

Fertilizer Research and Education Program  
**Final Report**

## A. Project Information

Project Title: Nitrogen Response of Industrial Hemp Cultivars Grown for CBD, Essential Oils, and Fiber (\*approved change in 3rd year to include cultivars grown for fiber)

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Kayagene Corp., Woodland, CA (Dr.  
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Cultivaris Corp., Encinitas, CA (Dr. Josh  
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Phylos Biosciences (Dr. John  
McFerson) – planting seed

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Beacon Hemp, Petaluma, CA (Dr. Nick  
Stromberg) – planting seed  
Alkemist Laboratories, Garden Grove,  
CA (Dr. Bryan Fine) - provided all  
chemotyping

## **B. Abstract**

Field trials were conducted in 2021 to 2025 at University of CA West Side REC (WSREC) in Fresno County in a Panoche clay loam soil, and in 2021 and 2022 at UC Davis Campus Farm (UCD) in Yolo County (Yolo fine sandy loam soil). The 2021-2022 projects focused on fertilizer nitrogen (N) rate responses for two biotypes of industrial hemp grown for essential oils (autoflower/shorter season types, and full-season photoperiod-sensitive types). These types of cultivars are typically grown for essential oils such as cannabidiol (CBD) and related compounds, are typically smaller than cultivars chosen for fiber production in our latitude in central CA, and are planted at low densities. Low planting densities are used for multiple reasons, but primarily due to high costs for seed or transplants. Primary goals were to: (1) evaluate for two biotypes of CBD-type industrial hemp (autoflower/short-season types, full-season photoperiod-sensitive types) the impacts of N application amount and variety/growth habit/plant type on N uptake and yield responses; and (2) assess impacts of N applications on THC and CBD tissue content in regulatory monitored cola portions of the plants.

During 2023 to 2025, field trials solely on fiber-type industrial hemp varieties were conducted at University of CA West Side REC (WSREC). The focus shifted to evaluation of fertilizer nitrogen (N) rate responses of limited cultivars of hemp grown for fiber materials. Grower contacts and researcher contacts at Oregon State University all expressed expanding interest in more research on hemp for fiber and building construction-type materials. The Chinese-origin fiber hemp cultivars we studied were photoperiod-responsive plants that initiate reproductive development in mid-to late-summer (late July/early August), such that growing season length (and to some extent plant size/yields) are dependent upon planting date as well as harvest timing. Goals of fiber hemp studies were: (1) evaluate for large biomass fiber-type industrial hemp (tall, late maturing cultivars) the impacts of N application amount and growth habit on biomass yield responses and plant N uptake; and (2) assess impacts of N management approach on THC tissue content if harvested when developing colas are present.

## **C. Introduction**

Cannabinoid Type Studies and Background. While there is significant experience with growing low-THC hemp cultivars in multiple parts of North America, including Canada and in multiple U.S. states (OR, CO, NC, NY, KY, IN, VT, others), up until the past 7+ years most of this experience has been with cultivars grown more for biomass, fiber and grain rather than with cultivars targeted for production of CBD and related compounds, with research in CA particularly limited. Early in development of CA industrial hemp production it's hard to guess the eventual focus of economically-viable harvestable products. Early market interest focused on production of CBD and similar compounds so this study was initiated to develop an improved understanding of: (1) nitrogen fertilizer needs for optimal yield production of flowers and likely harvested materials for

these cannabinoid compounds; and (2) the positive or negative impacts of plant N status on CBD and THC concentrations in harvested plant tissue. If management practices such as N fertilization or irrigation management can markedly impact THC content of tissues, this is of interest since levels >0.3% aren't allowable in fields to be harvested. Due to high potential value of crops and cost of planting materials (seeds or transplants) for cannabinoid types, drip irrigation was assumed to be the likely irrigation / fertigation method to be used by CA growers of CBD types of hemp.

The N fertilizer application ranges we selected for the first two years with cannabinoid types represented values within which we expected to observe crop responses ranging from at least borderline deficient to high (potentially excess) N fertilizer applications. Our experiences to date with photoperiod-insensitive autoflower (AF) biotype hemp grown in prior studies has been that the autoflower cultivars are much smaller plants with much shorter times to harvest maturity (perhaps 70-85+ days after emergence) than typical of the larger, photoperiod-sensitive (PPS) biotypes (where 100-110+ days can be more typical for timing between transplanting or seeding and harvests). For this study we used higher density plantings and an earlier irrigation and fertilization termination date with the AF types to accommodate differences in harvest maturity timing. We chose not to evaluate differences in application timing or irrigation level in this experiment in order to improve our ability to interpret crop responses without potentially confounding the results with interactions due to N application timing or water stress effects.

Fiber Type Cultivar Studies – 2023-2025. For these studies we added the objective of assessing basic nitrogen response studies of longer-season, larger industrial hemp cultivars grown for fiber and construction materials. Even though our original FREP-supported project was designed only as a two-field year study (2021-2022) at two sites (West Side REC and UC Davis), our grower contacts and research contacts with Oregon State University all expressed expanding interest in more research on industrial hemp for fiber and building construction-type materials (rather than CBD and Essential Oils cultivars), so we: (a) requested extensions of the funding period for our FREP project to end in 2025 instead of 2023; and (b) add these fiber hemp field trials to evaluate growth responses to applied nitrogen and demonstrate impacts of variable planting dates on dry matter yields of some potentially long-season fiber hemp cultivars.

## **D. Objectives**

**Objective #1:** Evaluate for two biotypes of industrial CBD-type hemp the impacts of N application amount and variety/plant type on N uptake, removal, and cola yields.

**Objective #:** (2) Assess impacts of N management approach on THC and CBD tissue content, including partitioning to harvested portions of plants.

**Objective # 3:** When information is developed in the study, provide information to appropriate grower groups, consultants and industry to give opportunities for feedback and to refine concepts of workable changes in N management approaches.

**Objective # 4:** Assess basic nitrogen growth and dry matter yield responses of longer-season, larger industrial hemp cultivars grown for fiber and construction materials.

## **E. Methods**

Field trials on Cannabinoid types of industrial hemp were conducted in Davis (UC Davis farm, Yolo fine silt loam) and Five Points (Univ. CA West Side REC, Panoche clay loam) in 2021 and 2022 in fields selected for low residual soil NO<sub>3</sub>-N following rotation with a deep-rooted summer and/or winter grass crop to utilize at least some residual NO<sub>3</sub>-N. Field trials with fiber type hemp were continued in 2023 through 2025 only at the UC West Side REC as a modification and extension of the original study.

Cannabinoid Type Studies – 2021-2022. At least two representative cultivars were chosen of each growth habit type: 1) full season, photoperiod sensitive (PPS), and 2) shorter-season photoperiod insensitive types/autoflower (AF) types. Seed company(s) assisted in identifying varieties targeted for CBD production potential, and also provided certificates of analysis to certify varieties bred for low THC content. We followed state and federal laws and University policy regarding reporting of hemp practices. Time from emergence to harvest differed between hemp types (about 70-85 days for AF cultivars, versus approximately 100-120 days for the PPS cultivar types. In 2021, seeds were provided by two seed companies (Phylos and Kayagene, for AF varieties N study), and transplants were provided by one company (Cultivaris, PPS varieties study). Full-season, PPS cultivars in 2021 were “Scarlett” and “The Wife”, while “Maverick” and “Alpha Nebula” were AF types. In 2022, due to multiple issues regarding seed and transplant availability, we direct-seeded plantings for both autoflower (Maverick, Alpha Nebula, Rincon cultivars) and full-season (Early Wu, Cookie Crush cultivars). Seed companies provided Certificates of Analysis for expected THC levels, and cultivars were selected based on expectations of acceptable, low cola THC content.

These decisions on management and nitrogen treatment differences used for AF versus PPS varieties were based upon experiences with similar cultivars in prior field trials conducted at UC West Side REC and UCD sites. Large differences observed between autoflower and full-season cultivars in agronomic characteristics include:

- branching (less branching in autoflower cultivars),
- duration of growth (much earlier initiation of flowering/colas in AF cultivars),
- size of plants and impact on planting density (autoflower cultivars smaller)
- autoflower varieties generally photoperiod-insensitive, while commercially available full-season/heavily branching types are photoperiod-sensitive

These characteristics resulted in different amounts of dry matter, duration of plant growth, and expectations of different needs for N and water with AF versus PPS cultivars. Plant densities were approximately 15,000-18,000 plants/ac for AF cultivars (typically smaller plants) and 4,000-5,500 plants/ac for larger, longer growing season PPS cultivars. Plots used were 25-30 feet in length and 3-4 beds of 60 inch width

(depending on field site conditions), with two planted rows per bed approximately 2.5 feet apart. Target plant spacings were 24-30 inch spacing down the row used for PPS cultivars, and approximately 9-12 inch plant spacing down rows for AF cultivars.

We provided soil moisture for establishment of transplants or seeds using surface line sprinklers (at WSREC) or surface drip (at UCD) for the first 2-3 inches of irrigation water, and then transitioned to subsurface drip irrigation (SDI) for in-season irrigations. Sprinklers at WSREC or surface drip tape (at UCD) were removed after about 12-14 days of use at both sites. Subsurface drip irrigation tape was installed at a depth of 8-10 inches pre-plant, with two drip tape lines per bed, 30 inches apart. A crop coefficient curve we have developed which hits a maximum of 0.65 was used with CIMIS weather station ETo data to determine irrigation amounts for AF cultivars, while a different crop coefficient curve that reaches a maximum of 1.05 was used with PPS cultivars. Table 1 shows that growing season duration between planting and harvest is about 3-4 weeks longer for PPS types than AF cultivars, resulting in large differences in total applied water. Differences in planting dates were caused by timing of availability or lack of access to transplants in PPS types, and failure of first plantings of AF cultivars (both sites) due to variable planting depths, combined with extremely hot weather at emergence. The 2<sup>nd</sup> plantings of AF cultivars in 2021 were more successful. Direct-seeded plantings in 2022 were successful due to changes in types of planters used in combination with more favorable weather and irrigations following plantings.

Table 1. Planting dates and harvest dates for nitrogen rate trials at West Side REC (WSREC) and UC Davis (UCD) sites.

Site	Operation Done	Autoflower 2021 *	Autoflower 2022 *	Full-season 2021 **	Full-season 2022 *
WSREC	Planting*	7/21	5/25-5/26	6/22-23	6/27-6/28
	Harvest	9/22-9/30	8/17-8/22	9/17-9/22	10/16-10/19
UCD	Planting*	7/01	5/26	6/22	6/29
	Harvest	9/10-9/13	8/09-8/10	9/28-10/05	10/12-10/20

\*autoflower varieties were direct-seeded both years; full-season were direct seeded only in 2022

\*\* full season varieties were transplants in 2021.

Dosatron fertilizer injector units were used to inject UN-32 liquid fertilizer into drip manifolds on one day per week to establish each nitrogen treatment. Five fertilizer levels were used, with applied N for AF cultivar treatments ranging from 20-30 lbs N/acre to about 120 lbs N/acre versus 20 to about 200 lbs N/ac in PPS cultivars. Exact application amounts are shown in tables with cola yield data. Fertilizer N application timing and relative amounts for AF cultivars are shown in Table 2, while Table 3 shows application amounts for PPS cultivars. Note the higher range of N applications used for larger, longer growing season PPS cultivars. The approach used for UN-32 injected fertilizer applications was to distribute applications starting just prior to rapid vegetative growth and ending about 2-3 weeks prior to expected harvests.

Table 2. Nitrogen fertilizer treatments used for Autoflower (AF) varieties at UC Davis site (UCD) and UC ANR West Side REC (WSREC).

Trial Location	Trial year	N applied Pre-plant dry fertilizer lbs N/ac	N applied at planting lbs N/ac	Growing Season Nitrogen Applications (liquid UN-32) Using Drip Injection (lbs N/acre)				
				Trt 1	Trt 2	Trt 3	Trt 4	Trt 5
UCD	2021	10*	25*	0	15	50	75	110
	2022	27	0	0	30	60	90	120
WSREC	2021	10*	0	0	30	60	90	120
	2022	0	0	0	30	60	90	120

\* applied as 11-52-0 dry fertilizer

Table 3. Nitrogen fertilizer treatments used for Full-Season (PPS) varieties at UC Davis farm site (UCD) and UC West Side REC (WSREC) site.

Trial Location	Trial year	N applied Pre-plant dry fertilizer lbs N/ac	N applied at planting lbs N/ac	Growing Season Nitrogen Applications (liquid UN-32) Using Drip Injection (lbs N/acre)				
				Trt 1	Trt 2	Trt 3	Trt 4	Trt 5
UCD	2021	11*	25*	0	45	85	135	170
	2022	27	0	0	50	100	150	200
WSREC	2021	11*	0	12	55	110	165	220
	2022	0	0	0	50	100	150	200

\* applied as 11-52-0 dry fertilizer

Fiber Type Studies – 2023-2025. Field studies on industrial hemp fiber types were conducted only at the University of CA WSREC (same soil type and area described above). We grew multiple China-origin cultivars we had experience with in prior small field studies with a central San Joaquin Valley grower. In 2023, cultivars grown were “Han NE”, “Yuma” and “Si-1” (Hemp Traders, Los Angeles, CA), all long-season, high biomass production, photoperiod-sensitive types that start the shift to reproductive growth when daylength falls below about 14 hours (late July at latitude of study location). Cultivars grown in 2024 studies included “Han NE” and “Han J6” (a slightly earlier maturing cultivar, Hemp Traders, Los Angeles, CA); plus “NWG 2463” (a shorter, earlier maturing cultivar from a U.S. company, New West Genetics, Fort Collins, CO). “Han NE” and “HanJ6” were grown in 2025 studies. Since these fiber hemp crops are: (1) sensitive to hard freezing conditions; and (2) respond strongly to shortening daylength for the trigger to reproductive development, it is important to note that the duration of growth and eventual size/yield of these cultivars can be greatly influenced by the planting date (ie. earlier planting dates in spring produce longer period of vegetative growth, larger plants, with potentially more water and nutrient use). Most existing literature on fiber hemp production suggests that for best fiber quality and yields, harvests should be done starting during early flower development. However, for a range of reasons (mostly lack of staff, harvest equipment), our harvests in fiber hemp studies were typically done about 2-3 weeks or more after initiation of flowering.

In 2023, for an initial evaluation of impacts of planting date on fiber hemp biomass production and plant heights, we planted Han NE, Si-1, and Yuma cultivars in April, May, July and August. Eighty-inch beds with 6 rows 12 inches apart per bed were direct seeded. For this study, we used only one nitrogen application rate per planting date. Pre-plant 11-52-0 fertilizer was applied at 100 lbs/acre due to relatively low surface soil P levels. Applied N totals for 2023 fiber hemp are shown in Table 4 (Appendix), and in 2023 studies, all N fertilizer applications were made using granular urea incorporated just prior to planting. Plants were sprinkler irrigated for establishment, and flood irrigated the remainder of the season (only in 2023 studies). In 2023, we also conducted a planting date study (four planting dates, April through August) at one nitrogen fertilizer application rate per planting date. Seed planting densities of about 340,000, 340,000, 132,000 and 147,000 plants per acre for the different planting dates, with lower plant populations in July and August plantings required due to hand planting (versus machine planted earlier dates) as well as limited seed. Applied nitrogen totals for different planting dates were adjusted based on expected differences in plant growth with different season lengths, resulting in applications of 170, 165, 110 and 60 lbs N/acre in April, May, July and August plantings, respectively.

2024 and 2025 studies: For 2024 and 2025 field studies, we again grew “Han NE”, and added another moderately earlier maturing China-origin cultivar “Han J6”, since we had some experience with it performing well in variety studies in 2023. In 2024 a US-origin cultivar from New West Genetics (Fort Collins, CO) named “NWG 2463” was added. It is more photoperiod responsive, resulting in mid- to late-July initiation of colas at planting dates used, resulting in earlier maturity for fiber harvest than Han NE or Han J6. Pre-plant soil residual nitrate-N in the upper 3 feet soil profile were low, averaging less than 20 lbs NO<sub>3</sub>-N/ac in 2024 and about 42 lbs NO<sub>3</sub>-N/ac in 2025. Pre-plant 11-52-0 was applied at 100 lbs/acre each year due to relatively low surface soil P. Eighty-inch beds with 6 rows 12 inches apart were direct seeded. Two subsurface drip lines about 35 inches apart and 10 inches deep were installed per bed. N fertilizer applications were made using liquid urea injected into drip manifolds using Dosatron. Irrigation amounts were determined using CIMIS Weather Station ETc data from WSREC in combination with a crop coefficient for fiber hemp developed previously. For 2024 and 2025 field studies, applied fertilizer N by treatment are shown in biomass dry matter yield tables.

## **F. Data/Results**

CBD/Cannabinoid Hemp Cultivars Nitrogen Trials: Soil nitrate-N levels at the beginning of the growing season were relatively low at both field test sites in late spring, 2021 (Appendix - Table 5). The AF cultivars began first cola (flower buds) development generally about 3-4 weeks earlier than PPS types at planting dates used. For purposes of running nitrogen fertilizer response trials, we adjusted irrigation water application amounts to reflect the difference in plant size and canopy cover between smaller AF versus PPS cultivars, resulting in about 50-plus percent lower water applications for AF cultivars due to reduced irrigation water amount per week (lower crop coefficient) and

shorter growth duration. Cola harvests for CBD type cultivars were initiated when colas were about mid-bloom in September and October 2021, AF cultivar 2022 harvests were in August, and 2022 PPS cultivar harvests were in October.

In 2021, cola yields in AF cultivars were more responsive to increasing N application at WSREC than at UCD site (Table 6), with large increases in cola yields at WSREC going from T1 to T3 level of N application (about 60 lbs N/acre). There was less response with increasing N beyond the 60 or 90 lbs N/acre rate. There was little or no response to applied N rates with AF cultivars at UCD site with Alpha Nebula cultivar, but a slight apparent increase at T3 (60 lbs N/acre) rate when compared to lower rates (Table 6). Similar patterns were seen in 2022 cola yield responses to applied N at WSREC, with all cultivar cola yields increasing up through the middle N treatment (Table 7). Plant height and # of secondary branch data at WSREC showed patterns similar to cola yields (Appendix, Tables 10, 11). Cola yields (Table 7) and plant height (Appendix, Table 12) for AF cultivars at UCD site showed little response to applied N with either cultivar. Unfortunately, at the UCD site, we did not collect adequate soil samples at pre-plant and post harvest timings for further analysis of potential reasons for the lack of N responses. We did not have soil water data that could verify that irrigation applications did not result in nitrogen leaching at the UCD site, or soil nitrate levels at depths greater than 3 feet to assess deeper soil N availability as a reason for lack of response to applied N levels at this site with AF cultivars. Significant leaching losses were unlikely at UCD site due to use of drip irrigation at levels based on weather station Eto data.

In full-season (PPS) cultivars in 2021 (Table 8), at both sites and with both cultivars there was a cola yield response to increasing applied N fertilizer from the T1 to T3 level of applications (more consistent across sites than observed with AF types), with a more variable yield response to increases in applied N in T4 and T5 treatments. The response to increasing levels of applied N tended to be greater with PPS cultivar “The Wife” than with cultivar “Scarlett” at both sites. 2021 plants were grown from transplants provided by the company Cultivaris Hemp, while 2022 plants were grown from direct seed planting of different cultivars. The direct-seeded plants with earlier planting date generally exhibited longer periods of growth and larger plants than with 2021 transplants. In 2022, plants at the WSREC had significant increases in cola yields up to T3 (100 lbs) and T4 (150 lbs) range of N applications (Table 9). In most cases, cola yields did not increase with increases in fertilizer beyond 110 lbs N/acre rate (2021) or 100 lbs N/acre rate (2022), but in 2022 the cultivar “Cookie Crush” at 200 lbs N/acre had a significantly higher cola yield than at the 100 lbs/acre rate. Secondary branch number and height at harvest data demonstrated treatment responses similar to the cola yields (Appendix, Tables 11, 13) at the WSREC site. In 2022, cola yields of PPS cultivars at the UCD site (Table 9) and plant height (Appendix, Table 13) showed no consistent response to applied N with either cultivar. As with the AF cultivar responses at UCD in 2022, we did not collect adequate soil samples to evaluate soil water uptake data and soil nitrate levels in deeper parts of the soil profile to assess potential reasons for lack of significant crop responses to applied

N at UCD site. Crop above-ground total biomass data (not shown) generally continued to increase with increasing applied N up through the T4 and T5 N application levels. However, in both T4 and T5 treatment levels in PPS cultivars, many of the additional branches had small colas at the end of branches and axillary colas that were not fully-developed at harvest time. Since these late-developing colas were small and immature at harvest time, they were not included in the field cola harvest since they would not be at a marketable stage for essential oils.

Table 6. Cola (flower bud) yields (in lbs/acre) as a function of applied nitrogen treatments for AF cultivars in 2021 at UCD and WSREC sites. Mean separation analyses were conducted for each site and cultivar type, different letters indicating differences at the 5% level.

Trial Site	Cultivar name	Cola yields (all colas larger than 3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
UCD		<b>T1 (0 lbs/ac)</b>	<b>T2 (15lbs/ac)</b>	<b>T3 (50 lbs/ac)</b>	<b>T4 (75 lbs/ac)</b>	<b>T5 (110 lbs/ac)</b>
	Maverick	1399 b	1395 b	1595 a	1561 a	1507 ab
	Alpha Neb.	1166 a	1144 a	1099 ab	954 b	1137 a
WSREC		<b>T1 (0 lbs/ac)</b>	<b>T2 (30lbs/ac)</b>	<b>T3 (60 lbs/ac)</b>	<b>T4 (90 lbs/ac)</b>	<b>T5 (120 lbs/ac)</b>
	Maverick	1676 b	1899 ab	2186 a	2344 a	2407 a
	Alpha Neb.	1532 b	1682 b	1971 ab	2126 a	2034 a

Table 7. Cola (flower bud) dry weight yields (in lbs/acre) as a function of applied nitrogen treatments for AF cultivars in 2022 at UCD and WSREC sites. Mean separation analyses were done by site and cultivar type, different letters indicating differences at 5% level.

Trial Site	Cultivar name	Cola yields (all colas larger than 3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
UCD		<b>T1 (0 lbs/ac)</b>	<b>T2 (30lbs/ac)</b>	<b>T3 (60 lbs/ac)</b>	<b>T4 (90 lbs/ac)</b>	<b>T5 (120 lbs/ac)</b>
	Rincon	1747 b	1778 b	1887 ab	1962 a	2001 a
	Alpha Nebula	1902 ab	1808 b	1992 a	1728 b	1855 ab
WSREC		<b>T1 (0 lbs/ac)</b>	<b>T2 (30lbs/ac)</b>	<b>T3 (60 lbs/ac)</b>	<b>T4 (90 lbs/ac)</b>	<b>T5 (120 lbs/ac)</b>
	Maverick	1007 c	1528 b	1828 ab	1976 a	2102 a
	Rincon	913 c	1205 b	1663 a	1704 a	1675 a
	Alpha Nebula	937 c	1364 b	1629 ab	1645 a	1699 a

Nitrogen Uptake. Increases in cola nitrogen content (lbs N/ac) with increasing N at WSREC site in AF and PPS type cultivars reflected both increases in cola dry weights through T3/T4 levels, and increases in cola N% with increasing N. In both PPS and AF cultivars in the West Side REC site shown in Table 14, leaf+stem and cola nitrogen content increased significantly up through the T3 nitrogen application levels. In the PPS cultivar “Cookie Crush” and AF cultivar “Maverick” a continued increase in cola and leaf N concentrations resulted in increases in total plant N content at T4 and T5 levels, although cola yield levels peaked at the T3 level, indicating some potential for excess N uptake unrelated to cola yields.

Table 8. 2021 Cola (flower bud) yields (in lbs/acre) as a function of applied nitrogen treatments for PPS cultivars in 2021 at UCD and WSREC sites. Mean separation analyses were done by site and cultivar type, different letters indicating differences at the 5% level.

Trial Site	Cultivar name	Cola yields (all colas larger than 3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
UCD		T1 (0 lbs/ac)	T2 (45 lbs/ac)	T3 (85 lbs/ac)	T4 (135 lbs/ac)	T5 (170 lbs/ac)
	The Wife	975 c	1192 b	1469 ab	1818 a	1896 a
	Scarlett	1536 b	2102 a	2018 a	2104 a	2142 a
WSREC		T1 (12 lbs/ac)	T2 (55 lbs/ac)	T3 (110lbs/ac)	T4 (165 lbs/ac)	T5 (220 lbs/ac)
	The Wife	885 c	1230 b	1589 ab	1812 a	1762 a
	Scarlett	712 b	860 b	1075 ab	1179 a	1269 a

Table 9. 2022 Cola (flower bud) yields (in lbs/acre) as a function of applied nitrogen treatments for PPS cultivars in 2022 at UCD and WSREC sites. Mean separation analyses were done by site and cultivar type, different letters indicating differences at 5% level.

Trial Site	Cultivar name	Cola yields (all colas larger than 3" length on main stem and branches) (lbs/acre)				
		Within growing season N application level				
UCD		T1 (0 lbs/ac)	T2 (50 lbs/ac)	T3 (100 lbs/ac)	T4 (150 lbs/ac)	T5 (200 lbs/ac)
	Cookie Crush	1698 bc	1576 c	1846 ab	1990 a	1542 c
	Early Wu	1919 b	2003 b	2610 a	2536 a	1984 b
WSREC		T1 (0 lbs/ac)	T2 (50 lbs/ac)	T3 (100 lbs/ac)	T4 (150 lbs/ac)	T5 (200 lbs/ac)
	Cookie Crush	1426 c	2013 b	2365 b	2448 ab	2929 a
	Early Wu	1456 c	1823 b	2208 ab	2246 a	2451 a

In terms of N levels that are removed with harvests of CBD-type hemp, it should be noted that most harvest methods (hand harvest or plant “topping”) would remove colas but leave most (estimate 75%) of the leaf plus stems in the field at harvest for recycling into soil. At the cola yield levels of about 1000 to 2000 lbs/acre in AF cultivars in 2022, cola nitrogen content ranged from about 30 lbs N/acre in lowest yield treatments to about 70-80 lbs N/acre in mid to higher N treatments where yields peaked. For comparison, with cola yields ranging from about 1400 to 2900 lbs/acre in PPS cultivars in 2022, cola N content ranged from close to 50 lbs N/acre in lowest yield treatments to about 80-100 lbs N/acre in mid to high N treatments where yields peaked.

Table 13. Average Nitrogen Content at harvest of partitioned plant parts (Leaf + Stem, all Colas) in lbs N/acre as a function of applied nitrogen treatments for AF and PPS cultivars in 2022 at WSREC site. Plants were direct-seeded.

Cultivar	Plant Part	Nitrogen Content at Harvest (lbs N / acre)				
		Within growing season N application level				
PPS Types		T1 (0 lbs/ac)	T2 (55 lbs/ac)	T3 (110 lbs/ac)	T4 (165 lbs/ac)	T5 (210 lbs/ac)
Early Wu	Leaf + Stem	41 b	58 b	97 a	119 a	113 a
	All Colas	46 c	64 bc	77 ab	84 a	96 a
Cookie Crush	Leaf + Stem	55 c	88 b	106 a	126 a	135 a
	All Colas	46 c	67 b	77 ab	80 ab	98 a
AF Types		T1 (0 lbs/ac)	T2 (30 lbs/ac)	T3 (60 lbs/ac)	T4 (90 lbs/ac)	T5 (120 lbs/ac)
Maverick	Leaf + Stem	19 c	29 c	47 b	65 a	57 ab
	All Colas	34 c	49 c	71 a	76 a	87 a
Rincon	Leaf + Stem	19 b	25 b	44 a	44 a	51 a
	All Colas	30 b	41 b	63 a	64 a	72 a
Alpha Neb	Leaf + Stem	19 c	34 b	54 a	56 a	57 a
	All Colas	29 c	47 b	66 a	65 a	69 a

Soil Nitrate Data – Pre-Plant versus Post Harvest. Limited data showing changes in soil nitrate occurring in AF and PPS plots in 2022 at WSREC site (Appendix, Table 14) in general showed that at low N treatment levels, there was more of a net reduction in soil residual NO<sub>3</sub>-N during the growing season, indicating that the lowest application treatments did not supply adequate N for higher yields. Conversely, the N application treatments that generally exceeded levels where yields peaked (>60 lbs N/ac in AF, >100 lbs N/ac in PPS plots) tended to show net increases in soil residual NO<sub>3</sub>-N during the season. While not an extensive data set, these net reductions or net accumulations tend to match what might be expected based on yield responses to applied N.

Cannabinoid (THC/CBD) Analyses – AF and PPS cultivars. Examples of data from the analyses of hemp cola samples for THC and CBD are shown (APPENDIX - Figures 1 and 2). Data from both full-season cultivars in 2022 at West Side REC are shown in Figure 1, while Figure 2 shows data for the AF cultivar “Alpha Nebula” at the UCD site in 2022. These figures demonstrate our general findings that there was no clear relationship or trend in response of THC or CBD levels to applied nitrogen rates, but some consistent issues with high THC “outliers” that showed up with several of the CBD-type cultivars, particularly when planted from seed instead of clones/transplants. This issue with the relatively small number of high-test THC samples in both AF and PPS cultivars planted from seed appeared to be quite random, suggesting that it was associated with mixed plant genetics in the populations making up the seed of cultivars.

One of the “quirks” of regulatory sampling required to assess cola THC compliance is that only the upper portion of main stem (including primary cola at stem end) is collected for THC analysis, regardless of the fact that other colas that develop somewhat later than the primary cola could be included in a cola harvest. Secondary colas are mainly later-developing colas that can be less-mature in terms of floral development compared with primary colas at sampling time. If the THC levels in these secondary colas were lower than in the primary colas, that would essentially reduce the average THC

concentrations of harvested colas. For the cola THC analyses presented in Figures 1 and 2 (in Appendix), we followed the regulatory “rules” and tested only primary colas. Limited analyses of secondary branch cola THC levels from harvest samples have indicated 20-30% lower THC levels in branch-end secondary colas. In our analyses, THC (and CBD) concentrations of cultivars (whether high, low, or intermediate) were largely controlled at the genetic level as a cultivar-specific trait. Some limited sampling also showed that THC concentrations measured for primary colas also increase from vegetative through flowering into early seed set (data not shown). We are not aware of studies that clearly define the rate of change in THC as the flowers mature for similar cultivars, but if that information becomes available from other studies, that would be valuable for grower decision-making. For some of these cultivars that can become marginal for allowable THC levels from a regulatory status, there would be a need to monitor cola THC at least weekly during the final several weeks pre-harvest to determine harvest timing that maintains colas below 0.3% THC.

Fiber Type Hemp Trials: Due to page limits on this report, results and discussion of 2023 to 2025 fiber hemp nitrogen response trials (authorized by CDFA-FREP as an extension of original project) were moved to the APPENDIX section. Field trials with long-season fiber hemp types at West Side REC were initiated in 2023 and continued through 2025 due to grower interest expressed to us in the San Joaquin Valley region for production-related issues with fiber hemp (as opposed to cannabinoid hemp).

## **G. Discussion and Conclusions**

Since the research conducted in this project included short-season autoflower CBD cultivars and photoperiod sensitive full season CBD cultivars grown for cola harvests, and long-season fiber hemp cultivars grown for stem fiber production, the range of nitrogen levels required to reach peak yields varied widely as might be expected. For the CBD type hemp, the discussion already included in the data/results (section F) of this report provides details on key findings and issues with interpreting the data. Discussion points and details for fiber hemp studies are found in the fiber hemp section (which had to be included in the APPENDIX section). Section M of this report (Factsheet) provides conclusions reached that summarize key points from both the CBD cultivar and fiber cultivar studies.

## **H. Challenges**

1. The volatility of the industrial hemp market and industry often made it difficult to get access to seed or transplants in back-to-back years to maintain continuity with trials. In 2021 field trials, full-season cultivars were provided as transplants (cultivars “The Wife” and “Scarlett”, Cultivaris Company), planted at a low density. In 2022, we were not able to locate a company able to produce transplants of the varieties utilized in the 2021 field

trials due to restructuring and down-sizing of companies. We had to rely on finding other cooperating companies for full-season varieties for 2022, and were only able to find companies with seed for direct field seeding instead of transplants. Access to planting seed was also difficult in 2022.

2. Difficulties with acquiring hemp transplants for 2022 field trials (associated with company restructuring, market issues). Had to change project to utilize direct seeding for establishing full-season cultivars for 2022 trials (instead of transplants used in 2021). Some similar difficulties with getting seed for 2023 field studies on fiber-type hemp. We had to purchase all seed used since no donated seed was available to us.

3. Weed problems and lack of registered herbicides and phytotoxicity information for unregistered materials. Other than Sonalan as a pre-plant herbicide, there are no registered pre-emergence or post-emergence herbicides for weed control in industrial hemp. This greatly adds to hand weeding labor costs in these trials.

4. First two years, difficulties in establishing plants (problems with plant emergence in the direct seeded cultivars). We changed planters used to have more control over seed planting depth, changed amount of seed used during planting (increased substantially), and used hand move sprinklers (WSREC) or surface drip (UCD) to establish crop.

5. Necessity to learn about pest management issues and potential for damage from specific pests (such as lepidoptera (worms of various types) and in 2024 and 2025, problems with stinkbugs damage to developing seed colas. This can be a serious issue when flower buds or seed are the harvestable economic product, but most plots in the earlier CBD studies (in 2021-2022) were not seriously affected. Since fiber types are harvested for stem fiber prior to seed set, damage from such pests was minimal.

## I. Project Impacts

This project provides improved information for growers and consultants on the nitrogen fertilizer needs and yield responses of a wide range of different types/growth habits of industrial hemp of potential interest to California growers. Field studies with autoflower versus full-season cannabinoid types of industrial hemp showed that peak cola yields in the Central Valley of CA were attained with 50-70 lbs N fertilizer per acre in autoflower hemp cultivars (yielding about 1800-2000 lbs colas/acre, harvested at about 80 days post planting), and with 100-140 lbs N/acre in full-season cannabinoid hemp cultivars (yielding 2000-2500 lbs colas/acre, harvested about 120-130 days after planting). Multi-season evaluations done with long-season, high-yield fiber types of industrial hemp in the San Joaquin Valley of CA demonstrated that under conditions with low to moderate residual soil nitrogen at planting, peak stem fiber biomass could generally be achieved with about 150 lbs N fertilizer per acre with dry matter yields in the 6 to 10 tons/acre range. Although some variety-specific issues with THC levels higher than regulatory limits were noted in the studies, nitrogen fertilizer applications ranging from deficient to excess did not exert a significant influence on THC or CBD levels in cola samples required for THC compliance

testing. More specific details regarding potential impacts of project findings can be found in section “M” of this report.

## J. Outreach Activities Summary

Event Type	SAS Quarterly Western U.S. Hemp Extension Meetings		
Presentation title	Updates on hemp research in California		
Location and date	Web-based zoom meeting / coordinated by Gordon Jones of Oregon State University (we are CA UCD representatives to the meeting) – <u>monthly meeting</u> held generally on 4 <sup>th</sup> Wednesday of month (July and December meetings were not held)		
Attendee demographics (CCAs, PCAs, growers, consultants, researchers)	Largely University and affiliated researchers, but also includes industry representatives and others on the research and industry list who request access		
CCA/Grower Continuing Education Units (CEUs) offered	No credit hours	Number of participants	Typically, 12 to 15 participants each time, including CA, OR, WA, NV reps
Event Type	World Agricultural Expo – Tulare California		
Presentation title	UC Irrigation and Nitrogen Management Studies: General Comments for CBD Type Industrial Hemp Growers		
Location and date	February 2023, February 2024 – Tulare Farm Show		
Attendee demographics	Seed company and grower representatives interested in industrial hemp, plus World Ag Expo attendees interested in industrial hemp		
CCA/Grower Continuing Education Units (CEUs)	No credit hours offered.	Number of participants	Estimated 25
Event Type	Field Meetings with Local Fiber Hemp Industry Reps / Growers - Updates Field Research: Fiber Hemp Planting Date, Irrigation, Fertilization (Bob Hutmacher)		
Presentation Title	Review of Varieties, planting date responses, irrigation and fertilization for long season fiber hemp – updates multiple times		
Location and date	West Side REC (University of California) Multiple dates in 2022-2023-2024: generally, April or May (one mtg), July (1 meeting), August-early September (2 mts/year)		
Attendee demographics	Industry growers, seed company rep, fiber and construction materials interested parties		
CCA / Grower Units	None		

Number of Participants	Varied by date (from as low as 3 to as many as 6 each time). Small group meetings in field to observe, answer questions, demonstrate planting date effects, variety observations.
Event Type	Sacramento Meeting – March 2025 Advancing Cannabis Research in a Changing Landscape: 2025 California Cannabis Research Workshop
Presentation Title	Review of “University of CA ANR and UC Davis field research on agronomics industrial hemp in California. (Bob Hutmacher)
Location and date	Sacramento, California – March 25, 2025
Attendee demographics	Industry growers, seed company rep, fiber and construction materials interests
CCA / Grower Units	None
Number of Participants	Diverse group representing researchers and regulatory agencies working with Cannabis in medicinal, recreational and industrial hemp applications. Provide updates on both Univ CA and Oregon State agronomic crops hemp research.
Event Type	Hemp Textile Workshop – Oregon State Univ., Corvallis Oregon
Presentation Title	Participate in industry review of stakeholders interested in fiber hemp research and interface with industry needs and applications. (Bob Hutmacher)
Location and date	Corvallis, Oregon – March 26-27, 2025,
Attendee demographics	Industry representatives from multiple areas of the fiber and construction materials industrial hemp industry, company reps, fiber and construction materials interests, University, some USDA and some private industry researchers
CCA / Grower Units	None
Number of Participants	Diverse groups representing researchers, company reps involved in fiber industrial hemp applications and industries (fabric, non-wovens, insulation, building products, etc.) Asked by Oregon State University partners to provide research updates and hear about needs from producers and end users.
Event Type	Agronomic Crops Field Day Hemp Presentation (Bob Hutmacher)
Presentation Title	Variety performance, Fertilization practices for CBD versus Long season fiber hemp cultivars
Location and date	Univ. CA Kearney REC (University of California) September 18, 2025,
Attendee demographics	Industry growers, seed company reps, fiber and construction materials interests, other researchers
CCA / Grower Units	Yes
Number of Participants	Field meetings and conference meetings – about 80-90 participants

## L. Appendix

**Fiber Hemp Nitrogen Field Trials - 2023 to 2025.** As we have learned with full-season hemp types grown for cannabinoids, there is great diversity in total yield/biomass potential in hemp fiber cultivars that is based in part on cultivar traits, and particularly in terms of photoperiod-response. Commercial fiber hemp cultivars cover a broad range of photoperiod-responses in terms of shortening day-lengths that “trigger” vegetative growth, and for this reason different cultivars need to be considered at different latitudes. For example, when some cultivars commonly grown in northern regions such as Montana or Canada are planted late-spring to mid-summer in the San Joaquin Valley, the vegetative growth period is shortened, with the plants shifting early on to reproductive growth, resulting in low biomass production. Plants more likely to grow vegetative for a longer period and produce higher biomass yields will have a different “trigger” in terms of photoperiod-response. As part of this study, we grew small plots (3 m of bed length) of 14 different commercial cultivars of fiber hemp, and noted that when planted in mid-April or late-May, all cultivars more adapted for northern latitudes tended to produce plants shorter than 3 feet and developed colas that matured mid-summer. For commercial fiber production, those very early, reduced growth cultivars would not be acceptable for production in areas such as the San Joaquin Valley. For these reasons, in 2023 we focused on use of three China-origin commercial fiber hemp cultivars (“Han NE”, “Si-1” and “Yuma”), all being dioecious cultivars obtained through Hemp Traders (Paramount, CA). We had one-year of prior experience working with these cultivars at a grower field site, and knew that they had both high biomass yield potential and a later photoperiod-response “trigger” for the switch to reproductive development that occurred in late July-August.

**Please note:** Dry weight yield values from 2023 and 2024 shown in the Tables of this report are corrected from values shown in prior data reports due to mistakes made previously in the bed size/harvest area calculations and conversions to properly report dry weight data at a uniform 12.5% moisture content that was determined to be closer to desired moisture status for fiber hemp processing (our apologies for these errors).

The earlier planting dates in April or May in the San Joaquin Valley provide more time for extensive vegetative growth than the later planting dates, with concomitant differences in total crop water (data not shown) and likely large differences also in nutrient uptake (to be determined). For these cultivars, regardless of the planting date, the timing of the initiation of cola/flower development was very similar and dictated mostly by photoperiod response, such that the duration of growth between planting and flowering growth stage was controlled mostly by the planting date. It should be noted that we reduced the range of applied nitrogen for later plantings, since we expected much reduced biomass production. The range of plant heights in “Han NE” variety in the fully irrigated plants at the different planting dates measure at harvest timing in

October were 14-18 feet (April planting), 12 to 15 feet (late-May), 9 to 11 feet (mid-July), and 7 to 10 feet (Late-August).

Table 15. Industrial Hemp fresh weight and dry weight yields (harvest in October/early November) as a function of planting date treatments in three cultivars in 2023 at the UC West Side REC. Plant densities were 340,000 plts/ac in April and May plantings and averaged about 155,000 plts/ac for July planting date. Dry weight yields were adjusted to 12.5 % moisture content for comparisons.

Planting Date	Cultivar	Nitrogen Applied (lbs/ac)	Harvest - final		
			Moisture % at Harvest	Moisture after greenhouse drying (%)	Dry Weight (T/ac @ 12.5% moist)
April 6-10	Han NE	170	32.4	22	12.61 a
	Si-1	170	27.6	17	12.15 a
	Yuma	170	31.0	17	12.18 a
May 15-16	Han NE	165	37.5	19	8.94 b
	Si-1	165	33.5	20	7.89 b
	Yuma	165	36.6	19	9.20 b
July 18-19	Han NE	110	46.0	16	3.08 c
	Si-1	110	42.3	15	2.31 c
	Yuma	110	44.8	17	2.63 c
Aug 17-18	Han NE	60	52.7	18	2.16 c
	Yuma	60	51.3	16	2.07 c

Table 16. Fiber hemp dry weights at harvest for cultivars shown as a function of nitrogen rate and planting date in 2023 in a Panoche clay loam soil at the University of CA West Side REC. Differences in planting density for the July planting were due to the need for hand planting and limited seed availability for that late planting date. Dry weight yields were adjusted to 12.5 % moisture content for comparisons.

Planting Date	Cultivar	Planting Density (1000's/ac)	Dry Weight Yields (Tons/ac @ 12.5% moisture)			
			Nitrogen Treatment Levels			
			T1 110 lbs/ac	T2 170lbs/ac	T3 230lbs/ac	T4 300lbs/ac
April	Han NE	340	4.47 b*	9.98 a	10.44 a	11.08 a
	Yuma	340	4.51 bc	8.55 a	10.08 a	10.96 a
May	Han NE	340	5.10 b	9.39 a	10.60 a	<i>Treatment not included</i>
	Yuma	340	5.62 b	9.74 a	10.93 a	
<b>**note change in N levels for July</b>			N1 60 lbs/ac	N2 110 lbs/ac	N3 160 lbs/ac	
July	Han NE	155	3.16 b	5.38 a	4.99 a	<i>Treatment not included</i>
	Yuma	155	2.95 b	4.90 ab	5.70 a	

\*means within a row followed by different letters were significantly different at the  $p < 0.05$  level.

The field site used in 2023 at West Side REC had low soil nitrate-N (less than 30 lbs nitrate-N/acre) in the upper 3 feet of soil when measured prior to planting, and received 100 lbs 10-52-0 fertilizer prior to planting to raise soil P levels. The nitrogen response evaluations for April, May and July planting dates demonstrated significant, positive biomass responses to applied N up to 170 lbs applied N/acre for the April and May planting dates, and up to the 110 lbs N/acre rate for the July planting. These were all late-maturing fiber hemp cultivars that are relatively high yielding for the San Joaquin Valley latitude. Most cultivars that are more photoperiod responsive would have been mature for fiber harvest at an earlier date. Yield evaluations in 2023 were mostly finished during October, when male flowering had declined and colas formed on female plants, while harvests in 2024 started in October but extended well into November due to large number of plots and limited labor availability for hand harvests. Greatly reduced yields were evident with July and August plantings when compared with mid-April or late-May plantings in 2023, as expected with later planting dates. However, significant nitrogen response was observed at the N-2 application level (110 lbs/ac) even with July planting since the residual soil nitrate levels were low.

#### Fiber Type Hemp Trials – 2024

For the 2024 field studies, we continued studies with the China-origin cultivar “Han NE”, and added another slightly earlier maturing China-origin cultivar “Han J6”, since we had some experience with Han J6 performing well in small variety studies in 2023. We also added a US-origin cultivar from New West Genetics (Fort Collins, CO), a cultivar named “NWG 2463”. This cultivar is more photoperiod responsive at this latitude, such that it starts to initiate colas in late-July/early-August with early summer plantings, resulting in much earlier maturity for fiber harvest than in the China origin cultivars (Han NE, Han J6). Dry biomass yields (stem versus leaf+cola fractions) are shown in tables 17, 19 below. Pre-plant soil residual nitrate-N in the upper 3 feet of soil profile in the plot area was extremely low at this site in 2024, averaging slightly less than 20 lbs NO<sub>3</sub>-N/ac. Prior to planting, a granular fertilizer application of 100 lbs/acre of 10-52-0 fertilizer was made due to relatively low soil test phosphorus levels.

Table 17. Industrial hemp cultivar “HAN NE” dry weight yields at harvest (mid-November) of cola+leaf and stem fractions as function of planting date and applied N in 2024 at University of California West Side REC. Moisture percent at harvest are shown. Dry weight yields were adjusted to 12.5 % moisture content for comparisons. Plant populations averaged about 390,000, 440,000, 420,000 in late April, early June and late July planting dates, respectively.

Planting Date	Dry Wt (DW) or % moisture	Nitrogen Treatments – parameter measured is biomass dry weight (T/ac corrected to 12.5% moisture)									
		T1 0 lbs N/ac		T2 60 lbs N/ac		T3 (120 lbs N/ac)		T4 (180 lbs N/ac)		T5 (240 lbs N/ac)	
		Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem
Late April	DW	0.30 c	3.56 c**	0.40 b	6.26 B	0.69 Ab	8.81 a	0.74 ab	8.90 a	0.89 A	9.23 A
	Moisture	16.7	20.2	23.5	25.7	25.7	27.3	25.5	28.1	26.2	27.6
Early June	DW	0.20 c	3.14 c	0.38 b	5.46 B	0.66 A	7.22 a	0.59 a	7.33 a	0.70 a	7.93 a
	Moisture	16.5	17.6	24.1	26.8	24.8	29.2	25.8	29.8	26.9	28.3
Late July	DW	0.12 B	1.72 b	0.24 a	2.49 A	0.23 a	2.65 a	0.20 a	2.60 a	<i>*this treatment not used due to late planting</i>	
	Moisture	27.9	24.4	32.5	29.8	31.7	26.8	33.6	30.8		

\*\*means for the same parameter (DW leaf+colas vs. stem) followed by different letters were significantly different at the 5% ( $p \leq 0.05$ ) level.

Table 18. Average Nitrogen Content at harvest of partitioned plant parts (Stem, leaf plus Colas) in lbs N/acre as a function of applied nitrogen treatments for the late April, early June and late July planting dates for fiber-type cultivar HAN NE in 2024 at WSREC site.

Planting Date	Plant Part	Nitrogen Content at Harvest (lbs N / acre)				
		Within growing season N application level				
		T1 (0lbs/ac)	T2 (60 lbs/ac)	T3 (120 lbs/ac)	T4 (180 lbs/ac)	T5 (240 lbs/ac)
Late April	Leaves+Colas	10 c	15 c	29 b	34 b	42 a
	Stems	63 c	133 b	199 a	212 a	225 a
Early June	Leaves+Colas	6 b	14 b	30 a	28 a	32 a
	Stems	68 c	136 b	185 a	198 a	217 a
Late July	Leaves+Colas	4 b	12 a	12 a	11 a	<i>This treatment not used due to late planting</i>
	Stems	39 b	61 a	67 a	72 a	

Table 19. Industrial hemp cultivar “HAN J6” dry weight yields at harvest (early-mid November) of cola+leaf and stem fractions as a function of planting date and applied nitrogen in 2024 at the West Side REC, Fresno County, CA. Moisture percent of samples at harvest time are shown, but dry weight yields were corrected to uniform 12.5% moisture content for comparisons. Plant populations averaged approximately 430,000, 475,000 and 435,000 in the April 30, June 4 and July 30 planting dates, respectively.

Planting Date	Dry Wt (DW) or % moisture	Nitrogen Treatments – parameter measured is biomass dry weight (T/ac @ 12.5% moisture content)									
		T1 0 lbs N/ac		T2 60 lbs N/ac		T3 (120 lbs N/ac)		T4 (180 lbs N/ac)		T5 (240 lbs N/ac)	
		Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem
Late April	DW	0.35 b	3.39 c**	0.53 B	5.83 b	0.85 a	9.52 A	1.07 a	10.68 A	1.10 ***	10.49 ***
	Moisture %	19.0	17.8	21.9	24.1	23.0	23.6	23.2	24.5	24.4	25.8
Early June	DW	0.27 c	3.47 c	0.43 Bc	4.76 bc	0.66 a	7.26 A	0.84 a	8.21 A	0.91 ***	8.34 ***
	Moisture %	21.0	19.4	25.6	24.5	26.0	26.2	24.6	26.1	25.4	26.9
Late July	DW	0.24 b	1.94 b	0.32 Ab	2.72 a	0.38 a	2.71 a	0.34 a	2.65 A	<i>*this treatment not used at this late planting</i>	
	Moisture %	24.9	26.3	29.9	28.8	26.7	31.8	29.8	29.5		

*\*\*means for the same parameter (DW of leaf+colas versus stems) followed by different letters were significantly different at the 5% (p<0.05) level. \*\*\*there was only one (1) replication of the N-4 treatment level for this cultivar, so this N treatment could not be included in the statistical evaluation.*

Table 20. Average Nitrogen Content at harvest of partitioned plant parts (Stem, leaf plus Colas) in lbs N/acre as a function of applied nitrogen treatments for the late April, early June and late July planting dates for fiber-type cultivar HAN J6 in 2024 at WSREC site.

Planting Date	Plant Part	Nitrogen Content at Harvest (lbs N / acre)				
		Within growing season N application level				
		T1 (0lbs/ac)	T2 (60 lbs/ac)	T3 (120 lbs/ac)	T4 (180 lbs/ac)	T5 (240 lbs/ac)
Late April	Leaves+Colas	13 b	21 b	37 a	45 a	54 a
	Stems	49 c	119 b	181 a	198 a	207 a
Early June	Leaves+Colas	11 c	18 c	31 b	38 ab	44 a
	Stems	58 c	111 b	170 a	183 a	198 a
Late July	Leaves+Colas	8 b	12 ab	16 a	17 a	<i>This treatment not used due to late planting</i>
	Stems	44 b	64 a	78 a	75 a	

Table 21. Industrial hemp cultivar “NWG 2463” dry weight yields at harvest (late-September) of cola+leaf and stem fractions as a function of planting dates and applied nitrogen at West Side REC, Fresno County, CA. Moisture percent of samples at harvest time are shown, but dry weight yields were corrected to uniform 12.5% moisture content for comparisons. Plant populations averaged 610000 and 640000 in the June 4 and July 30 planting dates. Seed was not available at the time of the April 30 planting date used for other cultivars.

Planting Date	Dry Wt (DW) or % moisture	Nitrogen Treatments – parameter measured is biomass dry weight (Tons/acre @12.5% moisture)									
		T1 0 lbs N/ac		T2 60 lbs N/ac		T3 (120 lbsN/ac)		T4 (180 lbsN/ac)		T5 (240 lbs N/ac)	
		Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem
June 4	DW	0.32 b	2.30 b	0.51 A	3.58 ab	0.57 a	4.75 a	0.51 a	4.66 a	0.50 a	4.37 A
	Moisture	15.0	23.6	20.8	22.9	25.8	23.8	27.8	24.1	29.7	25.0
July 30	DW	0.12 b	1.64 b	0.27 a	2.48 a	0.24 a	2.53 a	0.21 ab	2.58 a	<i>*this treatment not used for late planting date</i>	
	Moisture	29.1	28.0	22.3	30.0	28.0	30.1	31.8	31.5		

\*\*means for the same parameter (FW, DW or moisture) followed by different letters were significantly different at the 5% ( $p \leq 0.05$ ) level.

The limited soil nitrate data collected prior to planting compared with post harvest does not cover all treatments and cultivar combinations to complete a soil nitrate balance, but it does point out a few key issues. In the 0 to 3 foot zone of the soil profile (Table \_\_\_\_)

In all the plantings, there was a net accumulation of NO<sub>3</sub>-N associated with the fertilizer applications, with increasing accumulations at the higher fertilizer application rates. This suggests application rates (perhaps in the late season when plants approach flowering and seed set) exceeded plant uptake, recognizing that the initial soil nitrate levels pre plant were very low. This might mean that fertilizer applications could have been discontinued earlier when leaves started to show senescence prior to flower bud formation. However, in the data for the 3 to 6 foot zone in the soil profile, in all but the 240 lbs N/acre treatments, we observed net NO<sub>3</sub>-N depletion in treatments evaluated, ranging from nearly negligible in the high N application treatments, generally increasing in amount in the lower N application treatments. This limited soil nitrate data does support the findings in the biomass yield data that with low to moderate soil nitrate-N at planting, fertilizer N applications of between 120 and 180 lbs N/acre will produce peak yields in long-season fiber hemp under the study conditions in the San Joaquin Valley.

Table 22. Pre-plant versus post planting soil NO<sub>3</sub>-N in two zones of the soil profile (0 to 3 feet, 3 to 6 feet) in industrial fiber hemp trial at the West Side REC (Panoche clay loam soil) in 2024. Values are shown as total NO<sub>3</sub>-N in these zones of the soil profile as a function of N application treatments.

Planting Date	Nitrogen Treatment	Soil NO <sub>3</sub> -N content (lbs NO <sub>3</sub> -N/ac in zone of profile)					
		0 to 3 foot depth			3 to 6 foot depth		
		Average Pre-plant	Average Post Harvest	Change	Average Pre-plant	Average Post Harvest	Change
Late April	T2 (60 lbs)	20	25	+ 5	55	39	-16
	T3 (120 lbs)	20	22	+ 2	55	31	-24
	T4 (180 lbs)	20	38	+18	55	43	-12
	T5 (240 lbs)	20	53	+33	55	48	-7
Early June	T3 (120 lbs)	27	35	+ 8	53	26	-27
	T5 (240 lbs)	27	66	+39	53	59	+6
Late July	T2 (60 lbs)	25	31	+ 6	49	41	- 8
	T3 (120 lbs)	25	66	+41	49	58	+ 9

While we did not have root measurements to determine crop rooting depth, the general reduction in soil water content from planting time to post harvest (data not shown) indicated significant soil water extraction (about 1.5 to 2 inches net depletion at harvest from pre-plant levels in the 0-3 foot zone), and an additional 2 to 3 inches in the 3-6 foot zone. This not only indicates that the hemp crop was capable of extracting soil water and nutrients such as N from relatively deep in the soil profile, but the general drying of the soil profile helps in our assertion that we were not over-watering the crop at least during the primary growing season, and therefore were less likely to leach applied nutrients beyond the root zone. This would suggest that the crop coefficient that we used (along with CIMIS station potential Eto) to estimate water application needs was relatively accurate in meeting but not exceeding crop water use in this study. However, we did not have any mid-season soil water content measurements to also assess soil water balance situations mid-season.

THC/CBD Analyses – 2023-2024. Due to the fact that the THC and CBD levels in the cultivars we utilized in the fiber hemp studies were generally very low compared with Cannabinoid/CBD types, we only did a limited number of analyses for THC and CBD as part of this study. According to the literature available on a broad range of cultivars considered for fiber production in the U.S., selections for commercial hemp varieties are generally made during variety development to avoid cultivars with any tendencies to exceed the 0.3% THC regulatory limit at the growth stage when colas start to form. Most THC in hemp plants is produced in structures associated with the colas (trichomes on bracts, sugar leaves, etc.), so THC levels in cola sections of the plants required for regulatory compliance monitoring for THC tend to significantly increase as plants go from fully vegetative growth to the stage where they initiate colas and flowering. Since the recommended timing for initiating harvest is at or just prior to the start of flowering, fiber hemp harvest practices help avoid timing when THC% exceedance could be an issue. CBD levels in the cultivars grown were similarly quite low, at <0.5%.

Since most of our harvests were several weeks later than recommended for optimal fiber quality, THC levels in colas at our harvest timing might be expected to be somewhat higher than if the harvests occurred earlier, prior to most cola development. The Han NE cultivar in our studies had THC values at harvest ranging from about 0.09% to 0.19% THC across all treatments and years of studies (well below the 0.3% limit), with no trend toward impacts of N fertilizer rates on THC levels. The Han J6 cultivar (when harvested relatively late in this study rather than late vegetative stage) exhibited more variability in THC levels, with average THC levels ranging from about 0.2 to 0.31%, but with replicate samples that sometimes exceeded 0.35%, which would be unacceptable, requiring crop destruct if a production field. Testing done with the Han NE and Han J6 cultivars done in late vegetative stage or when only male flowers had started blooming showed that THC levels were consistently in the acceptable range (<0.3% THC). We did not observe any trends of nitrogen fertilization rates impacting THC concentrations. THC levels appeared to be more controlled by cultivar genetic factors and by growth stage (increasing when cola structures higher in THC start to develop). In the first year of our fiber studies in 2023, we did observe some issues with other tested cultivars (Si-1 and Yuma), with both exhibiting more variability in THC levels than the Han NE or Han J6, and replicate samples from mid-bloom sampling that in some cases exceeded 0.4 to 0.5% THC (levels that would require crop destruct). Based on this limited sampling, our expectation would be that growers would need to make sure those varieties were harvested for fiber prior to the initiation of flowering in order to be more assured of compliance with THC regulations.

#### Fiber Type Hemp Trials – 2025

For the 2025 field studies, we continued studies with the China-origin cultivars “Han NE” and “Han J6”, but focused only on a mid-May planting date (May 14) at three different planting densities for this year. For 2025 study, applied N totals by treatment are shown in the yield results in table 6. Subsamples of plant parts were oven dried, so dry weights shown are corrected to 12.5% moisture content. Dry weight yield results (stem and leaf+cola fractions) are shown in table 23. For the 2025 field studies, pre-plant soil residual nitrate-N in the upper 3 feet of soil profile was moderately higher than the sites for the 2023 and 2024 studies, 2025, averaging 47 lbs NO<sub>3</sub>-N/ac in the Han NE rows and 54 lbs NO<sub>3</sub>-N/ac in the HanJ6 beds. Dry weight biomass yields in field plots in the 2025 planting year were about 75-80 percent of the yield levels achieved in the prior years at the earliest planting date in those years. The 2025 planting was mid-May, which was about a month later than in 2024, so that may have impacted duration of growth and also shifted early vegetative growth into a warmer weather time of year.

Table 23. Industrial hemp cultivars “HAN NE” and “HAN J6” dry weight yields at harvest (mid-November) of cola+leaf and stem fractions as function of applied N fertilizer treatments in 2025 at the University of California West Side REC, Fresno County, CA. Plant populations in the three density treatments averaged 195,000, 335,000, and 462,000 plants/acre in the low, medium and high planting densities in the Han NE planting, and were thinned in the smaller

HAN J6 plantings to about 155,000, 270,000 and 405,000 plants/acre in low, medium and high density treatments.

Cultivar	Planting Density (low, medium, high)	Nitrogen Treatments – parameter measured is biomass dry weight (T/ac @ 12.5% moisture content)									
		N0 0 lbs N/ac		N1 60 lbs N/ac		N2 (120 lbs N/ac)		N3 (180 lbs N/ac)		N4 (240 lbs N/ac)	
		Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem	Leaf +cola	Stem
Han NE	Low	0.26 D	3.31 c	0.45 c	5.23 b	0.61 b	7.01 a	0.69 ab	6.99 a	0.72 a	7.32 A
	Medium	0.26 C	3.92 c	0.45 b	5.65 b	0.67 a	7.28 a	0.71 a	7.56 a	0.69 a	7.94 A
	High	0.33 C	3.84 c	0.53 b	6.21 b	0.79 a	7.86 a	0.77 a	8.20 a	0.80 a	7.77 A
Han J6	Low	0.20 D	2.83 c	0.40 c	4.21 b	0.54 b	5.53 a	0.64 a	6.05 a	0.61 a	5.84 A
	Medium	0.23 D	3.23 c	0.40 c	5.11 b	0.62 b	6.80 a	0.68 ab	6.95 a	0.77 a	6.75 A
	High	0.28 D	3.41 c	0.44 c	5.45 b	0.59 b	6.49 a	0.75 a	5.92 ab	0.79 a	6.98 A

*\*\*means for the same parameter (dry weights of leaf+cola versus stem dry weights) followed by different letters were significantly different at the 5% ( $p \leq 0.05$ ) level.*

**CBD (Cannabinoid) Type Hemp Nitrogen Studies**  
Additional Figures and Tables – CBD Type Hemp referenced in report

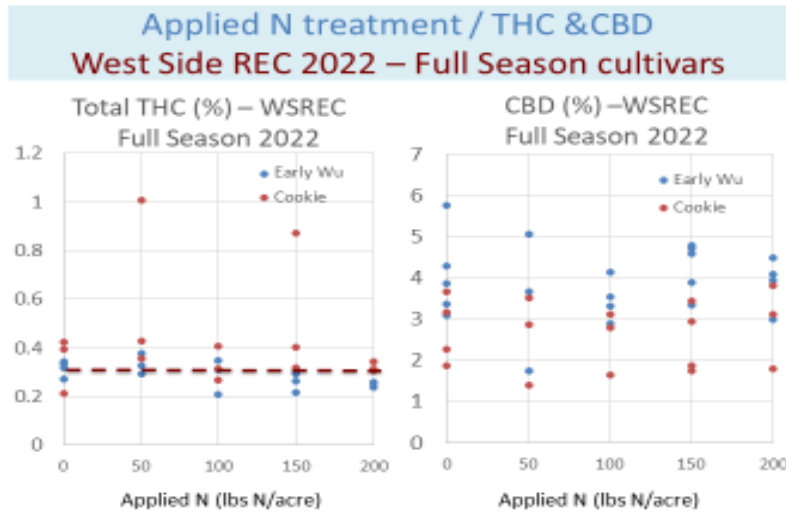


Figure 1. Total THC and CBD concentrations of primary colas as a function of nitrogen treatment in Full-Season cultivars grown at the West Side REC in 2022. Individual data points shown are from different field replicate samples analyzed for each N application level.

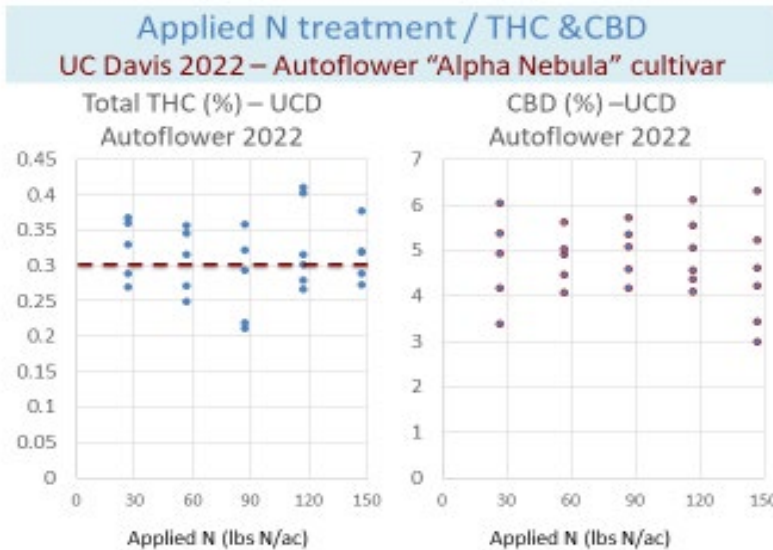


Figure 2. Total THC and CBD concentrations of primary colas as a function of nitrogen treatment in an Autoflower cultivar “Alpha Nebula” grown at UCD site in 2022. Individual data points shown are from different field replicate samples analyzed for each N application level.

Table 4. Total (for season) applied Nitrogen fertilizer in Fiber-Type Industrial Hemp nitrogen rate study done in April, May and July plantings in 2023 at UC West Side REC.

Planting Date	Nitrogen Applied (lbs N/acre)			
	T1	T2	T3	T4
Mid-April	110	170	230	300
Late-May	110	165	230	Not included
Mid-July	60*, **	110	160	Not included

\*Lower rates selected for mid-July plantings due to expected much lower growth and yields due to later planting, shorter growing season.

\*\*Due to limited seed quantities, average planting densities for July planting was 155,000 plants per acre.

Table 5. Soil nitrate-N levels in upper 3 feet of soil profile at WSREC and UCD sites prior to planting (late spring conditions), with average values shown based on composite samples at different locations taken at 0-12, 12-24, 24-36" depths.

Trial Location	Trial year	Top 3 feet - mean soil nitrate-N (lbs N/acre) prior to planting	
		AF cultivars plot area	PPS cultivars plot area
UCD	2021	30	30
	2022	40*	40*
WSREC	2021	34	41
	2022	23	31

\*\* evaluations done using Nitrate-quick test, results not confirmed by lab analysis of soil samples.

Table 10. Plant height at harvest and # of secondary branches as a function of applied nitrogen treatments for Autoflower (AF) cultivars in 2022 at WSREC site. Mean separation analyses for N trt effects were done by site & cultivar type, different letters indicating differences at 5% level.

Cultivar name	Within growing season N application level				
	T1 (0 lbs/ac)	T2 (30 lbs/ac)	T3 (60 lbs/ac)	T4 (90 lbs/ac)	T5 (120 lbs/ac)
	# of secondary branches per plant				
Maverick	1.22 b	1.62 a	1.64 a	1.86 a	1.81 a
Rincon	1.14 c	1.24 bc	1.58 ab	1.67 a	1.56 ab
Alpha Nebula	1.11 b	1.72 a	1.65 a	1.80 a	2.09 a
	Plant Height (inches)				
Maverick	16.1 b	17.5 b	18.1 ab	19.7 a	19.3 a
Rincon	14.1 a	15.6 a	15.4 a	15.8 a	15.6 a
Alpha Nebula	13.7 a	15.6 a	14.8 a	14.4 a	14.7 a

Table 11. Plant height at harvest as a function of applied nitrogen treatments for Full Season (PPS) cultivars in 2022 at WSREC site. Mean separation analyses for N treatment effects were conducted for each site and cultivar type, different letters indicating differences at the 5% level.

Cultivar name	Within growing season N application level				
	T1 (0 lbs/ac)	T2 (50 lbs/ac)	T3 (100 lbs/ac)	T4 (150 lbs/ac)	T5 (200 lbs/ac)
	# of secondary branches per plant				
Cookie Crush	15 b	19 ab	23 a	22 a	27 a
Early Wu	16 b	18 ab	21 a	21 a	23 a
	Plant Height (inches)				
Cookie Crush	38.3 b	42.5 b	51 a	50.3 a	51.7 a
Early Wu	33.8 b	37.5 b	45.0 a	46.0 a	45.3 a

Table 12. Plant height at harvest time as a function of applied nitrogen treatments for Autoflower cultivars and Full Season Cultivars n 2022 at UCD site.

Type of Hemp	Cultivar name	Within growing season N application level				
		T1 (0 lbs/ac)	T2 (30 lbs/ac)	T3 (60 lbs/ac)	T4 (90 lbs/ac)	T5 (120 lbs/ac)
		Plant Height (inches)				
Autoflower	Rincon	31.7 a	30.1 a	30.5 a	32.7 a	31.0 a
	Alpha Nebula	29.5 a	28.8 a	30.3 a	28.0 a	30.8 a
Full Season	Cookie Crush	86.6 a	81.7 a	83.2 a	85.6 a	77.0 b
	Early Wu	68.3 ab	66.7 b	65.4 b	70.7 ab	72.2 a

Table 14. Pre-plant versus post planting soil NO<sub>3</sub>-N in two zones of the soil profile (0 to 3 feet, 3 to 6 feet) in AF and PPS plots (one cultivar each) in 2022 CBD-type hemp trial at the West Side REC (Panoche clay loam soil). Values are shown as total NO<sub>3</sub>-N in these zones of the soil profile as a function of N application treatments. Pre-plant sampling was in random locations in fields used for the trials, and post harvest sampling was within treatment plots.

Plant Type	Nitrogen Treatment	Soil NO <sub>3</sub> -N content (lbs NO <sub>3</sub> -N/ac in zone of profile)					
		0 to 3 foot depth			3 to 6 foot depth		
		Average Pre-plant	Average Post Harvest	Change	Average Pre-plant	Average Post Harvest	Change
Autoflower (AF)	T2 (30 lbs)	23	19	-4	39	27	-12
	T3 (60 lbs)	23	27	+4	39	31	-8
	T4 (90 lbs)	23	42	+19	39	43	+4
	T5 (120 lbs)	23	57	+34	39	48	+9
Full Season (PPS)	T2 (50 lbs)	31	22	-9	42	36	-6
	T3 (100 lbs)	31	24	-7	42	31	-11
	T4 (150 lbs)	31	48	+17	42	54	+12
	T5 (200 lbs)	31	56	+25	42	No data	

## **Acknowledgements**

This industrial hemp multi-year nitrogen management trial is supported by the California Department of Food and Agriculture Fertilizer Research Education Program (CDFA-FREP) as project #20-0964, and that support is gratefully acknowledged. Additional support for conducting the West Side REC fiber hemp evaluations was provided as part of the sponsored project cooperative with Oregon State University (Global Hemp Center) entitled “Hemp-Based Fiber Materials, Technology, and Commerce as Drivers for Northwest American Indian Tribal Economic Development” (NIFA (National Institute of Food and Agriculture) Award #: 2024-68012-41751).

Support for vehicle use and staff were provided by the UC Davis Plant Sciences Department. These projects are also supported as approved field trials of the UC Davis campus farm and the UC-ANR West Side Research and Extension Center (West Side REC), and the support of these institutions and their staff is gratefully acknowledged. Donations of hemp seed (or transplants for earlier work on cannabinoid essential oil types of cultivars) for conducting the trials were received from multiple companies listed on the title page. The assistance of Tom Pires (West Island Gin, Riverdale, CA), Dan Nowell (Yuma, AZ grower) and Lawrence Serbin of Hemp Traders (Los Angeles, CA) in teaching us about fiber hemp and in discussions of management needs for fiber hemp and research is gratefully acknowledged. In addition, we received donated services and discounted price services for THC and CBD analyses from Alkemist Labs of Garden Grove, CA. These were very valuable donations from each of these companies to assist us, and we wouldn't be able to do the study without their contributions. Finally, we are grateful for the hard work and great attention to detail provided by our field research staff in these trials, including Jorge Angeles, Maya Hotz, Chris de Ben, and additional part-time staff, plus staff at the UCD Farm and UC-ANR West Side REC.

## **M. Factsheet**

This project “Nitrogen Response of Industrial Hemp Cultivars Grown for CBD, Essential Oils, Fiber” (CDFA-FREP Grant #20-0964) had the following objectives: (1) evaluate for two biotypes of industrial CBD-type hemp impacts of N application and variety/plant type on N uptake, removal, and cola yields; (2) assess impacts of N management on THC and CBD concentrations in harvested portions of plants; (3) provide information to appropriate grower groups, consultants and industry; and (4) assess basic nitrogen growth and dry matter yield responses of longer-season, larger industrial hemp cultivars grown for fiber and construction materials. Project Leaders were Robert Hutmacher and Dan Putnam (UC Cooperative Extension Specialists Emeritus, UC Davis Plant Sciences Dept.). Project Cooperators included Jorge Angeles, Sarah Light, Nicholas Clark, (UC Cooperative Extension Farm Advisors, Fresno, Tulare/Kings and Yuba/Sutter Counties, respectively), with assistance from UC Extension Specialist Daniel Geisseler (UCD), and Chris DeBen, Maya Hotz of UCD Plant Sci. Dept. and Geoffrey Koch of UC LAWR. In addition to the CDFA-FREP support, numerous seed companies and a laboratory provided donated or reduced cost seeds, transplants and

services to conduct the trials (Alkemist Labs, Kayagene, Cultivaris, Phyllos, Zera Farms, Beacon Hemp, Hemp Traders).

This project provides improved information for growers and consultants on the nitrogen fertilizer needs and yield responses of a wide range of different types/growth habits of industrial hemp. The work on crop yield and uptake responses of cannabinoid types of industrial hemp to applied nitrogen was conducted both at the UC Davis campus (Yolo County) and at the UC-ANR West Side Research and Extension Center (WSREC) near Five Points (Fresno County). Using irrigation requirement estimates from our prior hemp studies, drip irrigation was used in these studies to avoid excess irrigation and to reduce possible nitrate leaching losses. Nitrogen fertilizer applications in the cannabinoid type hemp studies was primarily done using liquid urea injected with irrigation water, while in the fiber hemp studies, N fertilizer was applied as a split between a granular urea pre-plant application and liquid urea with the irrigation water. The primary work on fiber types of hemp was all conducted at the WSREC facility. To our knowledge, little of this type of data was previously available for cannabinoid and fiber types of hemp grown in the western U.S., particularly in California.

### Highlights

- In studies done on autoflower versus full-season cannabinoid types of industrial hemp, field evaluations showed that peak cola yields in the Central Valley of CA were attained with 50-70 lbs N fertilizer per acre in autoflower hemp cultivars (which were harvested at about 80 days post planting), and with 100-140 lbs N/acre in full-season cannabinoid hemp cultivars (which were harvested about 120-130 days after planting).
- In studies done on long-season, high-yield fiber types of industrial hemp in the San Joaquin Valley of CA, field evaluations demonstrated that under conditions with low to moderate residual soil nitrogen at planting, peak stem fiber biomass could generally be achieved with 150 lbs N fertilizer per acre in these studies, even with dry matter yields in the 6 to 10 tons/acre range.
- Plant parts removed from the fields at harvest with types of hemp grown for cannabinoids are the flower bud clusters (colas) of the plants. In Autoflower short-season cultivars, with cola yields in the range of 1800 to 2500 lbs/ac, N removal with harvest ranged from about 60 to 75 lbs N/acre. In Full-Season cannabinoid types, with yields in the same range, N removal with harvests ranged from about 75 to 100 lbs N/acre. If harvest methods separate colas from the plants in the field, most stem and leaf tissue would remain in the field.
- Plant parts removed from fields at harvest with types of hemp grown for fiber and structural materials are stem tissue, consisting of about 15-20% long fibers (bast) and about 80-85% hurd (shorter fibers and stem conductive tissue). If grown for a full, long season, yields in the study ranged from about 6 to over 10 tons dry biomass/acre,

with over 90 percent of that biomass in the stems which would be removed from the field at harvest.

- THC levels in the parts of plants tested for regulatory THC compliance (upper main stem including colas) was not observed to be influenced consistently by nitrogen rate applied in the fiber hemp types or CBD types (AF or PPS cultivars). A recommendation to growers would be to: (1) focus mostly on selection of cultivars where commercial data exists for a history of low THC levels for compliance; and (2) harvest fiber types of hemp late in vegetative development or prior to flowering.

In reviewing available literature, there does not appear to be much prior information on cannabinoid hemp yield responses to applied nitrogen, or harvest removal of N for cannabinoid or fiber hemp with currently available cultivars. Such information should assist growers and consultants in choices for adequate nitrogen fertilizer regimes to consider when growing industrial hemp in the hot inland valleys of California.

## **N. Products – examples**

We have reported on results of this study to several local growers with interest in hemp production possibilities in CA, and to our research partners with the Global Hemp Center and Oregon State University. We participated in several sessions discussing hemp at the Tulare Farm Show, and at the Agronomic Crop Field days conducted both at the Davis campus and at the UC ANR Kearney Research and Extension Center. Our goal is also to continue work on the data sets to develop journal scientific articles, and also provide some general guidelines to Dr. Daniel Geisseler for his consideration to include in the CDFA Crop Nutrient guidelines.