the varieties at harvest, however, Fibranova had a greater stem diameter which may be a result of fewer plants per plot. Eletta Campana had a similar dry weight as SS Beta with a stem diameter between the other two varieties. Stem diameter is an important factor to consider in fiber varieties, because it influences the ratio of bast to hurd fiber.

Soil profile water content data indicated a slight difference among the three unirrigated varieties in the top 1 ft (Fig 4). At depths 2 – 5 ft there was no difference in soil water content between the varieties. Data from the unirrigated and irrigated fiber plots indicate no difference in soil water content at either depth (Fig 5). These data are not entirely surprising given the amount of precipitation received prior to planting and after planting. During the initial soil core sampling on 23 July, free soil water was observed at a depth of 4 ft.

The quantity of CBD and THC in the inflorescence was impacted by variety. None of the varieties in this trial produced enough CBD to be commercially viable (Table 5). Eletta Campana and Fibranova had the highest levels of CBD (1.9%) while the concentration in some varieties was near 0% (Hlesia, Hlukhivs'ki 51, USO 31). Fortunately, none of the varieties produced over 0.3% THC, with several producing no or undetectable quantities. Interestingly, the fiber varieties contained more cannabinoids (CBD and THC) than the dual-purpose varieties. At the time female inflorescence were harvested for cannabinoid concentration, dual-purpose varieties were full of mature grain whereas fiber varieties had less grain population. This may explain the higher cannabinoid concentration in the fiber varieties.

Although data was not collected, significant pest were noted throughout the growing season. There was a heavy presence of spotted cucumber beetle early in the season. Damage was mostly cosmetic and restricted primarily to foliar feeding. Later in the season an extremely heavy infestation of aphids (species undetermined) was observed on leaves and inflorescence. While there is no way to determine potential loss of vigor and yield due to aphids, the overwhelming presence likely had an impact. Accompanying the aphids was an equally heavy presence of ladybugs. As the grain matured a population of lepidopterous larvae were observed feeding in the inflorescence.

This was the first year of industrial hemp research in Kansas and there is a great need for further variety and production based research. This growing season was unusual with frequent precipitation and lacking extended periods of hot temperatures. Conducting this research under more typical conditions will be necessary so Kansas farmers can make informed decisions when selecting industrial hemp varieties for their farms. In our trials, seed availability and frequent spring rains prevented planting at the ideal (mid-May) time. As a result, our plants failed to achieve the anticipated height and possibly yielded less grain than they would have if they were taller with more branching inflorescence. With no insecticides or herbicides available, the impact of those pests will be difficult to determine. However, there is little doubt that insect pests and weed pressure will continue to be problematic and ultimately impact yield.

Table 1. Variety, percent germination, and origin information for dual-purpose industrial hemp (*Cannabis sativa*) planted at the K-State John C. Pair Horticultural Center in 2019.

Variety Name	Germination (%)*	Source
Canda	87	Parkland Industrial Hemp Growers
CFX-1	95	Hemp Genetics International
CRS-1	85	Hemp Genetics International
Fedora 17	96	Schiavi Seed
Felina 32	93	Schiavi Seed
Futura 75	69	Schiavi Seed
Helena	68	Schiavi Seed
Hlesia	84	Fiacre Enterprises
Hliana	90	Fiacre Enterprises
Hlukhivs'ki 51	85	Fiacre Enterprises
Joey	89	Parkland Industrial Hemp Growers
Katani	93	Hemp Genetics International
Tygra	77	Schiavi Seed
USO 31	92	Schiavi Seed

*From pre-plant germination tests.

Table 2. Variety, percent germination, and origin information for fiber industrial hemp (*Cannabis sativa*) varieties planted at the K-State John C. Pair Horticultural Center in 2019.

Variety Name	Germination (%)*	Source
Eletta Campana	63	Schiavi Seed
Fibranova	71	Schiavi Seed
SS Beta	80	Sunstrand

*From pre-plant germination tests.

Table 3. 2019 K-State John C. Pair Horticultural Center dual-purpose industrial hemp (*Cannabis sativa*) variety trial harvest data.

Variety	Stand (plants/A)	Stem DW (lbs/A)	Height (cm)	Caliper (mm)	Grain Yield (lbs/A)	Plant Yield (lbs/plant)
CFX1	73,855 bc	347 e	28.6 e	5.6	83 c	5.5 d
CRS1	63,738 bc	620 de	40.2 de	13.9	1,212 bc	9.1 bc
Fedora 17	132,029 a	1,135 c	52.2 cd	8.1	1,191 bc	4.6 d
Felina 32	125,959 a	1,99 b	67.1 b	8.4	1,576 b	6.4 bcd
Helena	55,644 c	2,680 a	94.7 a	12.0	2,123 a	17.9 a
Hlesia	51,260 c	819 cde	52.5 cd	8.4	798 c	7.9 bcd
Hlukhivs'ki 51	72,844 bc	975 cd	51.4 cd	8.7	805 c	5.3 d
Tygra	52,103 c	907 cd	59.4 bc	9.1	974 c	9.7 b
USO 31	100,160 ab	1,089 cd	42.5 de	7.5	1,202 bc	6.0 cd
Significance	$P<0.0002$	$P<0.0001$	$P<0.0001$	$P=0.46$	$P<0.0001$	$P<0.0001$

Means within a column followed by the same letters are not significantly different.
Data are a mean of four replications.

Table 4. 2019 K-State John C. Pair Horticultural Center industrial hemp (*Cannabis sativa*) fiber variety trial harvest data.

Variety	Stand (plants/A)	Stem DW (lbs/A)	Height (cm)	Caliper (mm)
Eletta Campana	178,062 b	8,917 a	159.8	8.5 b
Fibranova	85,510 c	6,194 b	176.0	9.7 a
SS Beta	459,845 a	10,882 a	161.2	5.8 c
Significance	$P<0.0001$	$P<0.0043$	$P<0.17$	$P<0.0003$

Means within a column followed by the same letters are not significantly different.
Data are a mean of four replications.

Table 5. 2019 K-State John C. Pair Horticultural Center dual-purpose & fiber industrial (*Cannabis sativa*) variety cannabidiol (CBD) and tetrahydrocannabinol (THC) analysis.

Variety	CBD (%)	THC (%)
Canda	0.3 cd	0.0 e
CFX1	0.5 c	0.0 de
CRS1	0.6 c	0.0 e
Fedora 17	0.5 c	0.0 e
Felina 32	1.4 b	0.1 bc
Futura 75	1.2 b	0.1 cd
Helena	1.4 b	0.1 cd
Hlesia	0.1 d	0.0 e
Hlukhivs'ki 51	0.0 d	0.0 e
Joey	0.6 c	0.0 e
Katani	0.4 cd	0.0 e
Tygra	1.5 b	0.1 bc
USO 31	0.1 d	0.0 e
Eletta Campana	1.9 a	0.2 a
Fibranova	1.9 a	0.2 ab
SS Beta	0.6 c	0.2 a
Significance	*P*<0.0001	*P*<0.0001

Means within a column followed by the same letters are not significantly different.
Values are a mean of 3 replications

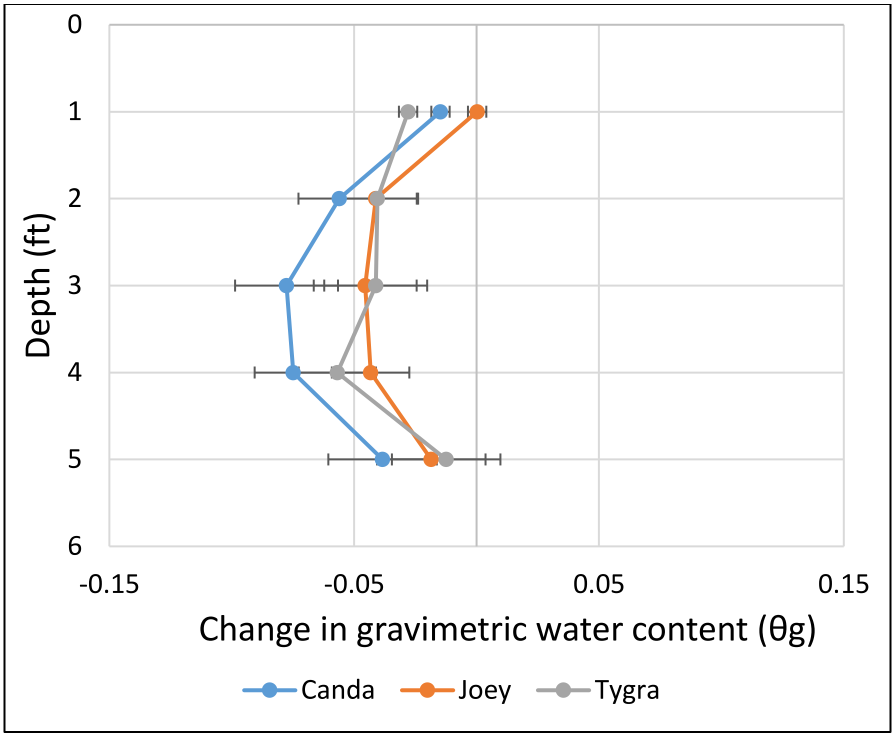

Fig 4. Soil moisture change for three hemp varieties, Sept-July 2019.

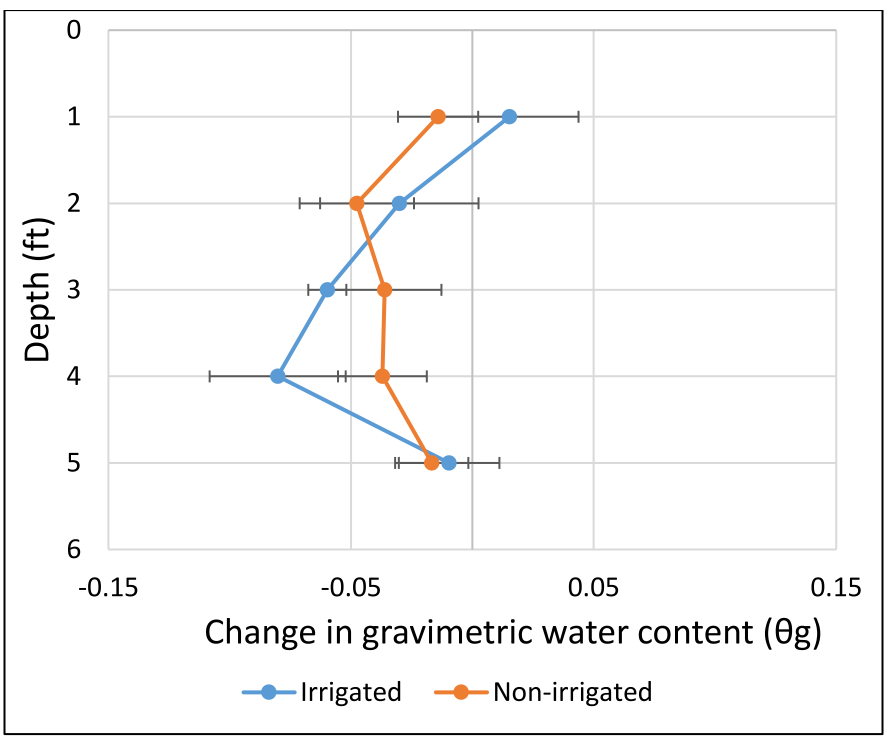

Fig 5. Soil moisture change in irrigated and unirrigated plots of hemp (SS Beta), Sept-July 2019.

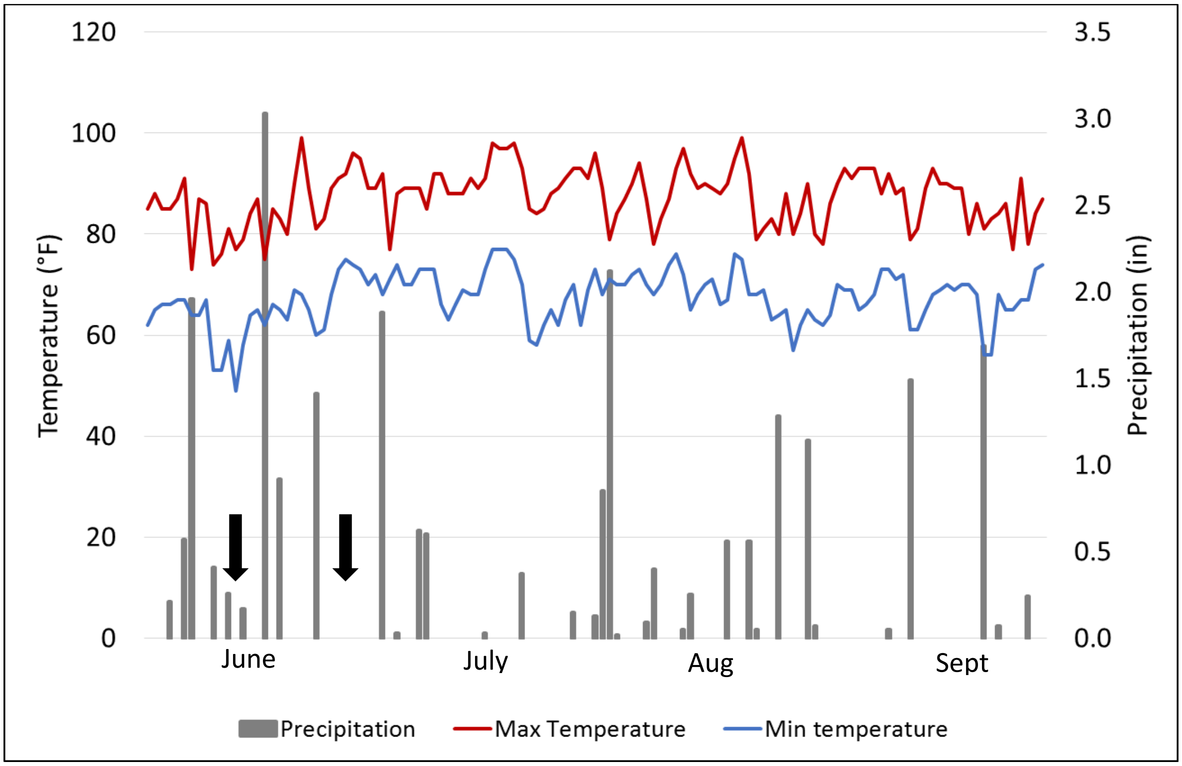

Fig 6. Daily high & low temperatures and precipitation at K-State John C. Pair Horticultural Center during the industrial hemp (*Cannabis* sativa) growing season of 2019. Planting dates are indicated by arrows. Data was obtained from the Kansas State University Mesonet weather station located on-site (mesonet.k-state.edu).