THE UNIVERSITY OF ARIZONA
Cooperative Extension

az1944 September 2021

CBD Hemp Production in Arizona

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Introduction

The 2018, the 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 production 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, as illustrated in Table 1 (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 formally summarize production considerations of this crop when it is grown in the arid desert southwest climate of Arizona, with particular emphasis on the commercial production systems of Yuma County, Arizona.

Variety Classification

Within the *Cannabis* genus there are three generally recognized 'landrace species': *indica*, *sativa*, and *ruderalis* that can be identified by genetic marker analysis, area of origin, and physical morphology (Hillig, 2005) (Hummer & Hancock, 2015). The *indica* species is reported to originate from Central and Eastern Asia and generally has a compact and 'bushy' appearance. The *sativa* is thought to originate from Europe, Asia Minor, and Central Asia, and typically grows tall and thin. The r*uderalis* species originates from northern latitudes of Eastern Europe and is typically significantly shorter in height than the other two species (Hillig, 2005). All three have annual lifecycles with physiologically distinct vegetative and flowering maturity stages. Flowering of daylength-dependent (DD) *indica* and *sativa* is initiated by short-daylengths (season change), while *ruderalis* flowers a certain number of days after

Table 1: Statewide planting acreage of hemp in Arizona, reported by the AZDA.

Statewide Grower Data	2019	2020
Acres planted	5,430	
Acres inspected near harvest	3,898	1,222
Harvest lots sampled	227	290
Samples passed	154	153
Samples non-compliant	73	136
Percentage of acres non-compliant	25%	47%
Percentage of acres non-compliant after remediation or retest	20%	39%

planting, known as daylength-neutral (DN) flowering (Halll, Bhattari, & Midmore, 2012) (Hillig, 2005). All three species are capable of interbreeding, and varieties, or 'strains', often consist of a mixed pedigree (Hillig, 2005). Selection of DD or DN strains will strongly influence agronomic and production considerations, such as planting date and growing season, as well as yield expectations.

Cannabis strains are further classified by their intended use. Breeding efforts have created plants specialized in producing grain (seeds), fiber (stem), or cannabinoid essential oils (THC and cannabidiol (CBD) in the flowers used medicinally or recreationally. (Pacifico D., Miselli, Carboni, Moschella, & Mandolino, 2008). Cannabinoid varieties are further classified by the quantity of THC and CBD produced (Hillig, 2005) (Toth, et al., 2019) (Sanchez, Baltensperger, & Kurouski, 2020). An example of a THC dominant strain is 'White Widow', a Dutch developed *sativa / indica* F-1 hybrid, that has an average THC level of 16-20% by dry weight, with nominal CBD levels (Leafly, 2021). CBD dominant strains such as 'Lifter', an Oregon developed *sativa / indica* F-1 hybrid, may have nominal THC levels and average CBD levels of 16% or greater (Leafly, 2021). Visually, THC and CBD dominant strains are identical and currently can only be differentiated through laboratory analysis during the flower maturation growth stage.

Legal Considerations

Cannabinoid production is strictly regulated by both the federal and individual state governments, as the complete effects of CBD on human health are not entirely known, and THC is currently considered a schedule I drug with "no currently accepted medical use and high potential for abuse" (DEA, 2020). Each state and Native American tribal government is responsible for creating their own hemp production guidelines, which are transitioning towards compliance with the newer federal law, issued by the USDA Agricultural Marketing Service (USDA-AMS, 2021). They may also turn this authority to the USDA if they so choose. Legal differentiation of 'hemp' (grain, fiber, CBD) from federally illegal 'marijuana' (THC) occurs when 'potential THC' levels exceed 0.3% by dry weight of sampled material. Potential THC is the measurement of psychoactive THC-Delta-9, and THCa, which is not psychoactive itself but a precursor to psychoactive THC-Delta-9, which becomes fully converted with heat or combustion. The mathematical formula used to calculate potential THC is: $[((THCa*0.877)+\Delta 9THC)]$. When levels exceed 0.3% potential THC, the non-compliant crop is reclassified as marijuana and must be destroyed or 'remediated' through bulk homogenization, which is the blending of lower value stems and leaves with the cannabinoid laden flower, making a less desirable product.

Seed Selection

Because THC and CBD dominant strains cannot be identified before flowering, and the consequences for THC compliance violation are so high, it is critical to ensure high quality seed is acquired from a reputable source. Certificates of Analysis (COAs) are issued with seed purchases listing the cannabinoid profile of parent material and expected behavior of progeny. Discrepancies between COAs and grower outcomes often occur for a wide range of reasons, some of which will be described more thoroughly in the subsequent pages of this publication. Traditionally, third party and government entities are used to vet seed varieties in the regions where they will be grown, which helps to manage grower expectations with more precision. Growers should ask their suppliers about participation in seed certification programs and local research trials, specifically requesting validation through established organizations used in the seed industry, such as: Association of Official Seed Certifying Agencies (AOSCA), European Seed Certification Agencies Association (ESCAA), and state institutions like the Arizona Crop Improvement Association (ACIA).

Cannabis varieties are either dioecious (separate male and female plants) or monecious (male and female on the same plant) (Amaducci, Colauzzi, Zatta, & Venturi, 2008). Although cannabinoid production occurs in both male and female plants, it is far more abundant in the capitate glandular trichomes (specialized hair-like structures) lining the exterior of unpollinated dioecious female flower buds and leaves (Mahlberg & Kim, 2004). Male flowers do not produce suitable levels of cannabinoids for production and are not desired within a CBD planting because they take up space where a female plant could be, and the fertilization process causes a reduction in cannabinoid levels in females, as energy is redistributed towards seed production (Mahlberg & Kim, 2004). Because growers desire virgin female flowers for cannabinoid production, all CBD varieties are dioecious, and male plants are eliminated whenever possible.

The ratio of females to males can be significantly increased upwards of >95% through a feminization process using chemicals such as ethylene, kinetin, or silver thiosulfate (Galoch, 1978) (Lubell & Brand, 2018). Like spinach, female cannabis plants can become monecious if a flower goes unpollinated for too long (Komai & Masuda, 2004). The feminization process exposes females to a ripening compound that causes pollen sacks to develop; this pollen can be used for self or cross pollination, resulting in feminized seed (Galoch, 1978). Feminized and non-feminized hemp seed are both commonly available on the marketplace. At the time of this publication feminized CBD hemp seed prices were, on average, 100 – 126 times that of non-feminized seed (Hemp Benchmarks, 2020). However, the grower must be careful when purchasing feminized seed, as it is visually indistinguishable from non-feminized seed, and nonfeminized seed is often fraudulently sold as feminized to generate higher revenue.

Clonally propagated transplants can be used to eliminate all males and increase genetic uniformity of the crop (Wang, et al., 2009). When sourcing transplants it is wise to discuss methods to ensure clean stock is used, such as greenhouse insect control, sample intake quarantine, and pathogen contamination isolation protocols. At the time of this publication, current spot prices for CBD clones were $1.35 per plant (Hemp Benchmarks, 2020). Company field trials in Yuma have documented a benefit to germination rate of four DN strains grown in 'PlantTape' transplant trays, where water was added to the seeds 0-3 days before transplanting. However, increased stand losses were seen in the 9-12-day-old transplant group (Antle & Smith, 2020). Grower discussions have also indicated that DD varieties can become rootbound in transplant trays quickly, caused by rapid early growth, which causes a twisting or 'corkscrewing' of roots that may damage the vascular structure. Increased mortality of transplants may also occur from shallow root development in transplant trays, which exposes more of the roots to the high soil sodium levels present at the soil surface.

Polyploidy, a greater than normal chromosome number, is often used to increase vigor and ensure sterility in domesticated plants such as seedless watermelon (Tate, Soltis, & Soltis, 2005). A novel method of creating polyploidy cannabis that encourages female sterility is currently under development in the public sector (Kurtz, Brand, & Lubell-Brand, 2020) and private industry (Oregon CBD, 2020).

Growing Season

According to a season summary report, the first plantings in Arizona after hemp prohibition was lifted were in July 2019 (AZDA, 2020). Most growers planted in the extreme summer heat, which resulted in a high mortality. Conversations with growers in Yuma confirm that continuous plantings have been made through the 2020 and 2021 winter seasons with greater success, but incidence of low cannabinoid production levels in winter were sometimes observed.

Spring 2020-2021 plantings showed strain dependent response to photoperiod at emergence sometimes resulting in premature early spring flowering. Many factors should be considered when designing a planting plan for the spring season, such as planting date, germination temperature requirements, daylength requirements, harvest temperature, and market prices.

Minimal, optimum, and maximum recommended soil temperatures for hemp germination have been observed at 6.2, 28.6, and 40.7°C, respectively (43.2, 83.5, and 105.3°F) (Lisson, Mendham, & Carberry, 2000). In Yuma, minimal soil temperature requirements for germination are met year-round (Figure 1). Heat may be a limiting factor to germination during Mid-June through mid-September, which can be mitigated with overhead sprinkler irrigation that creates evaporation cooling. First and last frost dates are between December 12th and January 24th, with a frost risk period from December 18th through to January 15th (Farmers' Almanac, 2020). Growing DD strains requires understanding of how changes in photoperiod affect plant growth. Diurnal photoperiods shift with latitude- minimum and maximum daylengths in Yuma (32.7°N latitude) are 10 and 14.3 hours, respectively (Figure 1). Other DD crops, like soybean, assign varieties to different 'maturity groups' which are then typically grown at their respective latitudes (Mourtzinis & Conley, 2017). For example, a group 000 soybean variety commonly grown in Canada planted in a group 11 latitude in Florida will likely bloom when only inches tall, while a group 11 planted at a 000 latitude may not bloom before the first killing winter frost. Currently, there is no maturity classification system for cannabis, but the global need for such a standardization is high.

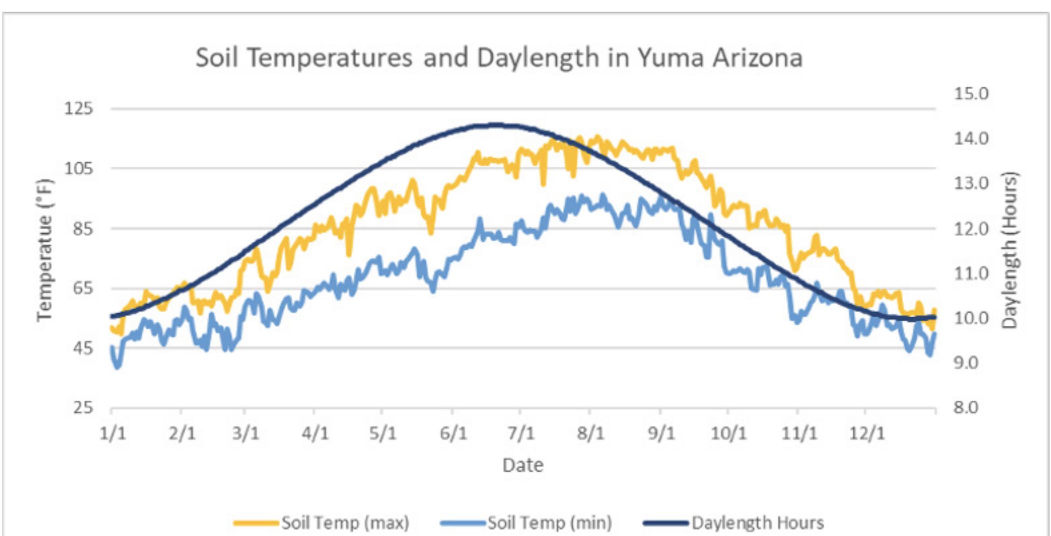

Figure 1: Average environmental conditions at 32.7°N 114.6°W. Soil temperature values reported at a two-inch depth.

IPM Practices

Pests that affect hemp are not well documented for the United States southwest region. Common corn earworm *Helicoverpa zea*, beet armyworm *Spodoptera exigua*, striped flea beetle *Phyllotreta striolata*, crab spider *Thomisidae*, and beet leafhopper *Circulifer tenellus* are all known to affect other similar agricultural crops grown during the spring and summer months (UofA Cooperative Extension, 2006). It is required that all pesticides used on hemp have low human toxicity, are food safe, and combustion tested. There are many pesticides currently approved for use on hemp, however they tend to be softer chemistries than most conventional 'restricted use', highly efficacious formulations(AZDA, 2020).

Yield and Cannabinoid Content

Seed COAs that report high CBD levels maximizes profitability, as CBD biomass is sold by the grower on a dollar per point of CBD percentage per pound of dried flower basis. Cannabinoid content is known to increase as the flower reaches maturity, maintaining a highly correlated CBD/THC ratio through the growing process, helpful in categorizing chemotypes and intended uses (Pacifico D. , et al., 2006) (Pacifico D. , Miselli, Carboni, Moschella, & Mandolino, 2008).

CBD flower harvest should be initiated when cannabinoid concentration within the bulbous tip of the capitate stalked trichome structure reach desired intensity. Trichome color (clear, cloudy, brown), stigma deterioration, and flower girth and texture are physical maturity stages often used to signal harvest (Clarke, 1993). Cannabinoid levels should be monitored frequently during flower development to ensure 0.3% THC compliance restrictions are never exceeded before compliance inspection. At the time of this publication, cannabinoid content can be accurately calculated through laboratory methods such as chromatography, spectrometry, and near infrared detection (NIR). Quantification processes are largely not standardized, but moving towards unification (Jikomes & Zoorob, 2018). Testing costs should be budgeted as mandatory inputs designed to minimize non-compliant crop loss.

Harvest index is a commonly used measurement in other crops to explain the ratio of desirable material (flower, grain, fruit) to total biomass (Hay, 1955). At harvest CBD hemp stem material is typically separated from flower, as non-cannabinoid producing stems devalue the crop unless removed.

Flowers can be dried and stored for long periods of time, but the extent of shelf-life stability for flowers is not entirely known. Care should be taken when handling dried CBD flowers! During the drying process the trichome hairs holding CBD become brittle and movement causes them to shed, reducing crop quality. Grower discussions have cited a speculative 10% loss in CBD percentage after each movement of dried flower. In some production systems, plants are dried in the field, wrapped in plastic 'silage bales', and stored until essential oil extraction. Wet extraction technology is also commercially available that uses freshly harvested, high moisture flower, or lightly dried material. At the time of this publication hemp was in the third year of production in Arizona. Cannabis grown for CBD and other not psychoactive essential oils (CBN, CBG, etc.) continues to be the predominant hemp crop planted, with very little acreage in the state dedicated to grain and fiber production (B. McGrew, AZDA, personal communication, May 13, 2021). Future hemp research goals should include: photo-period effects on flowering (maturity groups), developing insect and pathogen resistance, plant breeding to develop low THC strains, growing practice effects on THC compliance, screening of grain and fiber cannabis varieties for Arizona production, return on investment considerations for use of supplemental lighting to extend day length in winter, and exploration of alternate uses for cannabis to develop a robust economic demand (leafy greens, hempcrete, biochar from stover, grain and seed oil quality, and textile fiber).

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