Kansas Agricultural Experiment Station Research Reports

Volume 9
Issue 3 *Industrial Hemp Research Report, 2021-2022*

Article 2

2023

2021 Kansas State University Industrial Hemp Dual-Purpose Variety and Planting Date Trials

Kraig Roozeboom
Kansas State University, kraig@ksu.edu

Jason Griffin
Kansas State University, jgriffin@ksu.edu

Andrew Euler
Kansas State University, aeuler@k-state.edu

See next page for additional authors

Recommended Citation

Roozeboom, Kraig; Griffin, Jason; Euler, Andrew; Bahr, Ike; and Owuoche, Brian (2023) "2021 Kansas State University Industrial Hemp Dual-Purpose Variety and Planting Date Trials," *Kansas Agricultural Experiment Station Research Reports*: Vol. 9: Iss. 3. https://doi.org/10.4148/2378-5977.8455

2021 Kansas State University Industrial Hemp Dual-Purpose Variety and Planting Date Trials

Funding Source

Funding support is provided from K-State Research and Extension, and the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch-Multistate project 1019339: Industrial Hemp Production, Processing and Marketing in the U.S. The authors appreciate the Kansas Department of Agriculture for collaborative support throughout the project.

Authors

Kraig Roozeboom, Jason Griffin, Andrew Euler, Ike Bahr, and Brian Owuoche

2021 Kansas State University Industrial Hemp Dual-Purpose Variety and Planting Date Trials

Kraig Roozeboom,[1] Jason Griffin,[2] Andrew Euler,[1] Ike Bahr,[1] and Brian Owuoche[1]

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 again in the United States. There are many uses for industrial hemp, and the market for industrial hemp is rapidly growing as more states are legalizing its production. The market for industrial hemp exceeded $205 million in 2020 and could surpass $310 million by 2028 (Global Market Insights Inc., 2020). The main components of the industrial hemp market are oil, seeds, and fiber. Varieties have been selected for improved fiber and grain production that can service these markets. However, little research-based information is available regarding adaptability or production of these varieties in Kansas (Griffin et al., 2020; 2021). Hemp could be used to diversify both crop rotations and market opportunities for growers.

In 2021, Kansans were allowed to apply for research licenses to grow industrial hemp for the third year. Limited data from the 2019 and 2020 growing season demonstrated vast differences in growth and yield in Kansas. Therefore, ongoing variety trials are necessary to determine which varieties are best adapted to the state. Currently, farmers in Kansas must rely on the limited data from Kansas trials combined with information generated from other states, which have vastly different growing conditions than Kansas. Variety selection is vital in hemp production considering latitude (day length) and length of growing season influence the planting date, number of days to harvest, and ultimately yield.

The objectives of this research were to evaluate commercially available varieties of industrial hemp and the effect of planting date on a subset of those varieties at two locations in Kansas (Wichita and Manhattan).

[1] Department of Agronomy, College of Agriculture, Kansas State University, Manhattan, KS.
[2] Kansas State University John C. Pair Horticultural Center, College of Agriculture, Department of Horticulture and Natural Resources, Haysville, KS.

Procedures

Wichita Variety Trial

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 inches of precipitation annually. The experimental plot was industrial hemp in 2019 and 2020, and buffalograss for the previous 12 years. The plot was disked after the 2020 growing season and periodically through the winter to control volunteer hemp seedlings. Prior to planting in spring 2021, the plot was cultivated with a springtooth harrow. On May 12, 2021, 18 varieties of dual-purpose industrial hemp (Table 1) were seeded at a rate of 30 lb live seed/a.

Experimental plots were 4.5 ft × 22 ft and seeded to a depth of approximately 0.5 inch with a Hege 1000 drill outfitted with a Zero-Max gear box on 9-in. row spacing. Over the next 5 days multiple precipitation events, some heavy (Figure 1), caused severe soil crusting, which prevented emergence of nearly all seedlings. On May 26, 2021, glyphosate was applied to the field to control the weed population. The site was cultivated and replanted on June 8, 2021, but another intense rainfall three days later resulted in stands that were unacceptable for valid variety comparisons.

Manhattan Variety Trial

The same 18 hemp varieties were evaluated at the K-State Research and Extension Ashland Bottoms Research Farm (latitude 39.1230, longitude -96.6386) near Manhattan, KS. The predominant soil series in the experimental area was a Wymore silty clay loam. Soil samples were obtained before planting to characterize the site. Each sample consisted of 12 cores taken to a depth of six inches from random locations within each replication. Results of soil tests averaged across the experimental site were pH = 6.4; organic matter = 2.6% (loss on ignition); P = 12.8 ppm (Melich III); and K = 301 ppm (ammonium acetate extraction with ICP spectrometry).

The experimental site had been in winter wheat the previous year and was managed without tillage. A spring-oat cover crop was planted in September of 2020 to provide uniform residue cover. Although the spring oats died over the winter, volunteer wheat survived and was terminated with glyphosate on April 12 before heading. A second application of burn-down herbicides was applied immediately before planting to terminate weeds that had emerged since the April herbicide application. Oat and volunteer wheat residue was left undisturbed in an attempt to suppress weed emergence in the hemp.

Plots were planted on June 4 with a Great Plains No-Till cone drill at a rate of 20 pure, live seeds (PLS)/square foot (871,200 PLS per acre). Seeding rates for individual varieties ranged from 27 lb/a for a variety with small seed and a high germination rate to 60 lb/a for a variety with large seed and a poor germination rate (Table 1). Seed was placed into moist soil at a depth of 0.75 inches. Plots were 6-ft wide and 25-ft long and consisted of 9 rows spaced at 7.5 inches.

Nitrogen and phosphorus fertilizers were applied to the soil surface on June 14, soon after emergence, to avoid reduction in hemp emergence observed in previous years when fertilizers were surface-applied before planting. Fertilizer applications were made with a Gandy (Owatonna, MN) turf, drop spreader to achieve uniform distribution of the target rates. Nitrogen was applied at a rate of 130 lb/a as dry urea fertilizer (46-0-0), and phosphorus was applied at a rate of 60 lb P_2O_5/a as triple super phosphate (TSP, 0-45-0).

Samples and data were collected from a 10-ft length of four, bordered rows (25 ft^2) in each plot. Emerged plants were counted in late June and again at harvest. Plant survival (%) was calculated as (harvest plant number/June plant number) × 100. Late-emerging plants likely contributed little to stem or grain yield. Hand weeding was used to control weeds that emerged after planting. First-bud date was recorded as the date when at least 50% of plants in the sample area of a plot had male flowers. Days to first bud was calculated as the number of days from planting to first-bud date. Harvest consisted of hand cutting plants at ground level from the entire 25-ft^2 sample area within each plot. The entire sample was dried at 140°F for 7 days. After drying, total biomass weight was determined, plants were stripped of their grain, and grain was passed through a seed blower for a final cleaning before it was weighed to determine grain yield. Weight of the stem was calculated by subtracting grain weight from total biomass. The mass of 300 seeds was determined to facilitate calculation of harvested seed size (seeds/lb).

The experimental design was a randomized complete block design with 18 varieties replicated four times. Data were subjected to analysis of variance using the SAS GLIMMIX procedure with replications considered random to determine least-square means and mean separations for each response variable at $\alpha = 0.05$.

Planting Date Experiments

Some of the hemp varieties with sufficient quantities of high-quality seed were used in experiments designed to evaluate the effect of planting date on hemp performance. Planting date experiments were planted adjacent to the variety trials, and site characteristics and management were the same as previously described for the variety trials.

At Wichita, varieties Altair, Anka, Bialobrzeskie, CFX-1, and Henola were planted on April 12 and June 3, 2021. Plots were fertilized at a rate of 1 lb of N/1000 ft^2 with 13-13-13 four weeks after planting. The April planting was harvested on July 27, and the June planting was harvested on Sept. 1.

At Manhattan, varieties Altair, Anka, Bialobrzeskie, and Henola were planted on June 4 and June 28, 2021. All plots from both planting dates were harvested on either September 6 or 9 when they reached harvest maturity.

Treatments were arranged with two planting dates as whole plots and four varieties as subplots. Analysis of variance conducted with SAS GLIMMIX considered replications and the interaction of replication with planting date as random factors to account for the split-plot treatment structure.

Results

Wichita Variety Trial

No results are reported for the experiment planted at the John C. Pair Horticultural Center near Wichita, KS, because both the original planting and replanting had unacceptable stand establishment due to intense rainfall events soon after both plantings (Figure 1).

Manhattan Variety Trial

Although all varieties were planted with the same number of pure, live seed, plant density varied as much as five-fold (Table 2). The variety Hliana from Roher Seed had the fewest plants per acre at emergence and at harvest, which is not surprising given that the germination rate of seed for this variety was only 59% (Table 1). Previous research has shown that field emergence is often less than lab germination in many species, especially with low germination values (TeKrony and Egli, 1977; Hampton, 1981). Of the remaining 17 varieties, 14 had plant densities of more than 100,000 plants/acre, two had plant densities of roughly 80,000 plants/acre, and one had nearly 61,000 plants/acre at emergence. Although most plants had plant survival values greater than 100%, plants that emerged after the June plant count were very small and likely contributed little to grain or stem yield. Although one variety, Grandi, had fewer plants at harvest than at emergence, the 96% plant survival value was not significantly different than 100%, indicating that stand loss during the growing season was minimal.

The time to appearance of male flowers had a range of 15.5 days (Table 2). Varieties from Hemp Genetics International and IND Hemp possessed male flowers in fewer than 25 days. Varieties from New West Genetics had male flowers appear after 30 days or more. The remaining varieties had male flowers appear 27 to 32 days after planting. Although there was a range of 15.5 days for appearance of first male flowers, all varieties were harvested within an 11-day range. The number of days to appearance of male flowers and days to harvest were strongly correlated ($r = 0.68$), with many of the early-flowering varieties harvested first and the later-flowering varieties harvested later. All varieties were harvested within 94 days after planting or less.

Most varieties produced more than 3,000 pounds of total biomass per acre, and several varieties surpassed 4,000 pounds of biomass per acre (Table 3). Total biomass production had almost no correlation with plant density at emergence ($r = 0.05$) or with plant density at harvest ($r = 0.16$), reflecting the ability of hemp plants to adjust plant size in response to plant density. Partitioning of total biomass into stem and grain varied considerably.

Seven of the varieties produced more than 3,000 pounds of stem per acre, and four produced less than 2,000 pounds of stem per acre (Table 3). Stem yields had minimal correlation with plant density at emergence ($r < 0.01$) or at harvest ($r = 0.13$) (Figure 2a, 2b). Varieties that produced the most stem tended to bloom later ($r = 0.68$), be harvested later ($r = 0.61$), and be taller ($r = 0.79$) (Figure 2c – 2e).

Eleven varieties produced 1,000 pounds of grain per acre or more, with six of those varieties exceeding 1,200 pounds per acre (Table 3). Grain yield had no correlation with plant density at emergence (r = 0.13) or at harvest (r = 0.07) (Figure 2f, 2g). Varieties that produced the most grain tended to be somewhat sooner to bloom (r = -0.37) and harvest (r = -0.35) and relatively shorter in height (r = -0.52), but these relationships were not strong (Figure 2h – 2j). Although mean values for seed size ranged from 32,094 to 53,846 seeds per pound, the high degree of variability in these values within samples for the same variety prevented meaningful comparisons between varieties (Table 3).

Wichita Planting Date Trial

The number of plants at harvest was influenced by both planting date and variety (Table 4). Although variety stands depended on planting date, in general, the April planting had more plants per acre than the June planting. Henola and Bialobrzeskie planted in April produced the most plants at harvest. There were 63% and 47% reductions in plant number per acre when Henola and Bialobrzeskie, respectively, were planted in June. Anka had the fewest number of plants per acre in both plantings and was unaffected by planting date.

Individual varieties reached different heights by harvest, and the height difference between the varieties was similar at each planting date (Table 4). On average, varieties planted in April grew approximately 4 inches taller than they did in the June planting. Anka, Bialobrzeskie, and Altair grew taller than Henola and CFX-1. Similarly, the April planting date produced more stem biomass than the June planting date (Table 4). All varieties produced a similar amount of stem biomass except CFX-1, which was significantly less than the other four varieties.

Grain yield per acre varied based on variety only (Table 4). Interestingly, planting date did not influence grain yield. Henola yielded the most grain and CFX-1 yielded the least. The remaining three varieties all yielded a similar amount of grain. Even though the June planting generally reduced plant number, there was no influence of planting date on grain yield, which suggests the June plants produced more grain per plant than the April plants.

Manhattan Planting Date Trial

The number of plants per acre soon after emergence in June and at harvest was affected by both planting date and variety (Table 5). The second planting date resulted in more plants per acre compared to the first planting date averaged over the four varieties, but the difference between planting dates changed depending on variety. Anka and Henola had 42% to 43% increases in plants per acre from the first to second plating dates, but Altair and Bialobrzeskie had 71% to 79% increases. The germination rates for Anka and Henola were 75% or less, but were 82% or greater for Altair and Bialobrzeskie (Table 1). All varieties had similar rates of survival, with most values slightly greater than 100% regardless of planting date (Table 5). Although the later planting date had more plants per acre for all varieties, Bialobrzeskie and Henola had 28% more plants per acre than Altair. Anka had barely acceptable stands at both planting dates. The influence of planting date on plants per acre was likely influenced more by soil moisture conditions at planting and subsequent precipitation events than by day of year (Figure 1).

The first male flowers appeared three to four days sooner in the later planting date (Table 5). Regardless of planting date, Altair bloomed sooner than the other varieties, but it was three days sooner when planted on June 4 and only one day sooner when planted on June 28.

Later planting generally reduced plant height and yield parameters (Table 6). Height reduction with later planting was greatest for Bialobrzeskie and least for Henola. Anka was significantly taller than the other varieties in both planting dates. Henola was shorter than the other three varieties in the June 4 planting, but was similar in height to Altair and Bialobrzeskie in the June 28 planting.

All four varieties produced more biomass and stem when planted on June 4 vs. June 28 (Table 6). Averaged across planting dates, stem production did not differ between the four varieties, but Bialobrzeskie and Henola produced roughly 18% more total biomass than Altair and Anka. Grain yield, however, differed substantially between planting dates and varieties, with greater yields and larger differences between varieties in the June 4 planting. Henola produced the most grain when averaged across planting dates and in the June 4 planting, but was no different than Altair and Bialobrzeskie when planted on June 28. In the June 4 planting Henola produced ~50% more grain than any of the other varieties. However, in the June 28 planting, Altair, Bialobrzeskie, and Henola all produced ~30% more grain than Anka. Grain yield of Altair and Bialobrzeskie changed little with later planting, but was reduced by 30% and 33% for Anka and Henola, respectively. Seed size changed little with later planting for Altair, Anka, and Bialobrzeskie, but increased significantly (fewer seeds per pound) for Henola. These results suggest that timely planting can influence yield of both fiber and grain but is of greater importance for grain production than for fiber production.

Acknowledgments

Funding support is provided from K-State Research and Extension, and the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch-Multistate project 1019339: Industrial Hemp Production, Processing and Marketing in the U.S. The authors appreciate the Kansas Department of Agriculture for collaborative support throughout the project.

References

Global Market Insights, Inc. 2020. Industrial Hemp Market to exceed USD 310 million valuation by 2027, Says Global Market Insights Inc. https://www.prnewswire.com/news-releases/industrial-hemp-market-to-exceed-usd-310-million-valuation-by-2027-says-global-market-insights-inc-301464590.html. Accessed January 26, 2022.

Griffin, Jason; Roozeboom, Kraig; Haag, Lucas; Shelton, Michael; Wilson, Clint; and Myers, Tami (2020) "2019 Kansas State University Industrial Hemp Dual-Purpose and Fiber Trial," *Kansas Agricultural Experiment Station Research Reports*: Vol. 6: Iss. 1. https://doi.org/10.4148/2378-5977.7882.

Griffin, Jason; Roozeboom, Kraig; Haag, Lucas; Euler, Andrew; Shelton, Michael; Myers, Tami; Nielsen, Matthew; Petz, Jared; and Wilson, Clint (2021) "2020 Kansas State University Industrial Hemp Dual-Purpose and Fiber Trial," *Kansas Agricultural Experiment Station Research Reports*: Vol. 7: Iss. 9. https://doi.org/10.4148/2378-5977.8219.

Hampton, J.G. 1981. The relationship between field emergence, laboratory germination, and vigour testing of New Zealand seed wheat lines. New Zealand Journal of Experimental Agriculture. 9:2, 191-197, doi: 10.1080/03015521.1981.10427827.

TeKrony, D.M., and D.B. Egli. 1977. Relationship Between Laboratory Indices of Soybean Seed Vigor and Field Emergence. Crop Sci. 17:573-577. https://doi.org/10.2135/cropsci1977.0011183X001700040023x.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Variety, origin, seed characteristics, and seeding rates for dual-purpose industrial hemp varieties (*Cannabis sativa*) planted in 2021

Variety name	Source	Seed size	Germination†	Seeding rate‡
		seeds/lb	%	lb/a
Altair§	UniSeeds	29,712	82	35
Anka§	UniSeeds	25,061	72	48
Bialobrzeskie§	International Hemp	32,170	92	29
CFX-1	Hemp Genetics International	23,874	95	38
CFX-2	Hemp Genetics International	25,920	95	35
Grandi	Hemp Genetics International	27,162	90	35
H-51	Roher Seed	24,519	88	40
Henola§	International Hemp	28,583	75	39
Hlesia	Roher Seed	26,119	75	44
Hliana	Roher Seed	24,563	59	60
Lara	Omni Trade Inc	30,040	74	39
NWG-2730	New West Genetics	36,385	89	27
NWG-2463	New West Genetics	31,647	66	41
NWG-4000	New West Genetics	30,511	80	35
NWG-4113	New West Genetics	29,712	74	39
NWG-452	New West Genetics	33,194	92	32
Vega	UniSeeds	22,308	92	42
X-59	IND Hemp	28,409	82	37

†From pre-plant germination tests.
‡Pounds of seed per acre seeded at Manhattan to achieve a uniform rate of 20 pure, live seed per square foot for all varieties based on germination, purity (99% for all varieties), and seed size.
§Varieties included in planting date experiments.

Table 2. Duration of growth and plant density information for 18 dual-purpose industrial hemp varieties evaluated at Manhattan, KS, in 2021

Variety	First bud[†]		Harvest		June		Harvest		Plant survival[‡]	
	-------- days from planting --------				---------------- plants/a ----------------				%	
Altair	29.0	ef[§]	86.0	efg	111,078	efg	144,184	cdefg	130	a
Anka	31.3	bcde	85.0	fgh	171,626	abcd	214,315	abc	125	ab
Bialobrzeskie	29.0	ef	87.0	def	164,221	bcde	186,873	abcde	118	abc
CFX-1	23.0	h	84.0	gh	204,732	ab	200,812	abcd	100	bc
CFX-2	23.8	h	84.0	gh	154,638	bcde	162,043	bcdef	106	abc
Grandi	24.0	gh	83.0	h	123,275	def	116,741	efghi	96	c
H-51	29.0	ef	89.3	cd	156,380	bcde	185,130	abcde	117	abc
Henola	31.8	bcd	88.2	de	141,550	cde	167,619	bcde	116	abc
Hlesia	29.8	de	85.0	fgh	79,279	fgh	86,249	ghi	109	abc
Hliana	31.7	bcde	87.0	def	43,448	h	40,656	i	118	abc
Lara	30.5	cde	91.3	bc	131,987	cdef	151,589	cdefg	116	abc
NWG-2463	32.8	bc	92.0	ab	60,984	gh	68,825	hi	113	abc
NWG-2730	38.5	a	92.0	ab	183,388	abc	246,114	a	130	a
NWG-4000	33.5	b	91.0	bc	120,225	def	128,938	defgh	108	abc
NWG-4113	33.5	b	94.0	a	130,680	cdef	148,104	cdefg	113	abc
NWG-452	33.0	bc	92.0	ab	84,071	fgh	89,734	fghi	106	abc
Vega	26.8	fg	87.0	def	168,577	abcd	183,387	abcde	113	abc
X-59	24.0	gh	85.0	fgh	219,978	a	227,819	ab	104	bc

[†] Days from planting until at least 50% of plants had visible male flowers.
[‡] Calculated as Harvest/June plant density; values >100% indicate emergence of additional plants after plants were counted in June. Most of the late-emerging plants contributed little to grain or stem yield.
[§] Values within a column followed by the same letter are not different at $\alpha = 0.05$.

Table 3. Harvest information for 18 dual-purpose industrial hemp varieties evaluated at Manhattan, KS, in 2021

Variety	Height		Total biomass		Stem		Grain		Seed size	
	inches		----------------------------		lb/a		----------------------------		seeds/lb	
Altair	60	ef†	3755	bcde	2673	efg	1082	cdef	36124	a
Anka	67	bcd	4187	ab	3239	bcde	949	defg	48425	a
Bialobrzeskie	66	cd	4471	ab	3387	bcd	1084	cdef	46979	a
CFX-1	36	i	3054	ef	1618	h	1436	ab	32094	a
CFX-2	34	i	2713	f	1427	h	1287	abc	40151	a
Grandi	29	j	2512	f	1380	h	1132	cde	41837	a
H-51	58	fg	4125	abcd	3244	bcde	881	efg	53846	a
Henola	52	h	4388	ab	2868	cdef	1523	a	46809	a
Hlesia	53	gh	3285	cdef	2342	fg	942	efg	44138	a
Hliana	58	fg	3193	def	2092	gh	1095	cdef	44808	a
Lara	78	a	4149	abc	3480	abc	669	g	44277	a
NWG-2463	71	b	4446	ab	3190	bcde	1256	abc	32688	a
NWG-2730	71	bc	4850	a	4081	a	769	g	47081	a
NWG-4000	65	de	3803	bcde	2718	defg	1085	cdef	51452	a
NWG-4113	71	b	4480	ab	3647	ab	833	fg	45663	a
NWG-452	69	bcd	3774	bcde	2986	bcdef	788	fg	53492	a
Vega	50	h	3707	bcde	2476	fg	1232	bcd	44944	a
X-59	35	i	3020	ef	1558	h	1462	ab	35672	a

† Values within a column followed by the same letter are not different at $\alpha = 0.05$.

Table 4. Harvest results from five hemp varieties planted at two dates at Wichita, KS, in 2021

Factor	Level	Plant number		Height		Stem		Grain	
		plants/a		in.		lb/a		lb/a	
Planting date	Day of year								
12 April	102	135,776		30	a†	1,627	a	534	
3 June	154	76,084		26	b	967	b	507	
Variety									
Altair		119,386	a	30	ab	1,366	a	525	b
Anka		57,670	b	34	a	1,416	a	515	b
Bialobrzeskie		144,680	a	31	ab	1,730	a	481	bc
CFX		76,326	b	16	c	601	b	312	c
Henola		132,053	a	26	b	1,325	a	745	a
Interaction									
Planting date	Variety								
12 April	Altair	138,609	bc	31		1,679		645	
12 April	Anka	53,623	de	37		1,639		525	
12 April	Bialobrzeskie	189,197	ab	34		2,226		538	
12 April	CFX	104,210	cd	17		809		282	
12 April	Henola	193,244	a	30		1,781		681	
3 June	Altair	100,163	cd	29		1,052		405	
3 June	Anka	53,622	de	31		1,194		506	
3 June	Bialobrzeskie	100,163	cd	29		1,234		425	
3 June	CFX	39,134	e	16		324		351	
3 June	Henola	70,823	de	22		870		810	

† Values within a column followed by the same letter are not different at $\alpha = 0.05$.
If no letters follow a set of means, the *P*-value was > 0.05 for that factor or interaction.

Table 5. Plant density and days to appearance of male flowers for four hemp varieties planted at two dates at Manhattan, KS, in 2021

Factor	Level	June		Harvest		Plant survival†	First male bud	
		---------- plants/a ----------				%	days‡	
Planting date								
4 June		122,186	b§	131,007	b	108	31	a
28 June		196,347	a	218,562	a	111	28	b
Variety								
Altair		165,092	b	174,022	b	107	28	b
Anka		48,569	c	50,312	c	104	30	a
Bialobrzeskie		218,671	a	248,074	a	114	30	a
Henola		204,732	a	226,730	a	112	30	a
Planting date	Variety							
4 June	Altair	118,483	d	128,066	c	111	29	
4 June	Anka	40,075	e	37,897	d	99	32	
4 June	Bialobrzeskie	161,608	cd	185,130	b	114	32	
4 June	Henola	168,577	c	172,933	bc	107	32	
28 June	Altair	211,702	bc	219,978	b	103	27	
28 June	Anka	57,064	e	62,726	d	109	28	
28 June	Bialobrzeskie	275,735	a	311,018	a	113	28	
28 June	Henola	240,887	ab	280,526	a	117	28	

† Calculated as (Harvest/June plant density) × 100.
‡ Number of days from planting.
§ Values within each set of comparisons within a column followed by the same letter are not different at $\alpha = 0.05$.
If no letters follow a set of means, the P-value was > 0.05 for that factor or interaction.

Table 6. Harvest results from four hemp varieties planted at two dates at Manhattan, KS, in 2021

Factor	Level	Height		Total biomass		Stem		Grain		Seed size	
		in.		lb/a						seeds/lb	
Planting date	Day of year										
4 June	155	62	a[†]	3,139	a	2,331	a	808	a	42,865	
28 June	179	46	b	2,730	b	2,053	b	677	b	41,842	
Variety											
Altair		53	b	2,670	c	2,012		658	b	42,299	
Anka		63	a	2,720	bc	2,061		659	b	42,306	
Bialobrzeskie		54	b	3,148	ab	2,392		756	b	42,189	
Henola		46	c	3,201	a	2,303		897	a	42,620	
Interaction[§]											
Planting date	Variety										
4 June	Altair	62	bc	2,872		2,212		660	bc	45,269	ab
4 June	Anka	72	a	2,953		2,181		772	b	38,904	b
4 June	Bialobrzeskie	65	b	3,280		2,555		725	b	39,062	b
4 June	Henola	50	de	3,453		2,376		1,076	a	48,224	a
28 June	Altair	45	e	2,468		1,813		656	bc	39,329	b
28 June	Anka	54	cd	2,488		1,942		546	c	45,707	ab
28 June	Bialobrzeskie	43	e	3,016		2,228		787	b	45,315	ab
28 June	Henola	42	e	2,949		2,231		718	b	37,015	b

[†] Values within a column followed by the same letter are not different at $\alpha = 0.05$.
If no letters follow a set of means, the P-value was > 0.05 for that factor or interaction.

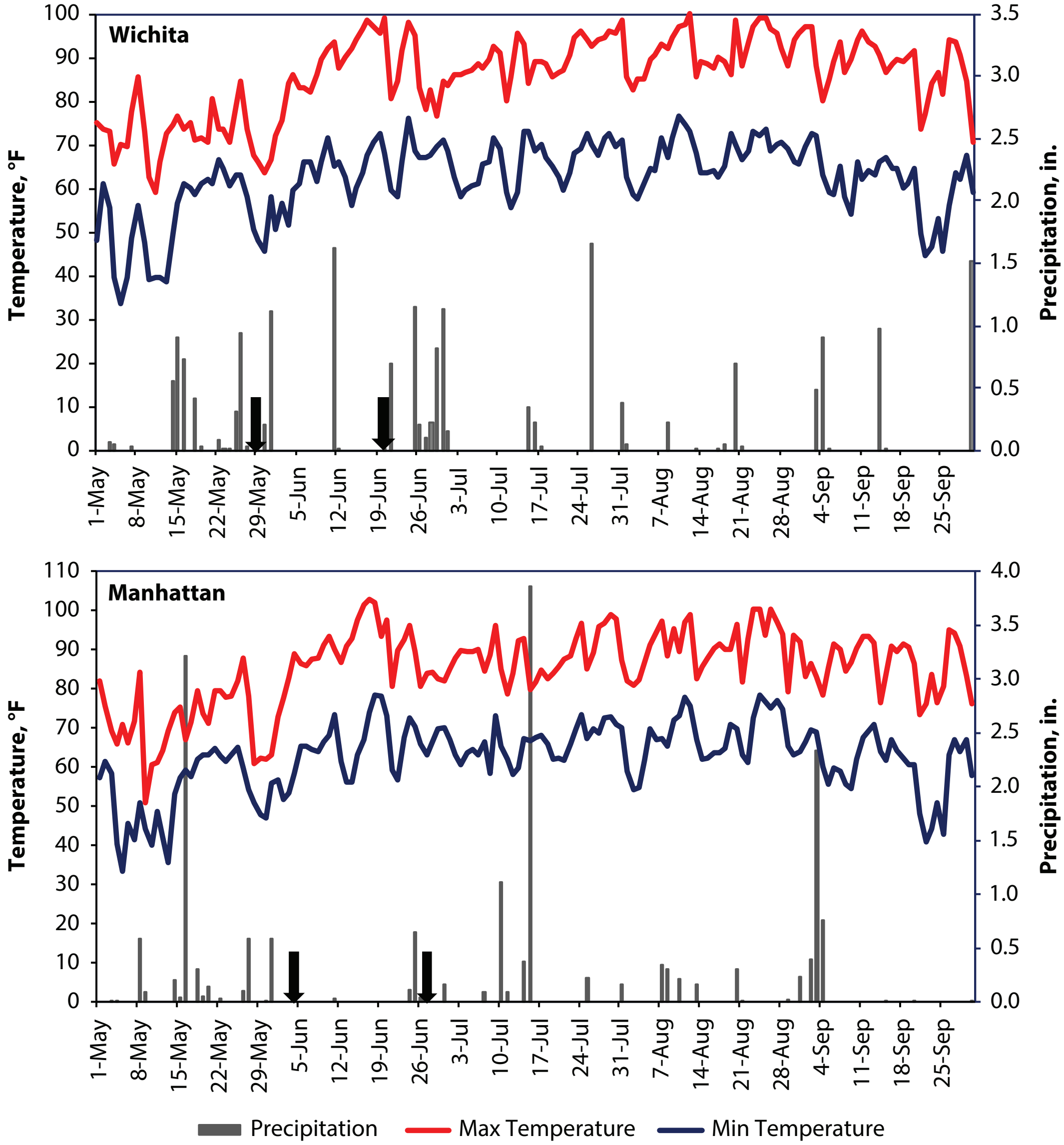

Figure 1. Daily maximum and minimum temperatures and precipitation at the Kansas State University John C. Pair Horticultural Center (Wichita - top) and Ashland Bottoms (Manhattan - bottom) during the industrial hemp (*Cannabis sativa*) growing season of 2021. Planting dates are indicated by the arrows. Data were obtained from the Kansas State University Mesonet weather station located at each site (mesonet.k-state.edu).

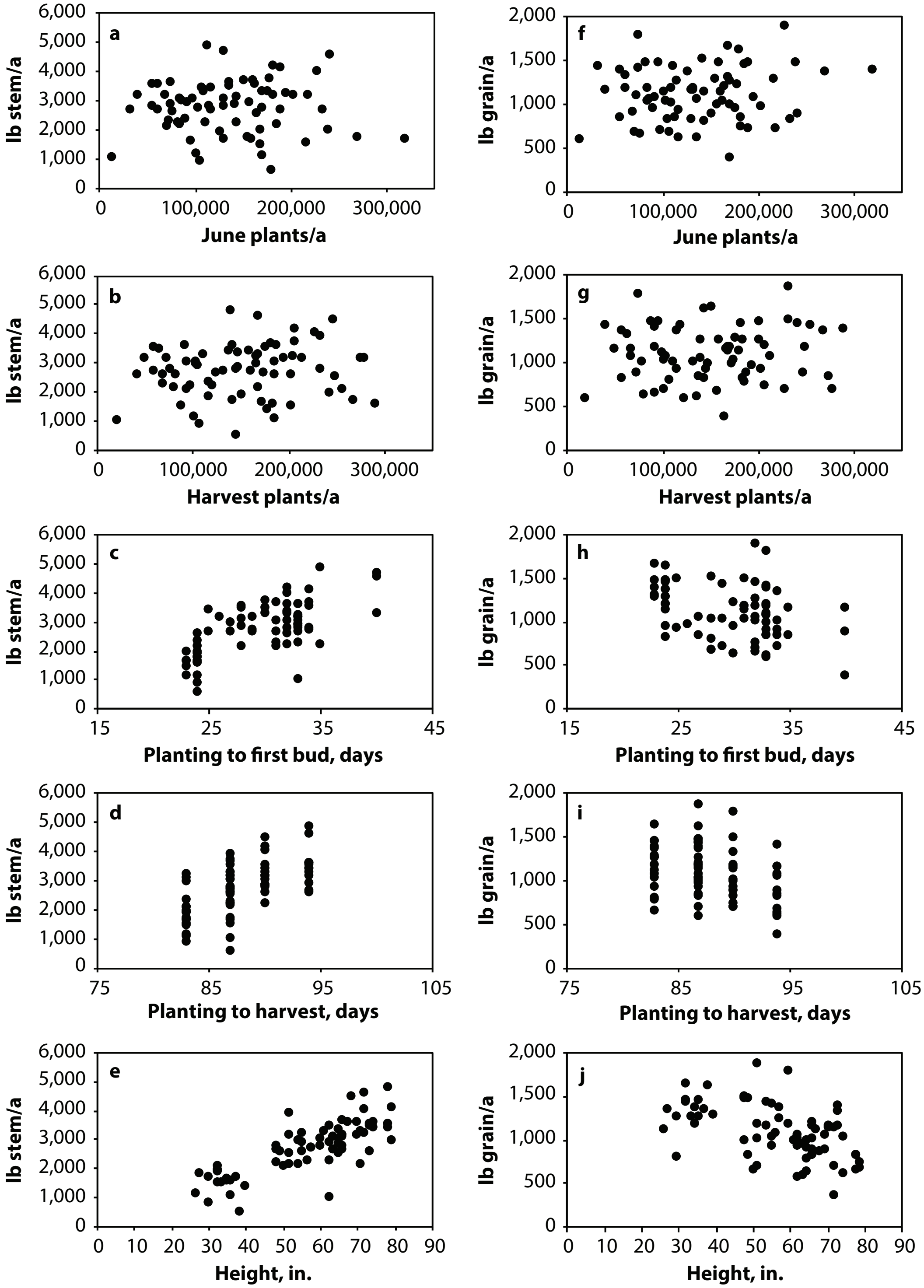

Figure 2. Relationships between stem (a - e) and grain (f - j) yields vs. plant density in June and at harvest, days to first bud and harvest, and plant height for 18 industrial hemp varieties evaluated at Manhattan, KS, in 2021.