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Cultivar Check Program Final Report

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Introduction

Hemp legalization has provided a unique opportunity to build an entirely new agriculture sector across food, fiber, and floral markets. Despite an overwhelming interest in hemp, there remains substantial uncertainty regarding agronomic best management practices for various types of hemp production. Additionally, concerns over regulatory compliance among the cultivars grown across the region poses additional challenges for growers. To address these issues, the Midwestern Hemp Research Collaborative (MHRC), a joint effort of land grant universities, non-profits, private laboratories and growers was formed. The MHRC conducts collaborative hemp research and outreach and maintains the Midwestern Hemp Database (MHD), which has become the largest public repository in the U.S. for information on hemp cultivar performance. This report will summarize findings from cooperative research trials which evaluated CBD-dominant/Chemotype III and CBG-dominant/Chemotype IV (Pacifico et al., 2007 and Fournier et al., 2006) hemp cultivars across the 2021-2024 growing seasons via the Cultivar Check Program (CCP).

Cultivar Check Program Overview

Established via a USDA Sustainable Agriculture Research and Education (SARE) Partnership Grant (2021-2025), the CCP operated as a series of participatory on-farm trials using an extensive grower-cooperator network across the Midwest. The main objective of these cultivar trials was to obtain data on the performance of high cannabinoid hemp cultivars across a range of latitudes/hardiness zones. Due to the infancy of the industry, a set of criteria were used to classify specific cultivars as "good potential." Criteria have evolved over time in response to industry and grower needs, but have included expected flowering dates, uniformity, overall performance, and cannabinoid production. A detailed list of these criteria can be found in previous CCP reports which are cited in the Resources/Additional Information section. Cultivars were chosen annually to be evaluated via the grower network based on prior performance, seed availability and grower/supplier interest.

All data generated from the Cultivar Check Program is currently available via the MHD and can be found at: https://cropsandsoils.extension.wisc.edu/midwestern-hemp-database/

Over the 2021-2024 growing seasons, the CCP has:

- Conducted trials via grower and researcher partnerships.
  - 89 Site-Years
  - 4 States
- Evaluated 52 high cannabinoid hemp cultivars for agronomic performance, disease resistance, and cannabinoid development.
  - 49 CBD-Dominant (Chemotype III)
  - 3 CBG-Dominant (Chemotype IV)
- Analyzed over 1621 samples for cannabinoids via partnership with Rock River Laboratories Inc.

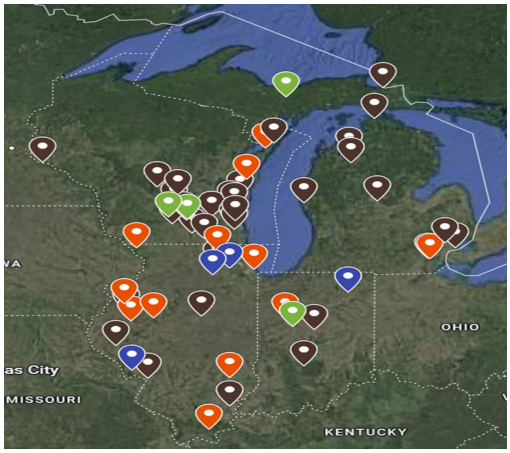

Figure. 1. Map showing geographic location of sites for MHD Cultivar Check Program. Brown represents sites with 1 site-year only, Orange represents 2 site-years, Blue represents 3 site years, Green represents 4 site-years.

Materials and Methods

Licensed hemp growers across the Midwest (Michigan, Illinois, Indiana, and Wisconsin) were recruited to participate in the CCP across the 2021-2024 growing seasons. Each grower received a subset of cultivars consisting of CBD Dominant (Chemotype III) and/or CBG Dominant (Chemotype IV) cultivars. Seedlings were established in late April or early May in indoor/greenhouse settings, and were allowed to develop in a greenhouse/hoop house for 4-5 weeks prior to a "hardening-off " period. Following a one week hardening-off period ~15 healthy, representative seedlings from each cultivar were transplanted into the field in early to mid-June according to field conditions. Growers were encouraged to utilize their own protocols for seed starting/transplanting, but the established production timelines were to be followed. Growers were responsible for submitting photographs, management updates, and performance data via SeedLinked®.

In addition to specific production milestones (seed start date, transplant date, flowering date, etc.), agronomic performance indicators (germination, uniformity, disease resistance, and overall performance) were rated on a scale from 1 to 5. Growers were provided a semi-quantitative guide to assist with their ratings. Flowering was confirmed visually via photographs by one of the project collaborators and a sampling schedule was developed. To ensure accuracy, growers were required to verify the terminal flowering date for each cultivar with the research team via SeedLinked®. Following confirmation of flowering for each cultivar, growers submitted floral samples for cannabinoid analysis at three time points: 3 weeks, 5 weeks, and 7 weeks post flower initiation (~21 days, 35 days, and 49 days, respectively). For sampling, growers followed the USDA sampling guidelines, collecting 5-8 inches of floral tissue from the top third 5 randomly selected plants for each cultivar at each sampling time point. The 5 flowers were placed into one bag to generate one composite sample per cultivar at each time point. Floral material was collected from the same plants throughout the sampling period. Floral material was sent to Rock River Laboratories (Watertown, WI) for analysis of cannabinoid potency using high-performance liquid chromatography (HPLC). Total THC = Δ9 THC + (THCA*0.877), Total CBD = CBD + (CBDA*0.877), and Total CBG = CBG + (CBGA*0.878).

Statistical Analysis of Data

The tables on the following pages have been prepared with the entries listed alphabetically and then by cannabinoid development/compliance categories (Table 1). Average values for cannabinoids at each time point were determined and used to create compliance categories based on weeks into flowering. This was done in an attempt to simulate Performance-Based Sampling standards in accordance with USDA guidelines. Qualitative traits (germination, uniformity, vigor, and overall performance) are not discussed in this report but summary data for each cultivar is currently available via the MHD.

Results/Discussion

The information synthesized from these trials marks a significant increase in regional hemp knowledge and is an important step towards successful adaptation of hemp as a viable crop option for Midwestern farmers. In an effort to be concise, only cultivars with n>5 samples per time point will be shown in this report. An annotated list of the cultivars, the source of seed, and number of samples evaluated at each time point can be found in Table 2. For a complete set of cultivar performance and compliance data, please visit the MHD.

Cannabinoid Development

For CBD-dominant (Chemotype III) cultivars, both Total THC and Total CBD increased throughout the flowering period (Figure 2 and Figure 3). Total THC and Total CBD were both significantly impacted by cultivar and sampling period (P<2.00e-16); however the interaction between cultivar and sampling period for both cannabinoids was not significant. Individual cultivar performance varied, but average values for Total THC and Total CBD at Week 7 post-terminal flower initiation were 0.33% and 8.26%, respectively. Most CBD-dominant hemp cultivars currently on the market will go "hot" (Total THC 0.3%) if not monitored during flowering. To illustrate, 28 (57%) of the 49 CBD-dominant cultivars evaluated via the CCP exceeded the regulatory limit at some point during the flowering period (Source: MHD). CBD:THC was impacted by sample timing (Figure 4 and Table 1). Most CBD-dominant cultivars did not exceed a CBD:THC of ~27:1 and are thus not able to achieve greater than ~8% Total CBD without exceeding the threshold of 0.3% Total THC (Alberti 2021 and MHD).

For CBG-dominant (Chemotype IV) cultivars, both Total THC and Total CBG increased throughout the flowering period (Figure 2 and Figure 3). Total THC and Total CBG were impacted by cultivar (P<.003 and P<2.21e-16, respectively) and sampling period (P<.001 and P<1.29e-7); however, the interaction between cultivar and sampling period for both cannabinoids was not significant. CBG:THC was slightly impacted by sample timing, but remained relatively consistent throughout the flowering period (Table 1). None of the three CBG-dominant cultivars exceeded the THC threshold for compliant hemp by the week 7 sampling period. CBG-dominant cultivars may therefore provide an alternative cropping option for those looking to reduce risk of non- compliance compared to production of CBD-dominant cultivars.

Previous reports suggest that cannabinoid production (CBD:THC) remains stable throughout flowering for uniform cultivars (Campbell et al., 2019; Toth et al., 2021). These variable ratios reported here throughout flowering (CBD:THC and CBG:THC) may be due to several factors. For instance, low levels of THC produced early in flowering (prior to or at Week 3, for example) may result in false negatives/ non-detect values for THC; these conditions can skew cannabinoid ratios resulting in abnormally large or null values. Limitations with instrument detection sensitivity of compounds at very low concentrations only increase the potential for this situation to occur.

As cultivars exhibit unique optimal harvest intervals for both compliance and profit potential, data from the 2021-2024 growing seasons has been utilized to develop estimated harvest/compliance schedules for Total THC (%) (Table 2); this decision was made to emulate the potential development of performance- based sampling guidelines per the USDA Final Rule. In order to adequately account for laboratory variation, a measurement of uncertainty (MoU) is included in these requirements. Rock River laboratory utilizes a limit of quantification (LOQ) of 0.02% for Total THC. Thus, a threshold of 0.32% (0.30% +0.02%) will be used as the threshold for compliance when establishing compliance schedules (Table 2).

Agronomic Performance

Differences in photoperiod and heat unit accumulation can have an impact on flowering dates. Considering these factors, and the large geographic range involved these trials, agronomic performance ratings (flowering date, germination, uniformity, overall performance etc.) will not be discussed in this report. Additionally, not all cultivars have been evaluated equally across sites, resulting in an imbalanced data set. Rather, interested parties are encouraged to visit the MHD, which will allow users to select various parameters (state of production, latitude, cannabinoid of interest, etc.) to refine the dataset to answer critical agronomic performance questions. University station trials may be more useful/accurate sources of information for yield metrics and will not be discussed here (Ellison et al., 2021; DeDecker et al., 2021).

Weeks After Flowering	Cannabinoid of Interest/ Chemotype	Total THC (%) Avg.	Total CBD (%) Avg.	CBD:THC Avg.	Total CBG (%) Avg.	CBG:THC Avg.	Number of Samples
3	CBD/Type III	0.19c	4.12c	21.85c	-	-	489
5	CBD/Type III	0.26b	6.13b	24.78b	-	-	449
7	CBD/Type III	0.33a	8.26a	26.68a	-	-	453
3	CBG/Type IV	0.06c	-	-	4.32c	71.29b	81
5	CBG/Type IV	0.09b	-	-	6.05b	81.15a	77
7	CBG/Type IV	0.12a	-	-	7.29a	71.69b	71

Table 1. Average values and standard deviation for various cannabinoids (Total THC, Total CBD, and Total CBG) for all CBD and CBG-dominant cultivars entered into the Cultivar Check Program across the 2021-2024 growing seasons.

Recommendations

Growers will want to consider Table 2 when making cultivar selections and both sampling and harvest timing to retain compliance. It should also be noted that seed certification standards in the hemp industry are still being developed and as such, some cultivars exhibit heterogeneity across and within lots that can make agronomic performance and cannabinoid development less predictable. Due to potential non- uniformity of the flowering process across and within cultivars, individual plants could reach maturity at different points in the growing season; this could have adverse impacts on cannabinoid levels as well as testing and harvesting strategies at the field level. Lastly, growers are encouraged to develop relationships with seed providers and to look to university published resources to guide their selections.

Cultivar	Seed Provider	Cannabinoid of Interest/ Chemotype	Weeks After Flowering	CBD:THC	Total CBD (%) Avg.	Total CBG (%) Avg.	Total THC (%) Avg.	Total THC (%) Std.	Number of Samples
Abacus	Arrowhead Seed Co.	CBD/Type III	3	21.85	5.82	0.36	0.27	0.07	9
			5	23.28	9.16	0.55	0.39	0.07	8
			7	24.56	11.21	0.52	0.46	0.07	5
ArkRyder	High Grade Hemp Seed	CBD/Type III	3	21.51	3.27	0.85	0.18	0.09	6
			5	28.48	6.69	0.80	0.28	0.11	6
			7	33.98	7.76	0.98	0.30	0.11	5
BaOX Hybrid	Arrowhead Seed Co.	CBD/Type III	3	26.00	3.49	0.19	0.10	0.08	17
			5	28.70	5.16	0.18	0.16	0.09	12
			7	29.33	8.13	0.32	0.29	0.15	15
Badger 5	Wisconsin Crop Innovation Center	CBD/Type III	3	30.80	4.35	0.23	0.15	0.07	11
			5	23.79	5.76	0.30	0.25	0.14	12
			7	26.80	8.66	0.40	0.33	0.10	44
Blue Merengue	High Alpine Genetics	CBD/Type III	3	31.09	3.78	0.31	0.17	0.11	7
			5	29.26	4.65	0.38	0.21	0.11	6
			7	30.78	7.85	0.42	0.31	0.10	7
Buffalo Soldier	KifCure	CBD/Type III	3	2.97	0.07	4.82	0.02	0.02	14
			5	0.55	0.01	6.05	0.02	0.02	14
			7	0.13	0.01	9.43	0.08	0.08	11
Cherry Blossom	Blue Forest Farms	CBD/Type III	3	21.97	4.75	0.48	0.23	0.11	16
			5	22.03	6.38	0.65	0.28	0.13	17
			7	23.76	8.43	0.44	0.36	0.13	16
Cherry Wine	Cheyenne Mountain Seed Co.	CBD/Type III	3	20.79	4.03	0.33	0.21	0.09	15
			5	24.41	6.14	0.42	0.25	0.08	14
			7	24.32	6.61	0.36	0.27	0.09	11
Early Cherry	Beacon Hemp	CBD/Type III	3	21.34	3.40	0.31	0.15	0.06	10
			5	20.67	5.65	0.45	0.28	0.09	10
			7	29.79	7.78	0.54	0.30	0.14	10
Early Nueve	Beacon Hemp	CBD/Type III	3	21.94	5.01	0.23	0.22	0.08	19
			5	26.15	6.78	0.26	0.27	0.12	18
			7	26.41	10.01	0.35	0.39	0.14	16
Early Remedy	Beacon Hemp	CBD/Type III	3	23.99	4.18	0.35	0.19	0.07	16
			5	22.90	5.91	0.45	0.26	0.07	14
			7	26.00	8.08	0.56	0.32	0.09	15
Early Spectrum	Beacon Hemp	CBD/Type III	3	19.65	3.86	0.55	0.20	0.09	15
			5	21.50	6.51	0.42	0.31	0.14	15
			7	23.15	8.17	0.43	0.36	0.12	16
EliRae	High Grade Hemp	CBD/Type III	3	17.54	3.34	0.53	0.19	0.11	5
			5	25.19	6.90	0.77	0.35	0.25	6
			7	20.75	8.24	0.71	0.41	0.12	6
Hawaiian Haze	Oregon CBD	CBD/Type III	3	20.53	4.99	0.34	0.24	0.10	16
			5	22.14	7.52	0.44	0.34	0.11	15
			7	22.91	7.65	0.43	0.33	0.13	17
Legendary Platinum	High Alpine Genetics	CBD/Type III	3	22.90	4.51	0.40	0.20	0.09	16
			5	27.42	6.03	0.44	0.25	0.11	14
			7	29.60	8.27	0.49	0.31	0.13	14
Lifter	Oregon CBD	CBD/Type III	3	20.93	5.61	0.35	0.27	0.08	15
			5	22.03	8.37	0.44	0.37	0.13	16
			7	24.07	10.41	0.48	0.43	0.14	14

Table continues on the following page

Cultivar	Seed Provider	Cannabinoid of Interest/ Chemotype	Weeks After Flowering	CBD:THC	Total CBD (%) Avg.	Total CBG (%) Avg.	Total THC (%) Avg.	Total THC (%) Std.	Number of Samples
Matterhorn CBG	High Grade Hemp Seed	CBG/Type IV	3	3.37	0.14	2.22	0.05	0.03	12
			5	2.66	0.18	3.85	0.08	0.04	12
			7	3.16	0.16	4.21	0.08	0.04	12
Mountain Mango	Cheyenne Mountain Seed Co.	CBD/Type III	3	19.66	2.79	0.21	0.14	0.03	9
			5	23.30	4.55	0.26	0.19	0.08	12
			7	21.15	4.04	0.22	0.19	0.04	6
Oregon Guava	East Fork Cultivars	CBD/Type III	3	21.21	3.56	0.31	0.17	0.08	9
			5	23.15	5.36	0.33	0.24	0.11	8
			7	28.27	5.92	0.32	0.25	0.10	10
Oregon Sweetgum	East Fork Cultivars	CBD/Type III	3	18.02	3.24	0.28	0.17	0.08	9
			5	24.93	5.29	0.40	0.22	0.09	8
			7	22.90	7.15	0.37	0.31	0.11	8
Pineapple Kush	East Fork Cultivars	CBD/Type III	3	22.01	5.00	0.37	0.23	0.10	17
			5	21.05	6.26	0.43	0.30	0.15	16
			7	21.40	7.99	0.47	0.38	0.12	17
Queen Dream	Blue Forest Farms	CBD/Type III	3	22.42	4.26	0.30	0.19	0.05	25
			5	22.22	5.86	0.40	0.28	0.12	23
			7	27.12	7.59	0.40	0.32	0.14	23
Quick Kush	Cheyenne Mountain Seed Co.	CBD/Type III	3	21.26	4.05	0.29	0.19	0.06	14
			5	22.91	5.59	0.42	0.25	0.12	14
			7	24.59	7.09	0.32	0.29	0.13	10
Sour Pineapple	East Fork Cultivars	CBD/Type III	3	20.75	4.54	0.36	0.21	0.09	14
			5	23.90	5.95	0.38	0.25	0.09	11
			7	31.78	7.09	0.39	0.30	0.14	11
StemCell CBG	Oregon CBD	CBG/Type IV	3	2.02	0.19	4.29	0.09	0.05	23
			5	1.05	0.12	5.50	0.10	0.04	21
			7	0.92	0.11	6.65	0.14	0.07	18
Super Wife	Trilogene Seed Co.	CBD/Type III	3	20.00	3.12	0.26	0.15	0.05	11
			5	24.31	6.21	0.40	0.25	0.06	6
			7	23.33	7.98	0.42	0.35	0.11	5
Superwoman	Trilogene Seed Co.	CBD/Type III	3	18.31	3.12	0.27	0.18	0.09	8
			5	31.13	4.83	0.32	0.18	0.05	7
			7	28.93	8.25	0.41	0.29	0.06	5
Suver Haze	Oregon CBD	CBD/Type III	3	23.43	5.57	0.31	0.23	0.10	34
			5	28.58	8.63	0.34	0.34	0.12	32
			7	24.97	11.12	0.39	0.45	0.15	28
Sweet Wife	Trilogene Seed Co.	CBD/Type III	3	23.91	2.73	0.25	0.12	0.05	10
			5	27.47	5.12	0.37	0.23	0.11	8
			7	27.40	6.60	0.36	0.24	0.07	6
White CBG	Oregon CBD	CBG/Type IV	3	1.47	0.10	4.92	0.07	0.05	32
			5	0.46	0.05	7.32	0.13	0.10	30
			7	0.47	0.08	8.12	0.15	0.13	30

Table 2. Table showing cannabinoid concentrations Total THC (%), Total CBD (%), and Total CBG (%) over time from cultivars entered into the MHD Cultivar Check Program. Colors used to indicate compliance potential at various flowering intervals: Red (compliance through week 3), Yellow (compliance through week 5), and Green (compliance through week 7). For these purposes, compliance is defined as having an average Total THC < 0.32%.

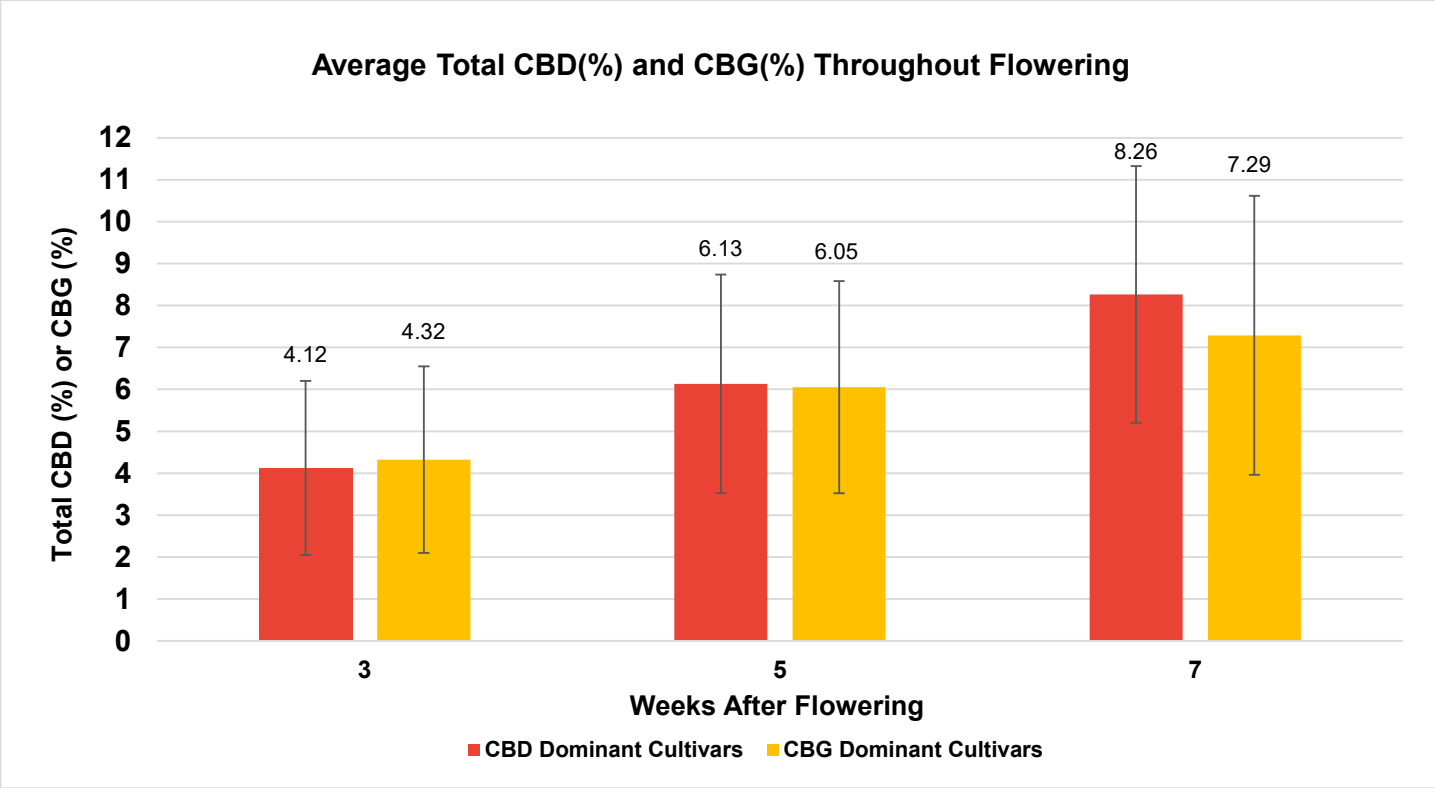

Figure 2. Total CBD (%) and CBG (%) accumulation at 3, 5, and 7 weeks after flowering from cultivars evaluated within the Cultivar Check Program. Data is presented in terms of averages across all locations at each time point as shown in Table 1. Red bars signify CBD-dominant cultivars while yellow bars signify CBG-dominant cultivars.

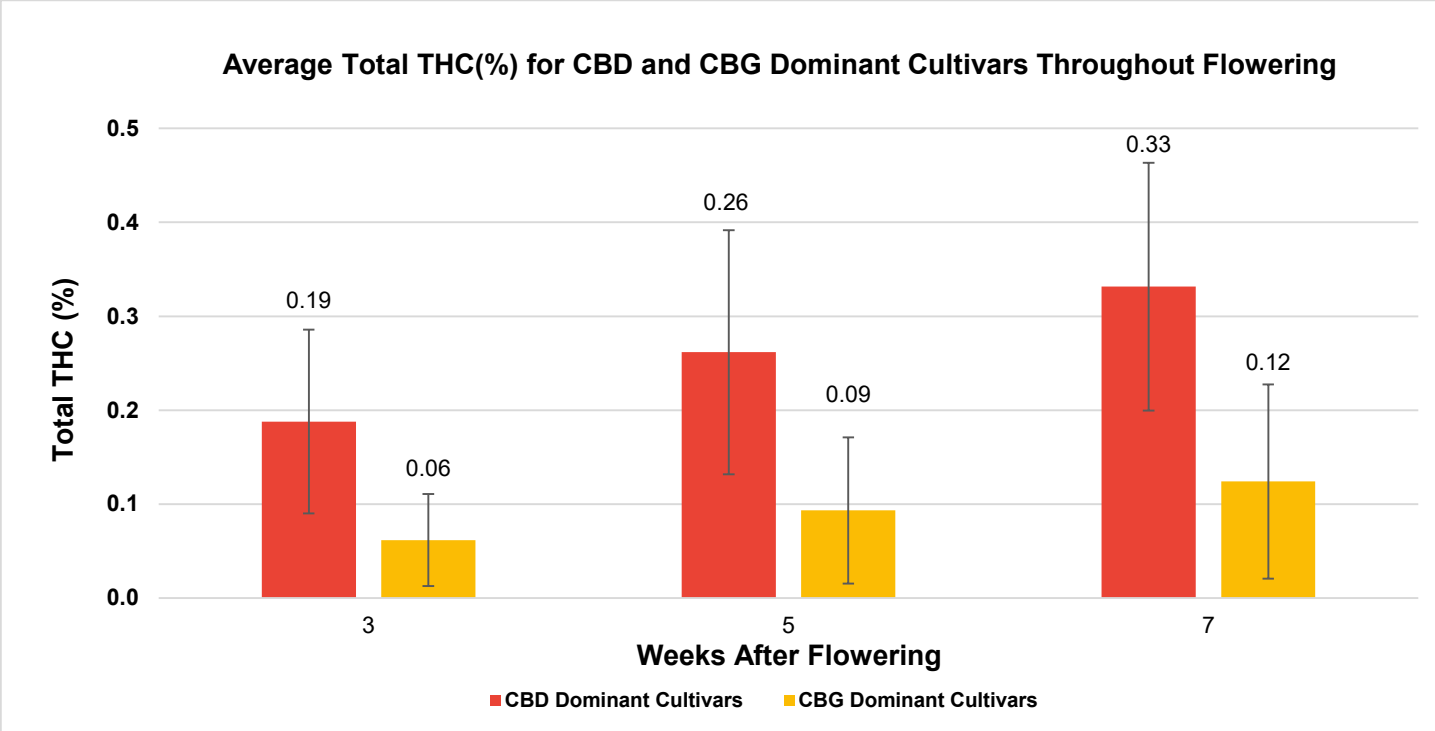

Figure 3. Total THC (%) accumulation at 3, 5, and 7 weeks after flowering from cultivars evaluated within the Cultivar Check Program. Data is presented in terms of averages across all locations at each time point as shown in Table 1. Red bars signify CBD-dominant cultivars while yellow bars signify CBG-dominant cultivars.

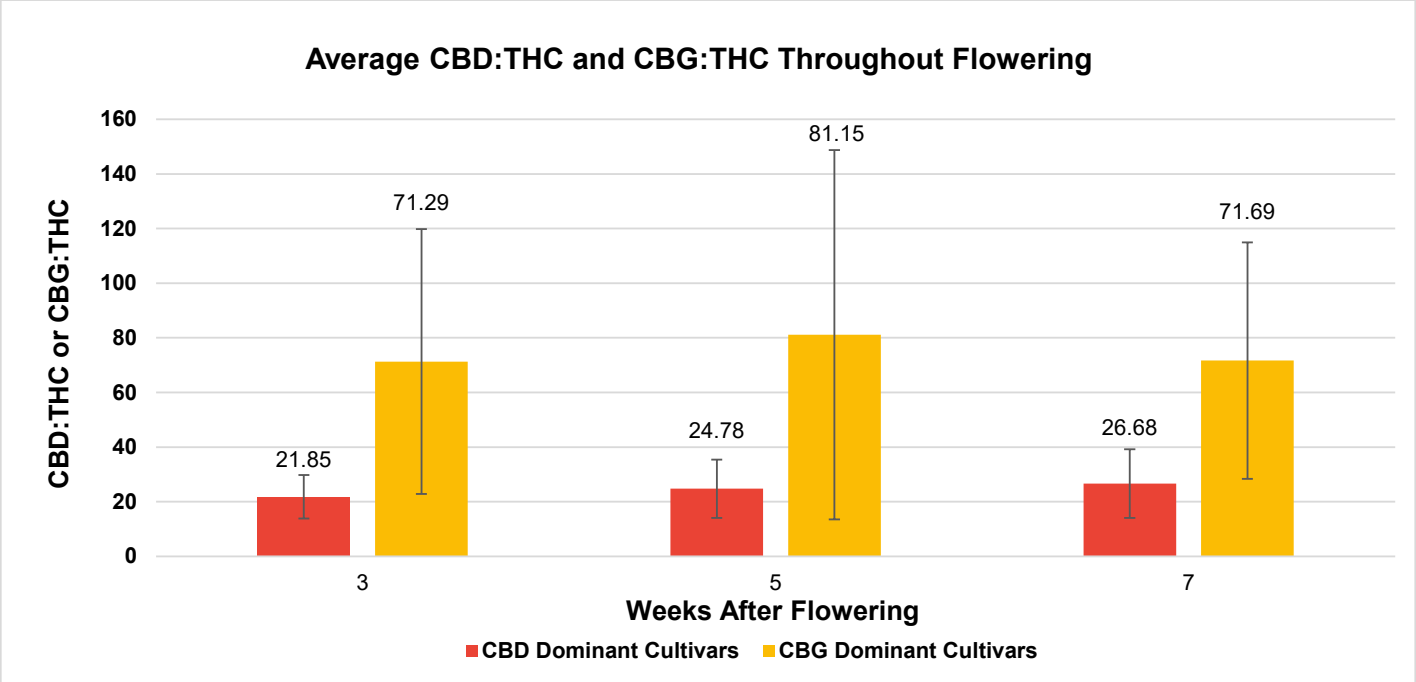

Figure 4. CBD:THC and CBG:THC at 3, 5, and 7 weeks after flowering from cultivars evaluated within the Cultivar Check Program. Data is presented in terms of averages across all locations at each time point as shown in Table 1. Red bars signify CBD-dominant cultivars while yellow bars signify CBG-dominant cultivars.

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