

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

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Recommended Citation

Roozeboom, Kraig; Griffin, Jason; Euler, Andrew; Bahr, Ike; and Owuoché, 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>

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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.

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

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and Brian Owuoché¹*

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).

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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 P₂O₅/a as triple super phosphate (TSP, 0-45-0).

Samples and data were collected from a 10-ft length of four, bordered rows (25 ft²) 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-ft² 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, Bialobrzieskie, 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 ft² 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, Bialobrzieskie, 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 Bialobrzieskie planted in April produced the most plants at harvest. There were 63% and 47% reductions in plant number per acre when Henola and Bialobrzieskie, 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, Bialobrzieskie, 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 planting dates, but Altair and Bialobrzieskie had 71% to 79% increases. The germination rates for Anka and Henola were 75% or less, but were 82% or greater for Altair and Bialobrzieskie (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, Bialobrzieskie 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 Bialobrz- eskie 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-Multi-state 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.

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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
Bialobrzescie§	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 e [§]	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 inches	Total biomass ----- lb/a -----	Stem lb/a -----	Grain -----	Seed size seeds/lb
Altair	60 e†	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	Height	Stem	Grain
		number			
		plants/a	in.	----- 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
	Bialobrzescie	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	Bialobrzescie	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	Bialobrzescie	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 in.	Total biomass		Stem lb/a	Grain	Seed size 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	
Bialobrzieskie		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	Bialobrzieskie	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	Bialobrzieskie	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.

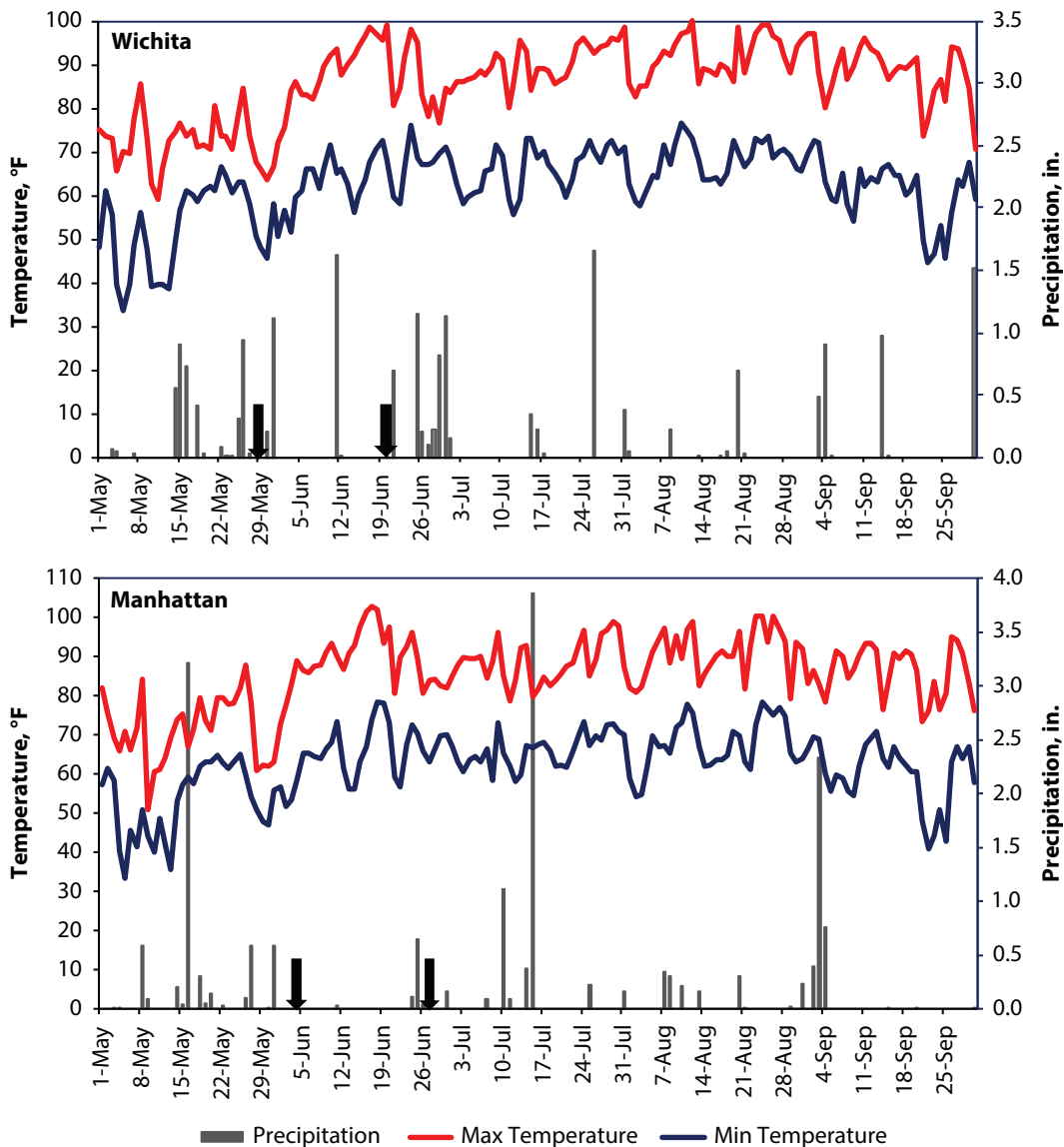


Figure 1. Daily maximum and minimum temperatures and precipitation at the Kansas State University John C. Pair Horticultural Center (Wichita - top) and Ashland Bottoms (Manhattan - bottom) during the industrial hemp (*Cannabis sativa*) growing season of 2021. Planting dates are indicated by the arrows.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

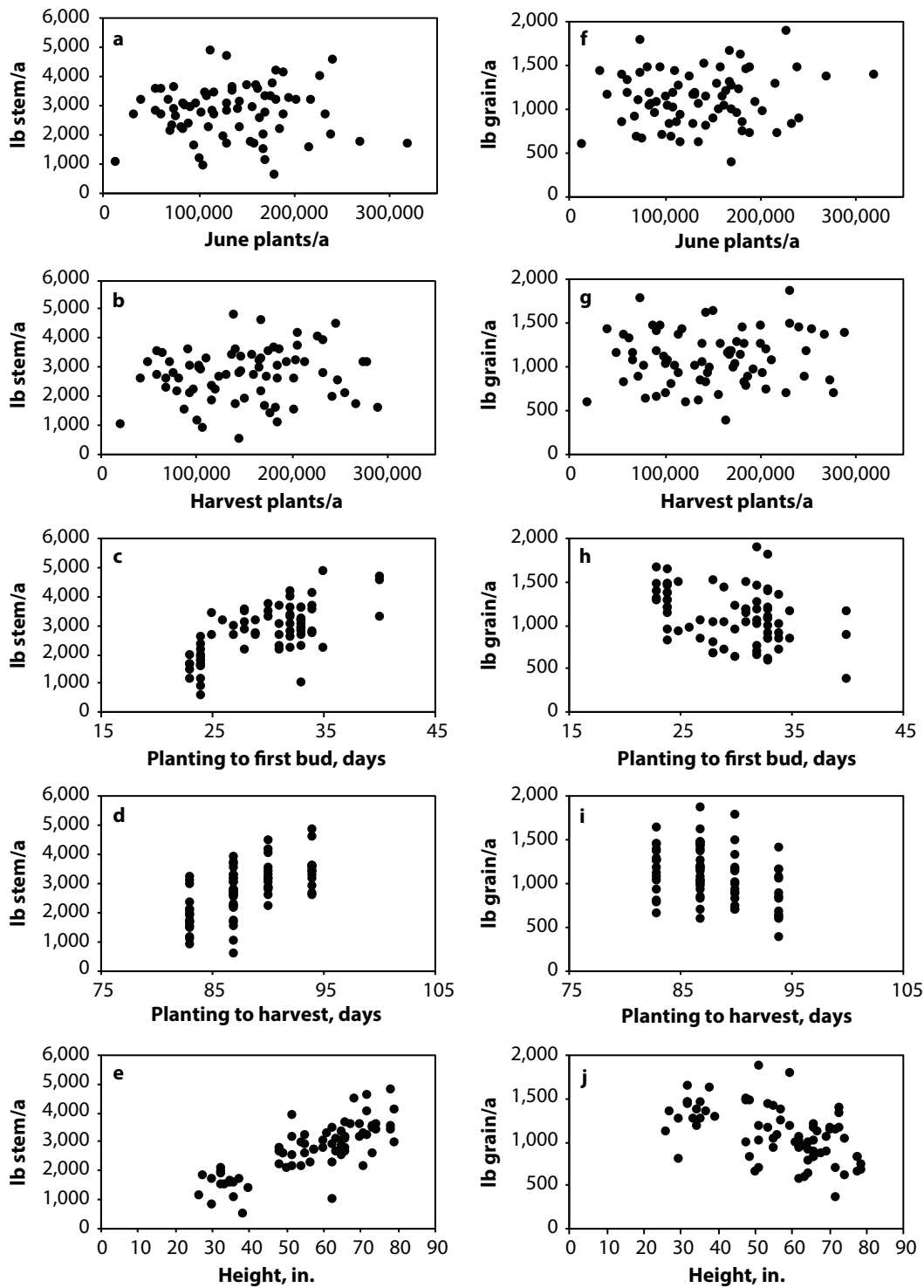


Figure 2. Relationships between stem (a - e) and grain (f - j) yields vs. plant density in June and at harvest, days to first bud and harvest, and plant height for 18 industrial hemp varieties evaluated at Manhattan, KS, in 2021.