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University of Arizona 2020 CBD Hemp Variety Trial

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Introduction

The 2018 U.S. Farm bill legalized cultivation of industrial hemp in the United States, delegating regulation and enforcement to the individual states (USDA-AMS, 2021). In the state of Arizona, the Arizona Department of Agriculture (AZDA) issues licenses and regulates the production and processing of industrial hemp, maintaining records of every planting in the state (AZDA, 2021). The first year growing permits were issued to the public was in 2019 and 5,430 acres of hemp were planted in the state the same year. Statewide, only 72% of planting acres were inspected by the AZDA at harvest (AZDA, 2020), indicating a high rate of crop termination before inspection. Of the inspected acres, 25% produced psychoactive tetrahydrocannabinol (THC) levels, in excess of legal compliance limits, resulting in mandatory crop destruction of 20% of inspected acres. In total, the hemp growers of Arizona suffered a 42% crop loss at the end of the 2019 season. It is the purpose of this paper to grow different varieties of CBD hemp, purchased from different seed companies, in the arid desert southwest climate of Arizona, with particular emphasis on evaluating varietal differences in the production systems of Yuma County, Arizona.

Materials and methods

During the spring season of 2020, two field trials were created to compare performance of DN (day length neutral) and DD (day length dependent) CBD hemp varieties commercially available in the marketplace. Seed from 17 varieties (14 DD and 3 DN) were sourced from seven seed companies operating in the United States. Two fields were chosen at different locations of the Yuma Agricultural Center (YAC) research farm in Yuma Arizona: one that reflected the alluvial valley (Holtville Clay: 18% sand 46% silt, 36% clay) and another that reflected the sandy mesa soils (82% sand, 6% silt, 12% clay) endemic to the region. Two, four-replication, randomized block design trials were created, one for each of the soil types (mesa and valley). Raised beds were listed on 42- and 84-inch row spacings at the Mesa and Valley stations, respectively. DD and DN varieties were separated and planted apart to prevent shading from neighboring plot plants, as they were expected to grow to different heights. All DD strains were hand seeded in single plant lines per bed, in 30-foot plots, using a 1.5-foot seed spacing, which was later thinned to 3 feet. The 42-inch mesa DN plots were 15 foot in length and had two seed lines per bed, planted at 1.5-foot seed spacings and not thinned. The 84-inch valley DN plots were 7.5 feet in length and were made of four seed lines per bed, planted on 1.5-foot seed spacing and not thinned. In this manner, each plot contained 30 linear feet of planted seed line with a shallow seeding depth of 1/8 inch. The mesa location was seeded on April 2nd and the valley location on April 7th.

Day lengths at emergence at the mesa and valley locations were 12.5 hours and 13.0 hours, respectively, and average soil temperature was approximately 75°F at both locations (Figure 1). Sprinkler irrigation was used at both locations to facilitate germination, and crops changed to flood irrigated at the three-to-four-leaf stage. Irrigation was then switched to surface drip irrigation at the valley location on June 6th, which was used to reduce ground moisture and administer acid fertilizers used to combat sodium toxicity.

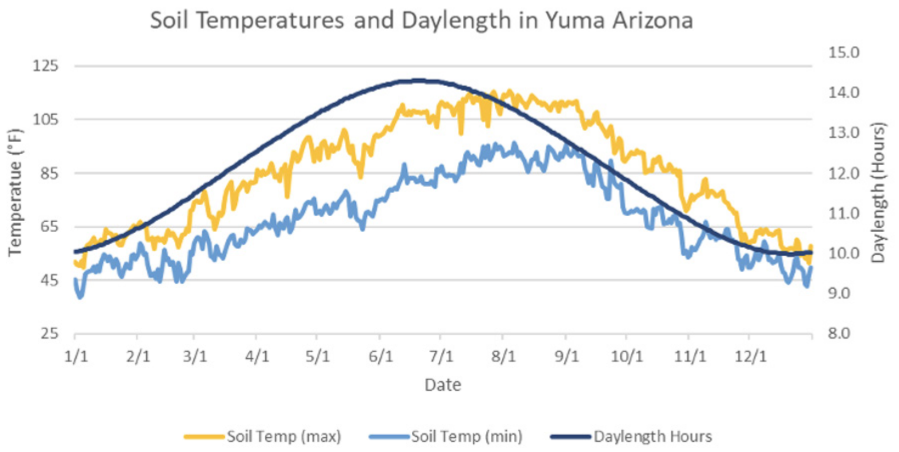

Figure 1: Average soil temperature and day length in Yuma, Arizona. AZMET weather service, 2 inch depth.

Fertilizer regime similar to a standard corn or cotton regime was used: 400 lbs/ac of 11-52-0 MAP preplant fertilizer was broadcasted on bed tops, incorporated into the bed, then bed shaped before planting. Preplant herbicides were not used at either location, as most effective herbicides are not yet labeled for hemp. UN-32 was used as the primary nitrogen source at both locations. To combat sodium toxicity stress at the valley station, N-pHuric acid, phosphoric acid, and micronutrients were applied through the drip-line, which was primary source of N and P for latter half of life cycle. The Mesa farm location received two additional foliar chelated micronutrient sprays during the season and valley twice administered through drip. Plots were inspected weekly during growth and the following information was recorded during the season: emergence rate, plant height, stem diameter, flowering date, male flowers, and cannabinoid content during flowering (Tables 1, 2, 3 & 4).

Table 1. Mesa location data for Spring 2020 CBD variety trial.

Entry	Variety Name	Company Name	Photoperiod Type	Emergence (%)	Male (%)	Early Flowering (%)	50% Flowering (DAP)	Plant Height 60 DAP (IN)	Plant Height 123 DAP (IN)
1	Auto CBD	Phylos	DN	82	0	100	35	15.4	-
2	Auto Tune	Beacon Hemp	DN	98	0	100	35	17.5	-
3	SF/Auto V2	KLR	DN	94	0	100	35	11.0	-
4	Super Rich	United Global Partners	DD	95	5	1	123	23.4	41.3
5	Kino Vision	United Global Partners	DD	74	0	9	123	26.4	45.4
6	Early Spectrum	Beacon Hemp	DD	85	0	88	43	21.4	28.8
7	Z-1	Zoetic	DD	90	0	0	130	14.7	34.6
8	Z-2	Zoetic	DD	98	0	0	137	25.2	47.3
9	Z-3	Zoetic	DD	91	0	1	123	20.7	43.0
10	Z-4	Zoetic	DD	84	0	1	137	21.2	40.8
11	Z-5	Zoetic	DD	85	0	4	130	23.9	41.9
12	KLR_C5	KLR	DD	83	0	1	130	17.2	36.7
13	KLR_#1	KLR	DD	93	0	0	137	17.6	31.8
14	Queen Dream	Blue Forest Farms	DD	92	0	0	130	18.5	44.4
15	BCS_3	Black Canyon Seed	DD	92	14	23	123	24.3	45.1
16	BCS_9	Black Canyon Seed	DD	81	4	16	123	25.7	47.4
17	BCS_10	Black Canyon Seed	DD	83	0	45	116	25.5	44.6
	Average of DN			91	0	100	35	14.6	-
	Average of DD			88	2	13	122	21.8	40.9
	Total Average			88	1	29	106	20.6	40.0

Table 2. Valley location data for Spring 2020 CBD variety trial.

Valley									
Entry	Variety Name	Company Name	Photoperiod Type	Emergence (%)	Male (%)	Early Flowering (%)	50% Flowering (DAP)	Plant Height 60 DAP (IN)	Plant Height 123 DAP (IN)
1	Auto CBD	Phylos	DN	86	-	100	32	15.0	-
2	Auto Tune	Beacon Hemp	DN	89	-	100	32	17.6	-
3	SF/Auto V2	KLR	DN	91	-	100	32	12.0	-
4	Super Rich	United Global Partners	DD	78	-	0	132	24.0	46.5
5	Kino Vision	United Global Partners	DD	78	-	0	132	28.4	49.9
6	Early Spectrum	Beacon Hemp	DD	89	-	0	104	23.8	34.3
7	Z-1	Zoetic	DD	90	-	0	132	20.8	37.3
8	Z-2	Zoetic	DD	94	-	0	132	27.6	47.3
9	Z-3	Zoetic	DD	95	-	0	132	24.6	43.4
10	Z-4	Zoetic	DD	90	-	0	132	25.1	42.6
11	Z-5	Zoetic	DD	96	-	0	132	24.6	38.6
12	KLR_C5	KLR	DD	90	-	0	132	16.5	34.5
13	KLR_#1	KLR	DD	91	-	0	132	23.1	43.8
14	Queen Dream	Blue Forest Farms	DD	84	-	0	132	23.1	43.7
15	BCS_3	Black Canyon Seed	DD	85	-	0	132	28.0	46.2
16	BCS_9	Black Canyon Seed	DD	73	-	1	132	29.5	45.4
17	BCS_10	Black Canyon Seed	DD	85	-	1	132	28.9	47.3
	Average of DN			89	-	100	32	14.9	-
	Average of DD			87	-	0	131	24.9	42.9
	Total Average			87	-		113	23.1	42.9

Table 3. Mesa location data for harvest

Mesa															
Entry	Variety Name	Harvert Date (DAP)	Harvest Plant Height (IN)	Harvest Stem Diameter (IN)	Harvest Biomass Yield (lbs/plant)	Harvest Flower Yield (lbs/plant)	Harverst Index Flower to Stem Ratio	Flower Maturation (Days between 50% Flowering and Harvest)	Cannabinoid Maturation (Days from 50% Flowering to 0.3% THC)	CBD/ THC CAVG Ratio During flowering	Correlation Between Observed CBD and THC values	Estimated CBD value at 0.3% THC Compliance Level	Actual CBD value at 0.3% THC Compliance Level (linear equation)	Maximum Observed CBD (%)	Maximum Observed THC (%)
1	Auto CBD	73	16.1	0.4	0.09	0.07	0.9	73	23	19	0.89	5.7	7.2	9.3	0.50
2	Auto Tune	73	18.2	0.7	0.12	0.11	0.9	73	23	20	0.92	6.0	6.3	13.1	0.62
3	SF/Auto V2	73	12.4	0.6	0.10	0.09	0.9	73	23	19	0.99	5.7	6.2	13.8	0.77
4	Super Rich	170	50.0	1.0	1.12	0.63	0.6	170	14	16	0.85	4.8	4.3	7.7	0.48
5	Kino Vision	165	51.8	1.1	1.61	1.22	0.8	165	36	11	0.68	3.3	3.2	5.5	0.41
6	Early Spectrum	144	22.7	0.6	0.60	0.47	0.8	-	-	20	0.36	6.0	6.0	14.4	0.74
7	Z-1	165	36.8	0.5	0.63	0.38	0.6	165	-	15	0.97	4.5	5.5	4.9	0.28
8	Z-2	171	55.5	1.2	2.39	0.81	0.3	171	42	18	0.42	5.4	5.3	9.5	0.39
9	Z-3	168	43.7	1.2	1.17	0.84	0.7	168	21	15	0.75	4.5	2.8	11.7	0.61
10	Z-4	172	46.5	1.2	1.93	0.91	0.5	172	22	13	0.84	3.9	4.2	7.7	0.53
11	Z-5	170	46.5	.06	1.66	1.11	0.7	170	34	16	0.92	4.8	4.2	14.5	0.67
12	KLR_C5	162	41.5	1.2	1.35	0.84	0.6	162	-	-	-	-	-	-	-
13	KLR_#1	173	28.7	1.1	0.51	0.23	0.4	173	-	-	-	-	-	-	-
14	Queen Dream	170	51.2	1.2	1.97	1.06	0.5	170	14	14	0.97	4.2	4.0	11.2	0.76
15	BCS_3	168	51.3	1.1	1.99	0.77	0.4	168	7	12	0.45	3.6	2.2	14.0	0.93
16	BCS_9	163	49.3	1.2	1.58	0.76	0.5	163	9	17	0.69	5.1	3.0	12.7	0.83
17	BCS_10	167	43.6	1.1	1.60	0.97	0.6	167	63	9	0.67	2.7	3.8	5.4	0.45
	Average of DN	73	15.6	0.6	0.10	0.09	0.9	73	23	19.3	0.93	5.8	6.6	12.1	0.63
	Average of DD	166	44.2	1.0	1.44	0.79	0.6	168	26	14.7	0.71	4.4	4.0	9.9	0.59
	Total Average	150	39.2	0.9	1.20	0.66	0.6	150	25	15.6	0.76	4.7	4.5	10.4	0.60

Table 4. Valley location data for harvest

Valley															
Entry	Variety Name	Harvert Date (DAP)	Harvest Plant Height (IN)	Harvest Stem Diameter (IN)	Harvest Biomass Yield (lbs/plant)	Harvest Flower Yield (lbs/plant)	Harverst Index Flower to Stem Ratio	Flower Maturation (Days between 50% Flowering and Harvest)	Cannabinoid Maturation (Days from 50% Flowering to 0.3% THC)	CBD/ THC CAVG Ratio During flowering	Correlation Between Observed CBD and THC values	Estimated CBD value at 0.3% THC Compliance Level	Actual CBD value at 0.3% THC Compliance Level (linear equation)	Maximum Observed CBD (%)	Maximum Observed THC (%)
1	Auto CBD	66	15.1	-	0.05	0.04	0.81	34	68	24		7.2	5	5.0	0.39
2	Auto Tune	66	17.6	-	0.08	0.06	0.83	34	58	21		6.3	7.3	8.6	0.60
3	SF/Auto V2	66	12.0	-	0.05	0.04	0.88	34	58	19		5.7	7.3	7.2	0.54
4	Super Rich	168	54.1	1.4	1.66	0.54	0.32	36	-	-		-	-	-	-
5	Kino Vision	168	55.1	1.4	2.19	0.91	0.42	36	-	-		-	-	-	-
6	Early Spectrum	133	25.0	0.7	0.85	0.40	0.46	29	-	-		-	-	2.1	0.17
7	Z-1	-	-	-	-	-	-	-	-	-		-	-	-	-
8	Z-2	168	49.6	1.5	1.72	0.68	0.39	36	-	14	0.30	4.2	-	3.8	0.26
9	Z-3	168	46.9	1.0	1.20	0.52	0.43	36	-	17	0.14	5.1	-	14.4	0.67
10	Z-4	168	56.7	1.7	1.98	0.79	0.40	36	-	14	0.58	4.2	4.3	10.8	0.47
11	Z-5	168	53.4	1.4	1.88	0.72	0.39	36	-	-	-	-	-	-	-
12	KLR_C5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	KLR_#1	-	-	-	-	-	-	-	-	11	-	3.3	3.5	2.5	0.26
14	Queen Dream	168	46.9	2.1	3.31	1.50	0.45	36	-	-	-	-	-	-	-
15	BCS_3	168	46.3	1.0	0.85	0.25	0.30	29	-	18	-	5.4	4	4.0	0.31
16	BCS_9	168	52.1	1.4	1.85	0.57	0.31	36	-	13	-	3.9	-	2.4	0.17
17	BCS_10	168	50.0	1.2	1.26	0.42	0.33	36	-	-	-	-	-	-	-
	Average of DN	66	14.9	-	0.06	0.05	0.84	34	61	21	-	6.4	6.5	6.9	0.51
	Average of DD	165	48.7	1.4	1.70	0.66	0.38	35	-	15	0.34	4.4	3.9	5.7	0.33
	Total Average	144	41.5	1.4	1.35	0.53	0.48	35	61	17	0.34	5.0	5.2	6.1	0.38

Single plants from each of the 17 varieties' first replication were repeatedly sampled and analyzed for cannabinoid content at different dates through flowering (158 total samples). The same plant was used for each sampling event to minimize plant to plant variation, as irregular within variety bloom dates were observed. Ideally, this would have been an aggregate sampling, but plant to plant variation was severe. The current state and federal compliance sampling procedure of harvesting flowers, stems, and leaves from the top 6 inches of the plant was used (USDA, 2019). Sample material of each individual plant was dried at low temperatures (110 – 130°F) and grinded to a powder in a 'magic bullet' kitchen blender. CBD and THC cannabinoid content was determined in-house, with the Orange Photonics: Light Lab 2 - Hemp Compliance and CBD Flower modules (Orange Photonics Light Lab, 2020).

Harvest/yield selection criteria for individual plants was >90% shriveled flower stigmas. At the end of the season, individual plants from each plot of replications 2, 3, and 4 were hand harvested, air-dried, and the following measurements recorded: survivorship, plant height, stem diameter, aboveground biomass yield, and flower yield. Ten plants from each DN plot and all surviving plants in DD plots were harvested for yield.

Results and Conclusions

Crop Establishment

The first plants began to emerge from the ground 5 days after planting (DAP) at both locations. Differences in emergence rates among varieties were observed, with emergence averages ranging from 73 – 98% (Tables 1 & 2). Emergence trends for each variety were similar at both locations, indicating differences in seed quality, which could be further grouped by seed company. Further discussions with seed companies revealed differences in seed cleaning and selection techniques that could have impacted germination rates. Early season fast growth and excellent vigor were noted for all plots in both trials. Differences in plant height and stem diameter developed quickly among DD varieties and persisted throughout the season, indicating a wide genetic base and diverse phenotypic response to the Yuma environment.

Foliar symptoms of sodium stress were observed at 35 DAP at the valley location. Soil tests revealed a very high sodium level of 520 ppm at the valley location (data not shown). The DN group was more negatively impacted by sodium stress than the DD group. Sodium is known to aggregate near the soil surface, as water evaporates and leaves residues behind. It is possible that the DN strains were more affected because they had a more shallow root system than the DD strains that grew deeper into less saline ground. Use of acid-based soil amendments through the dripline was effective at neutralizing sodium toxicity symptoms by mobilizing sequestered soil calcium, which displaced sodium in the cation exchange, as well as created leachable sodium sulfate (Provin & Pitt, 2001; Weil & Brady, 2019). Another method for combating sodium toxicity consists of watering every other row, which pushes the salt line to one side of the bed, away from the central seed lines. Mesa location plants did not manifest any visible sodium damage, likely due to moderate sodium levels of 171 ppm.

Pest Pressure

Intermittent foliar chlorosis began to appear at 60 and 70 DAP at both locations. Soil tests confirmed sufficient levels of macro- and micronutrients were present. Presence of beet curly top virus (BCTV) (Nachappa, Chiginsky, & Hammon, 2020) was confirmed with molecular diagnostic tests based on polymerase chain reaction analysis conducted at the University of Arizona's Extension Plant Pathology Laboratory in Tucson (Hu, Masson, & Dickey, 2021; Hu, Masson 2021). Symptoms began as light green chlorosis of new growth, similar to sulfur deficiency, paired with dark green 'blotchy' mottling of older leaves. As the season progressed, Witches' Broom of new growth occurred, but was only isolated to individual branches of the plants, presumably, where infection occurred from a feeding site made by the only known vector, the beet leafhopper (Nischwitz & Olsen, 2011). No major difference was observed among varieties for resistance to BCTV (Table 5). Incidence started low and spread to a greater number of plants as the season progressed.

Vascular wilt, followed by rapid death, or 'dampening off' of randomly distributed plants within the trial, was first observed at 64 DAP at both locations. Symptoms began to spread to other plants and the presence of *Pythium aphanidermatum* 'Pythium crown and root rot', was confirmed with molecular diagnostic tests based on polymerase chain reaction amplification of marker gene fragments, conducted at the University of Arizona's Extension Plant Pathology Laboratory in Tucson (Hu, Masson, 2021). The valley location produced higher rates of mortality than the mesa field (Figures 2 & 3). Differences in survivorship were observed among varieties, with variety number eight providing the highest level of resistance at both locations, and entry five providing some resistance at the valley location (Figures 2 & 3). Pythium pressure was likely greater in valley soil because of wetter conditions caused by larger bed size, heavier soils, and increased irrigation events used to treat sodium toxicity. *Pythium aphanidermatum* is the most common Pythium in the low desert, and is most active in wet, warm, soils of summer (Olsen, 2011). Seed treatments and allowing soil to dry between irrigation events are effective measures in slowing fungi progression (Olsen, 2011). Measures should be taken to prevent this disease, as it caused significant crop loss across the state, with 100% loss in many fields (Figures 2 & 3). It is also important to note that CBD hemp flowers may have lower water-use requirements near harvest than other crops that set seed or produce high moisture fruit. Liquid-filled tensiometers and portable or in-situ digital moisture meters are recommended to facilitate reading moisture levels at various depths.

Several insect species were observed during the season Corn earworm *Helicoverpa zea*, beet armyworm *Spodoptera exigua*, striped flea beetle *Phyllotreta thomisidae*, beet leafhopper

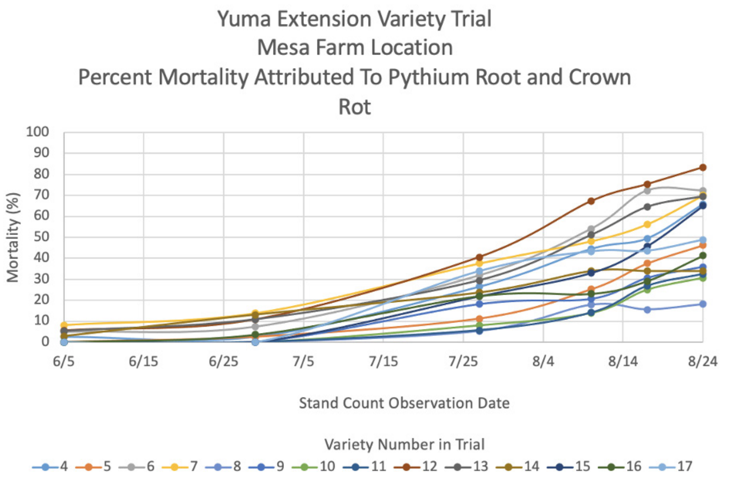

Figure 2 Mesa mortality

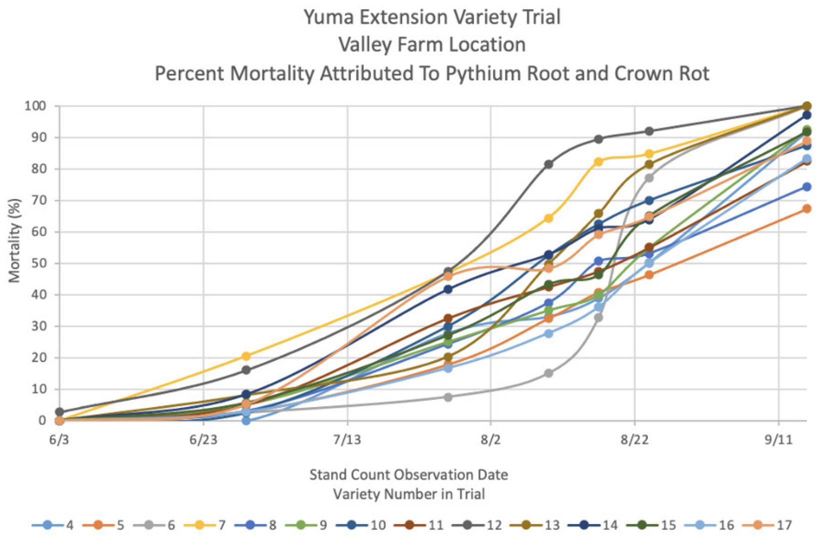

Figure 3 Valley mortality

Circulifer tenellus, and crab spider *striolata*. Small early flower damage done by feeding pests, such as corn earworm, appeared as larger blemishes as the flower grew in size, devaluing its ability to be sold as a smokable flower. Economic threshold levels are not entirely known, as discussions with growers indicated physical blemishes are somewhat inconsequential for mechanically processed and extracted CBD essential oils. Spiderwebs were also commonly seen in the trial, which also lessened the smokable flower value. Striped flea beetles took up residence in purslane *Portulaca* weeds bordering and inside the field at 117 DAP and were observed feeding on hemp leaves. Insecticide was used to control flea beetles, as the insect damage likely would have resulted in losses to crop yield.

Spring Flowering

Many of the DD plants at the mesa location began to prematurely flower around 30 DAP. Betweenlocation differences were observed for early flowering, with the mesa location experiencing earlier flowering, and valley hardly any, and only a difference in planting of five days.

At the mesa location, there was a great deal of difference within and among varieties. Three varieties showed high rates of early flowering (entries 6, 15, 17), six were partially affected (entries 7, 8, 9, 11, 12, 16) and five had no early blooms at all (entries 4, 5, 10, 13, 14). At the valley location, planted five days later, there were only two plants with early blooms in the entire field (Tables 1 & 2 and Figures 4 & 5). The differences in variety response to low photo-period indicate a genetic response that varies among varieties, which is useful in developing a maturity group system similar to other DD crops (Mourtzinis & Conley, 2017). The varying flower response to short days of early spring is helpful in formulating planting date recommendations. In Yuma, and perhaps other locations with identical latitude, when planting DD strains without supplemental lighting, it may be best to plant no earlier than April 7th, or risk premature flowering; however, this is highly cultivar dependent. It is also important to note that day lengths during this early flowering period at the mesa location were much longer than 12 hours (12.5 hours at emergence 5 DAP), dispelling the commonly held notion of hemp requiring a photoperiod of 12-hours or less to flower (Figures 1, 4, & 5). Greater than 50% flowering was observed on all the DN plants by 35 and 32 DAP, at mesa and valley locations, respectively.

Several weeks after early flowering, all of the six partially affected DD varieties reverted back to vegetative growth, but the three highly affected varieties retained flowers to some extent until final fall flowering (Figures 4 & 5). The lasting effects of changing back and forth between vegetative and flowering cycles are not entirely known, but are generally thought to negatively impact uniformity of growth and optimal yield. DN varieties showed very little among variety variation in flowering dates.

Fall Flowering

The summer solstice is the longest day of the year, occurring in Yuma, around June 20th and lasting 14.3 hours (Figure 1). After the summer solstice, photoperiods shorten and the plants begin the fall blooming cycle. At both locations, most plants began to flower near 103 DAP (July 14th) and increased to maximum levels near 144 DAP (August 24th), with an average DD DAP to >50% flowering of 122 and 131 days, at the mesa and valley locations, respectively (Tables 1 & 2 and Figures 4 & 5).

Differences were observed among varieties for flower initiation dates (Tables 1 & 2). Recording of flowering dates was terminated on 139 DAP (August 24th) at the valley location due

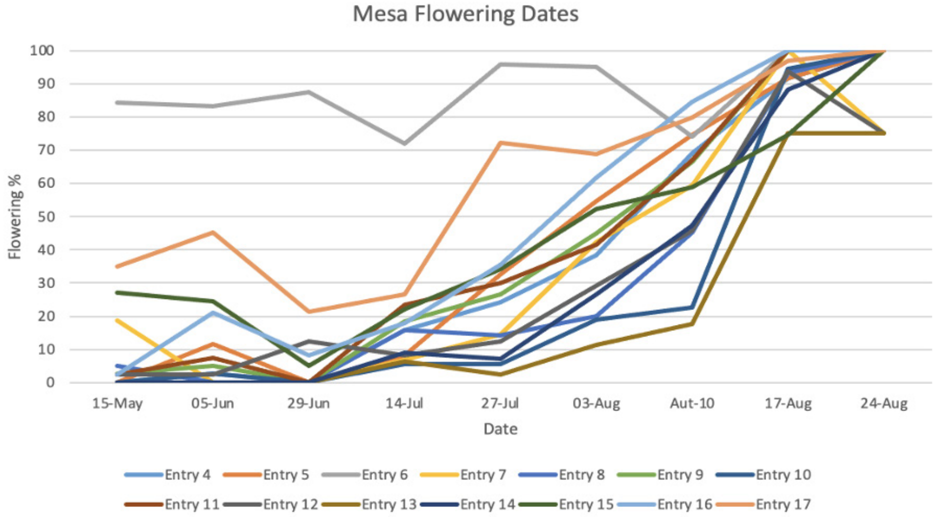

Figure 4 Mesa flower dates

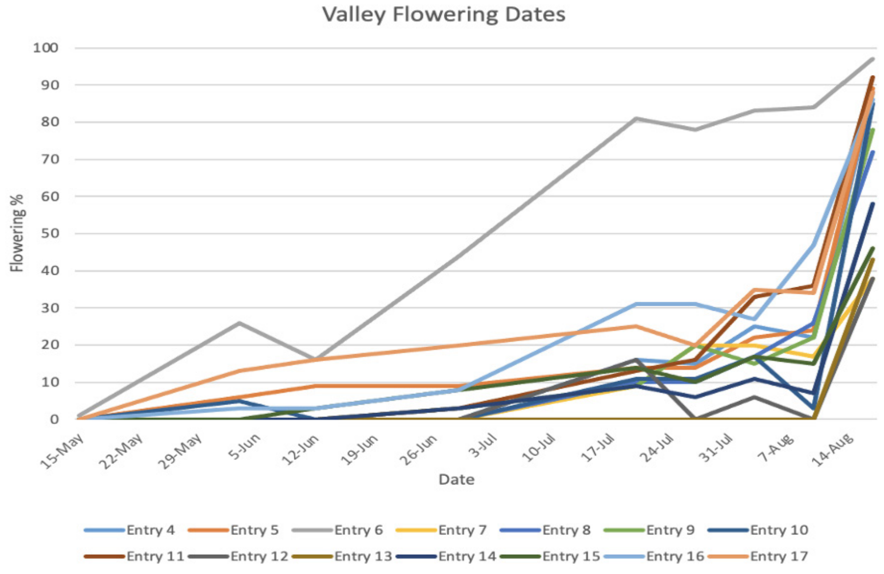

Figure 5 Valley flower dates

to high mortality rates. A high degree of variance was observed within varieties for flowering date (Figures 4 & 5); suggesting high degree of within variety genetic variation, residual effects of early season flowering and revegetation, and/or pathogen effects. Breeders should prioritize photoperiod sensitivity uniformity, in favor of breeding for high CBD levels, as yield is dictated by THC compliance and not maximum CBD. THC compliance would be easier to predict and attain with more uniform flower dates.

It is important to note that the three varieties that exhibited high rates of early spring blooming also showed early >50% fall flowering dates, further confirming a variety-specific response to photoperiod change (Figures 4 & 5). Entry number 6 bloomed much earlier than other DD varieties. Entry 6 pedigree was confirmed with a company representative as an, "F1 progeny of a DN and DD cross", which heavily influenced the 88% early spring bloom rate and earlier harvest than other varieties in the DD group.

Male flowering was only seen in three of the varieties grown: entries 4, 15, and 16 (Tables 1 & 2). The other varieties produced only female plants, a testament to the efficacy of the companies' feminization process. Sexing of plants at the valley station could not be completely accomplished because of high mortality.

Harvest Observations

Only 18% and 42% of plants were harvested from the valley and mesa locations, respectively, due to high preharvest mortality rates at both locations (Figures 2 & 3). Harvest occurred at 73 and 66 DAP for all DN varieties, and an average of 166 and 168 DAP for all DD varieties, at mesa and valley locations, respectively (Tables 3 & 4). DN harvest quality was far superior at the mesa location, which can be largely attributed to negative effects of sodium toxicity at the valley location. The valley location was harvested earlier than desired due to excessive disease pressure, causing much of the data from this location to not be recorded. Differences were observed in plant heights and stem diameters among varieties of both DN and DD groups, with average DD variety values ranging from 22 to 55 inches tall and 0.5 to 1.2 inches in diameter (Tables 1 & 2).

Yield weights were calculated on a per plant basis instead of per acre basis due to high mortality. Differences in total biomass and flower yield was observed among DN and DD varieties with DN entry number 2 and DD entry numbers 5, 11, and 14, producing higher yields than others within the same day length group (Tables 3 & 4). The harvest index ratio of flower to stem was calculated for each variety; smaller plants, such as the DN group, produced larger amounts of flowers per pound of total biomass than all of the larger DD varieties, averaging 0.9 and 0.6, respectively (Tables 3 & 4). Further research should be conducted to determine optimum DD/DN planting densities and dates that maximize harvest index values to reduce waste and increase harvest and processing efficiency.

Cannabinoid Production

Days to 'flower maturation' (flower initiation to >90% shriveled stigmas) and 'cannabinoid maturation' (flower initiation to 0.3% THC compliance level) varied among varieties, with average values of 40 and 25 days, respectively, indicating that THC levels rose above compliance levels well before the flower was physiologically mature (Tables 3 & 4). With a 25 day to non-compliance average it may be advisable to call or pre-schedule compliance inspection shortly after flower initiation, where hemp can be determined non-psychoactive, even when not at full maturity. The grower is then free to harvest within the prescribed 'days after inspection' date, currently set at 15 days for Arizona, with pending change to 30 days to meet federal recommendations (AZDA, 2020), (USDAAMS, 2021). Harvest indicators such as maturity should be used in conjunction with trichome color, and lab analysis. Some of the variance observed in this study in cannabinoid development might be attributed to variance in flowering date, observed within most varieties, as older flowering plants in the population produce higher cannabinoid concentrations than younger blooms (Tables 3 & 4).

CBD/THC ratios can be useful in predicting CBD levels at a given THC level. A mathematical model was developed based on different CBD/THC ratios to predict theoretical CBD levels at non-compliance (Figure 6). The chart uses the formula [(CBD/THC Ratio) = (Predicted CBD% / Predicted THC%)], which can be simplified as, (CBD/THC ratio*0.3 = Expected CBD) to predict CBD levels at THC compliance level. For example, using this model, a CBD/ THC ratio of 15, 20, 25, and 30 would have a maximum CBD level attainable of 4.5, 6.0, 7.5, and 9.0%, at the 0.3% compliance level, respectively. CBD/THC ratios were calculated for each sample tested (158 total samples) (Tables 3 & 4). The varieties with highest CBD/THC ratios were mostly found in the DN group, with an average in the 19 to 20 range; entries 6 and 8 produced the highest ratios in the DD group, much similar to those of the DN group (Table 3 & 4).

CBD and THC ratios appeared to be highly correlated to each other, on average, 71% in DD varieties and 93% in DN. Two DD entries produced values below 50%, and eight above 85%, indicating relative consistency of CBD/THC ratios at different stages of growth, in most varieties tested (Tables 3 & 4).

The CBD/THC ratio predictive model was evaluated against what was observed. CBD levels were compared at the 0.3% THC level for both groups (Tables 3 & 4). A paired T-test between the groups produced average values of 62% and 36%, at the mesa and valley locations, respectively. When the two entries exhibiting lowest CBD/ THC correlations (entries 6 & 8) were dropped from the mesa data, the same paired T-test results rose to 89%, indicating the CBD/THC ratio model may be a good predictor of harvest CBD levels if correlations between CBD and THC is high.

Table 5 Percent incidence of BCTV.

Entry	Variety Name	Company Name	BCTV Incidence (% of plants affected)			
			Mesa Location		Valley Location	
			64 DAP	116 DAP	66 DAP	111 DAP
1	Auto CBD	Phylos	-	-	-	-
2	Auto Tune	Beacon Hemp	-	-	-	.
3	SF/Auto V2	KLR	-	-	-	-
4	Super Rich	United Global Partners	7	60	28	46
5	Kino Vision	United Global Partners	4	44	21	66
6	Early Spectrum	Beacon Hemp	9	42	28	67
7	Z-1	Zoetic	0	40	23	48
8	Z-2	Zoetic	1	39	21	50
9	Z-3	Zoetic	3	41	33	44
10	Z-4	Zoetic	0	48	18	62
11	Z-5	Zoetic	9	49	23	42
12	KLR_C5	KLR	0	48	21	76
13	KLR_#1	KLR	0	54	26	71
14	Queen Dream	Blue Forest Farms	6	49	3	62
15	BCS_3	Black Canyon Seed	4	52	27	64
16	BCS_9	Black Canyon Seed	4	56	28	56
17	BCS_10	Black Canyon Seed	4	48	35	54

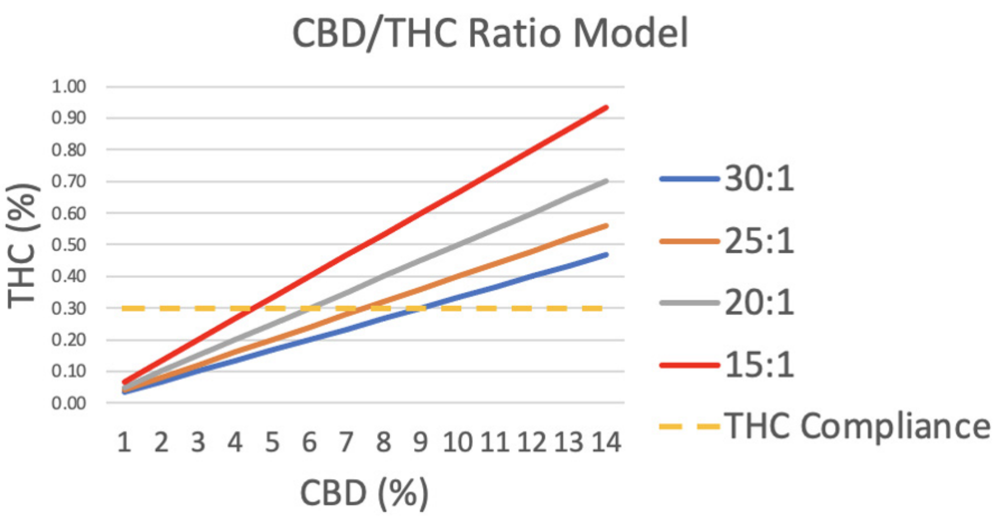

Figure 6: CBD:THC Ratio derived from the formula: [(CBD%/THC%) = (X/Y)], where X is the predicted CBD percentage level at the Y THC level.

Maximum CBD levels for each variety ranged from 5 to 14.4% and 2.1 to 7.2% at the mesa and valley fields, respectively. Maximum THC ranged from 0.28 to 0.93% and 0.17 to 0.67 % at the mesa and valley fields, respectively (Table 3 & 4). All varieties at the mesa location had maximum THC levels rise above 0.3%, indicating that careful monitoring of cannabinoid levels should be used to assist with harvest decisions to track the progress over time. It is also important to note that inspection date by the AZDA is critical, as there is a high degree of likelihood that late inspected flower will produce non-compliant THC levels within the 15 day post-inspection harvest period.

As more information is gathered about the production of CBD hemp, future efforts should be put into breeding plants that: match Arizona day lengths to prevent early flowering, increase pythium and BCTV disease resistance, and provide more uniform flowering dates to avoid THC non-compliance. This would increase yield and mitigate the heavy losses seen in this trial, and across the state, and in turn help to minimize grower risk.

Public recognition is deserved for the participating seed companies and Arizona Crop Improvement Association for fully funding this trial.

Works Cited

AZDA. (2020). Arizona Department of Agriculture - Industrial Hemp Program 2019 End of Year Report. Phoenix: AZDA. Retrieved from https://agriculture.az.gov/sites/default/files/AZDA-Hemp2019Report.pdf

AZDA. (2020, 12 25). Pesticide use on hemp. Retrieved from https://agriculture.az.gov/sites/default/files/Hemp%20-%20Pesticide%20Use_2.pdf

AZDA. (2021, March 31). Industrial Hemp Program. Phoenix, Arizona, USA. Retrieved from https://agriculture.az.gov/plantsproduce/industrial-hemp-program

Hu, J., Masson, R. (2021). Beet Curly Top Virus in Industrial Hemp. University of Arizona Extension Publication: AZ1931. Retrieved from https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1931-2021.pdf

Hu, J. Masson, R.(2021) Pythium Crown and Root Rot of Industrial Hemp. University of Arizona Extension Publication: AZ1868. Retrieved from https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1868-2021.pdf

Hu, J., Masson, R., & Dickey, L. (2021). First report of beet curly top virus infecting industrial hemp (Cannabis sativa) in Arizona. Plant disease, 105(4), 1233. https://doi.org/10.1094/PDIS-11-20-2330-PDN

Mourtzinis, S., & Conley, S. P. (2017). Delineating soybean maturity groups across the united states. Crop Ecology and Physiology, 109:4 1397-1403.

Nachappa, P., Chiginski, J., & Hammon, B. (2020). Colorodo State University. Retrieved from Beet Leafhopper and Beet Curly Top Virus: https://webdoc.agsci.colostate.edu/hempinsects/PDFs/Curly%20Top%20Beet%20Leafhopper%202020.pdf

Nischwitz, C., & Olsen, M. (2011). Beet curly top disease (Curtoviruses) in spinach and table beets in arizona. Arizona Cooperative Extension: Publication number AZ1522, https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1552.pdf.

Olsen, M. W. (2011). Dampening-off. Arizona Cooperative Extension Bulletin AZ1029, 1-2.

Orange Photonics Light Lab. (2020, 12 28). Retrieved from https://www.orangephotonics.com/

Provin, T., & Pitt, J. L. (2001, 7). Managing soil salinity. Retrieved from Texas A & M Extension: https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/86985/pdf_1397.pdf?sequence=1

USDA. (2019, 10 31). Sample Guidelines for Hemp Growing Facilities. Retrieved from USDA Agricultural Marketing Service: https://www.ams.usda.gov/sites/default/files/media/SamplingGuidelinesforHemp.pdf

USDA-AMS. (2021, 10 31). Establishment of a Domestic Hemp Program. Retrieved from https://www.federalregister.gov/documents/2019/10/31/2019-23749/establishment-of-a-domestic-hemp-production-program

Weil, R. R., & Brady, N. C. (2019). Elements of the Nature and Properties of Soils: 4th Ed. Pearson Education Inc. Pg: 362

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