Exploring IPM Strategies in Southeastern Hemp (*Cannabis sativa* L.)

by

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Abstract

Due to its numerous uses across various industries, hemp, a flexible and ecological crop, has recently attracted much interest. Farmers and academics have been excitedly examining the potential of hemp for economic growth, environmental sustainability, and medical applications after recent legalization and acceptance. However, hemp is not without problems as it is plagued by a variety of pests that can jeopardize its quality and output. Therefore, effective Integrated Pest Management (IPM) techniques must be developed and put into practice to achieve successful and long-term hemp cultivation.

Cannabis sativa is a member of the hemp family that has long been grown for its fibrous stems, seeds, and therapeutic properties, including cannabinoids like cannabidiol (CBD). Hemp has attracted much attention due to its industrial usefulness in textiles, building materials, biofuels, and therapeutic benefits. Additionally, the legalization of hemp farming in many nations and states has created new opportunities for farmers and business owners looking to profit from this developing market.

However, hemp farming is not exempt from other crops' difficulties. Pests seriously threaten the health and output of hemp plants, and the lack of a straightforward IPM approach worsens the situation. Arthropods, including aphids, spider mites, caterpillars, and nematodes, along with weeds and fungi, are some of the frequent pests connected to hemp. These pests have the potential to spread illnesses, endanger the overall health of the crop, and directly harm the plants, resulting in lower yields and lower-quality harvests. The traditional pest control method of relying on synthetic pesticides is inappropriate for growing hemp for many reasons. First, regulatory authorities' residual limitations for CBD extracts and other goods

derived from hemp frequently call for rigorous restrictions on the use of pesticides. Second, pesticides have complex regulations in hemp. In addition, pesticide resistance is a recurring issue, necessitating the investigation of alternate and environmentally friendly pest control methods.

IPM offers a comprehensive and ecologically impressive strategy for pest management in hemp farming. IPM attempts to reduce insect damage while lowering dependency on synthetic pesticides by combining various pest management techniques such as cultural, physical, biological, and chemical treatments. Crop rotation, trap crops, companion planting, mechanical barriers, biological control agents, and targeted pesticide sprays are a few examples of IPM techniques that can be used with hemp.

These methods support the overall health of crops and the balance of the ecosystem, in addition to helping manage pests. Hemp offers several industrial benefits, although there are potential pest management issues. Thus, it is imperative to develop proper IPM strategies to overcome these obstacles and guarantee sustainable hemp production. Farmers can reduce pest-related hazards, enhance crop quality and yields, safeguard the environment, and adhere to regulatory requirements by implementing IPM strategies explicitly designed for hemp cultivation. IPM techniques that are appropriate for hemp farming are explored in this research, along with their efficacy, viability, and possible effects on the long-term sustainability of this promising crop. My research explores fertility management and variety selection as cultural control as an integrated pest management (IPM) strategies.

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

Δ 8-THC	Delta-8-Tetrahydrocannabinol
CBC	Conservation Biological Control
CBD	Cannabidiol
CBDA	Cannabidiolic Acid
CBDV	Cannabidivarin
CBG	Cannabigerol
CBGA	Cannabigerolic acid
CBN	Cannabinol
DEA	Drug Enforcement Agency
IPM	Integrated Pest Management
NASS	National Agricultural Statistics Service
THC	Tetrahydrocannabinol
THCA	Tetrahydrocannabinol Acid
THCV	Tetrahydrocannabivarin
USDA	United States Department of Agriculture

Chapter 1

Introduction and Literature Review

Cannabis sativa

Hemp, *Cannabis sativa* L., belongs to the Cannabaceae family (Clarke 1999). According to the 2014 and 2018 United States Farm Bills, *C. sativa* is split between industrial hemp (less than 0.3% delta-9 tetrahydrocannabinol [THC] concentration) and marijuana. Three species make up this genus: *Cannabis sativa, Cannabis indica,* and *Cannabis ruderalis* (Etienne and de Meijer 1997). Among the *C. sativa* species, industrial hemp is primarily grown for its derivative products that have industrial uses (Roulac and HempTech 1997). Hemp is cultivated for three major components: grain/seeds, fiber, and cannabidiol (CBD) (Clarke 1999).

Hemp versus Marijuana

Although both are variations of the *Cannabis sativa* plant, hemp and marijuana have different THC contents and intended purposes (Small 2015). There are diverse *Cannabis* plant varieties with genetically different chemical makes-ups (Pate 1997). Typically, marijuana is grown for its psychoactive effects and is used as a recreational or therapeutic substance (Pate 1997). Hemp is cultivated for industrial purposes and has uses in various goods, including food and drink, cosmetics, dietary supplements, clothing, paper, and building materials (Small 2015). Hemp is cultivated worldwide and used as a source of fiber and oilseed (Roulac and HempTech 1997).

Industrial hemp cultivation is prohibited in the United States unless a grower has a Drug Enforcement Agency (DEA) permit, which is required by drug enforcement regulations (Clarke 1999). Although hemp and marijuana are sometimes confused with one another, it's crucial to note that marijuana is grown for higher THC levels, whereas hemp only contains minor amounts of THC. However, compared to marijuana, hemp contains higher CBD concentrations (Small

2015). Although THC and CBD have the same chemical composition, their atomic arrangements differ, leading to different effects on the body and mind (Cascini and Boschi 2017). They each contain two oxygen atoms, thirty hydrogen atoms, and twenty-one carbon atoms, each with different arrangements (Small 2015). Due to this difference, CBD does not produce the same intoxicating effect as THC (Cascini and Boschi 2017). CBD lacks intoxication qualities and is thought to have several therapeutic benefits, while THC is responsible for the psychoactive effects (Small 2015).

Endocannabinoids similar to CBD and THC are found in the human body. This enables the body's cannabinoid receptors to take up either CBD or THC (Reggio 2006). Although THC levels as high as 25% have been documented, recreational marijuana usually has a THC value of 5–10% (Stuyt 2018). THC levels in industrial hemp, less than 0.3%, are typically considered too low to cause intoxication (Fike 2016).

Hemp Growing Conditions

Hemp can be grown in various ways, from greenhouses to hoop houses and outdoor field settings (Cherney and Small 2016, Small and Marcus 2002). According to a 2020 survey by Owen and Behe, 62.5% of hemp grown in the United States was in an outdoor field. Greenhouse production makes up about 29.5% of U.S. hemp grown whereas hoop houses or high tunnels make up 15.9% of production (Owen and Behe 2020). Hemp is affected by photoperiod that influences the shift from vegetative to reproductive stages (Clarke 1999, Atoloye et al. 2022). The plant adapts to various soil types and can grow in temperatures ranging from 13°C to 22°C (Rehman et al. 2021). Hemp prefers well-aerated loam soil with highly abundant organic matter (> 2%) and a pH of 6.0–7.5 (Rehman et al. 2021). Studies demonstrate that hemp requires 500-7000 milliliters of water to achieve plant health and optimize yield. Plant spacing varies depending on the type of hemp cultivated, such as CBD, fiber, or grain (e.g., Sebastian et al. 2023).

Types of Hemp

Grain

Grain hemp cultivars have higher protein, fatty acids, and fiber concentrations and lower CBD concentrations. Grain hemp is often grown for their potential application in nutritional supplements (Clarke 1999). Compared to fiber hemp, grain hemp plants are shorter in height and yield less biomass (Roulac and HempTech 1997). Grain hemp has a higher concentration of omega-3 and omega-6 fatty acids, making it a highly healthy dietary supplement (Roulac and HempTech 1997, Desanlis et al. 2013). Due to the relatively high oil content of grain hemp, processors can create a variety of goods from it, including toasted hemp seeds, hemp seed oil, hemp flour, and even hemp coffee (Small 2015). Grain hemp can also be used for animal feed and bedding (Roulac and HempTech 1997).

Fiber

Since the late 19th and early 20th centuries, fiber hemp was mostly used for rope and fabric (Clarke 1999). The capacity to produce long fibers and higher biomass levels define fiber hemp cultivars (Roulac and HempTech 1997). Fiber hemp has taller plants with more vegetative development than hemp cultivated for seed production (Allegret 2013). Hemp fiber is used for a wide variety of products like concrete additives and building materials (Robinson 1996).

Cannabidiol (CBD)

Currently, the most profitable agricultural hemp products for marketing and production are those with CBD (USDA NASS 2022). Due to its potential health benefits, such as lowering pain and inflammation, CBD oil is used as a health supplement. The production of CBD and other related value-added products is expected to drive significant expansion in industrial hemp

(Johnson 2018). Numerous medicinal, dietary supplements, and nutraceutical uses for CBD derived from hemp are possible (Robinson 1996). These types can pose regulatory issues when striving to produce the largest output of CBD while maintaining the THC within accepted limits. Female hemp plants are used to generate high CBD strains since male plants produce seeds and less cannabidiol (Pate 1997). Lower yield is the result of a decrease in the number of cannabinoids in the buds. High CBD and THC levels in the buds are only found in the female plant, making feminized seed and plant production required (Small 2015).

Gender Identification and Reproduction

Hemp has separate male and female reproductive organs, making it dioecious (Clarke 1999). It can also be hermaphroditic, but it is rare. Female plants contain blooms and pistils, the female reproductive part (McPartland et al. 2000). Male plants produce pollen and have stamina, the male reproductive parts. The male plants' staminate forms are tall and thin, with few leaves enclosing the flowers. The pistil of the female plant in each terminal inflorescence is characterized by its long and stocky structure, often featuring multiple. The male plants will die soon after they drop their pollen sacs, while female plants will remain alive until their seeds are fully mature (Small 2015).

The reproductive organs of hemp plants are found at the junction of a branch or leaf with the main stem (McPartland et al. 2000). Pre-flowering, which begins four to six weeks after the seeds have germinated, is the time when the gender of the plant can be identified (Small 2015). Female plants can be identified by their pointed calyxes, which sprout white, hair-like projections (Clarke 1999). Male plants are distinguished by the absence of white, wispy pistils and the presence of green pollen sacs (Small 2015). A single male hemp plant can exude up to 350,000 pollen grains in preparation for wind pollination (Knight 2022). Pollen grains from the male plant are released and the wind carries them to the female plant. Once pollination has occurred, a female plant will stop producing flowers and focus all its energy on creating seeds (Small 2015).

Origin

Humans have used hemp for thousands of years, starting with the earliest known hemp harvests in Central Asia about 8,500 years ago (Small 2015). One of the first plant species to be domesticated, people grew hemp for various purposes, including fiber and seeds (Robinson 1996, Allegret 2013). The fiber types of cannabis, known for their remarkable strength and ability to withstand harsh weather conditions, spread eastward toward China and westward toward Europe (Small and Marcus 2002). These fiber types were used to produce textiles such as ropes, paper, and ship sails (Roulac and HempTech 1997). Between 1000 and 2000 BCE, hemp fiber manufacturing was introduced to Western Asia, Egypt, and Europe. In the 16th century, hemp was brought to the Americas by the Spanish, who obtained the plant from Chile (Robinson 1996).

United States Hemp

In the New England colonies, hemp was raised for fiber and later developed into a significant crop for the American colonies due to its usage as rope. (Robinson 1996). A prevalent crop in colonial America, hemp had a significant economic influence that contributed to the development of the modern United States (Clarke 1999). Former President George Washington was a hemp farmer and believed that hemp was a more profitable cash crop than tobacco (Robinson 1996). President Washington used most of the hemp he produced for textiles including rope, thread, canvas, and fishing nets. Former President Thomas Jefferson also grew hemp and was a supporter of the crop and its potential (Robinson 1996). Hemp farming spread to Virginia and Pennsylvania in the years preceding the American Revolution (Robinson 1996, Clarke 1999). Immigrants transported hemp from Virginia to Kentucky in 1775, where it flourished under hospitable conditions and gave rise to a prosperous business. Between 1840 and 1860, as the population of the United States increased and more people moved west, hemp farming flourished more widely across North America. The commercial fiber industry started to develop in Kentucky after 1775 and expanded significantly because of the great demand for sailcloth and cordage. In the middle of the 1880s, this industry grew and reached Missouri and Illinois. Although several other states continued to grow hemp in the late 1800s and early 1900s, Kentucky remained the main state for hemp cultivation in the United States from the Civil War until 1912 (Robinson 1996, Clarke 1999).

As the 20th century progressed, hemp fiber lost market share in the manufacture of rope, clothing, and paper, making it unsuitable for many smaller applications like waterproof packing. Hemp production in the U.S. decreased for several reasons. Reduced demand and competition from other fiber sources significantly influenced this crop (Robinson 1996, Clarke 1999). The invention of the cotton gin decreased the cost of processing cotton, leading to increased cotton production and reduction in reliance on hemp. Additionally, the hemp market began to see pressure from less expensive imported fibers like jute and abaca. Additionally, the hemp market decreased when steam- and fossil fuel-powered ships gradually supplanted sailing ships. All these elements contributed to the decline of hemp in the U.S. fiber market (Roulac and HempTech 1997).

Marihuana Tax Act of 1937

Fears about how hemp might be used as a hallucinogen caused hemp to encounter considerable difficulties (Robinson 1996). In response, the United States Congress approved the Marihuana Tax Act of 1937, giving the U.S. Treasury Department authority over all cannabis cultivation (Roulac and HempTech 1997). This legislation virtually stopped hemp cultivation in the United States by requiring growers to register and receive licenses to prevent the production of psychotropic cannabis types (Robinson 1996).

However, the stoppage of a consistent fiber supply during World War II brought on a resurgence in hemp cultivation (Robinson 1996). The "Hemp for Victory" effort enlisted several thousand farmers to grow hemp (Roulac and HempTech 1997). To meet the urgent demand for hemp during the war, the United States Department of Agriculture's Commodity Credit Corporation hired War Hemp Industries, Inc. to develop processing mills in the Midwest of the country (Robinson 1996, Clarke 1999). This brief increase in hemp output was extremely important in aiding the war effort (Robinson 1996).

The Marihuana Tax Act of 1937 focused specifically on marijuana-type cannabis, while still including hemp-type cannabis (Robinson 1996, Roulac and HempTech 1997). This act prohibits the importation, cultivation, possession, and distribution of marijuana (Roulac and HempTech 1997). The act did not explicitly state that hemp was included, but aimed to make production too cumbersome for growers. While imported hemp required registration and a $24 annual tax levy, revenue collectors placed a Marijuana Tax Act stamp on every hemp shipment to ensure tax payment (Ferraiolo 2007). Following the 1937 passage of the Marihuana Tax Act, hemp was subject to higher taxes and restrictive legislation (Ferraiolo 2007). Despite the legislation not explicitly making hemp illegal, the U.S. gave broad authority to the Treasury Department. It required approval for cultivation by the U.S. Drug Enforcement Agency (DEA) (U.S. House. 75th Cong., first session., H.R. 6906, 1937).

While hemp production in the U.S. peaked during World War II, it fell off after the war due to its inability to compete with other fiber sources like cotton, especially considering the new taxes (Ferraiolo 2007). The USDA only permitted Ren's Hemp, a single production business, to grow hemp for fiber by 1958 (Roulac and HempTech 1997). The Comprehensive Drug Abuse Prevention and Control Act of 1970 replaced the Marihuana Tax Act, treating hemp and marijuana without distinction (Ferraiolo 2007).

Agricultural Act of 2014

Beginning around the early 2000s, the political climate surrounding hemp production underwent significant changes as numerous states sought to advance hemp cultivation and research. However, it wasn't until the passage of the 2014 Farm Bill in the United States that some substantial progress was made in this regard. (Cherney and Small 2016, Johnson 2018). The 2014 Agriculture Act, sometimes called the 2014 U.S. Farm Bill, was instrumental in bringing about this shift. The legislation contained Section 8506, titled "The Legitimacy of Industrial Hemp Research," which offered a place for the investigation and research of hemp (U.S. H.R.2642 - Agricultural Act of 2014 113th Congress [113-333]).

Due to the provision in the Farm Bill, research organizations, academic institutions, and state departments of agriculture can now conduct studies and pilot projects on hemp production, market potential, and economic effects (U.S. H.R.2642 - Agricultural Act of 2014 113th Congress 113-333). Its objective was to evaluate hemp's viability and feasibility as a crop. A big step was taken in reintroducing hemp as a viable crop and investigating its potential uses with the inclusion of section 8506 in the Farm Bill. It allowed states to investigate and implement rules, licensing schemes, and research projects relating to industrial hemp (Cherney and Small 2016, Johnson 2018). This change set the stage for the U.S. hemp industry's continued growth and expansion.

The 2014 Farm Bill established that hemp is the same plant as marijuana, *Cannabis sativa*, but explicitly stated the difference between hemp and marijuana. It distinguished hemp from marijuana based on 0.3% delta-9 tetrahydrocannabinol (THC) concentration (U.S. H.R.

2642 – 113th Congress 113-333). The 2014 Farm Bill did not change the designation that both marijuana and hemp are Schedule I drugs under the Controlled Substances Act of 1970 and regulated by the Drug Enforcement Administration (DEA). Hemp was only allowed in U.S. states and territories that passed production regulations. The program did not include hemp cultivation in Indian tribes (U.S. H.R. 2642 – 113th Congress [113-333]).

Agriculture Improvement Act of 2018

The 2018 Farm Bill (Agriculture Improvement Act of 2018) modified hemp requirements from the 2014 Farm Bill (Cherney and Small 2016, U.S. H.R. 2 –115th Congress [15-334]). The 2018 Farm Bill made a statutory definition of hemp and marijuana, allowing hemp to be removed from the Controlled Substances Act and grown for commercial production. The 2018 Farm Bill also expanded on the definition of hemp to include all derivatives of cannabinoids, such as extracts, isomers, acids, and salts. The 2018 Farm Bill established the Domestic Hemp Production Program, which amended the Agricultural Marketing Act of 1946. This made hemp production federally legal and regulated by the USDA. Under the 2018 Farm Bill, all U.S. states and territories, including Indian tribes, were now eligible for hemp production. Under the 2018 Farm bill, the USDA allowed eligibility for crop insurance and grant funding in hemp production (U.S. H.R. 2 –115th Congress [15-334]).

Modern hemp

U.S. Industrial hemp was farmed outdoors and indoors in 2021, with a combined market value of $824 million (USDA NASS 2022). The value of the outdoor industrial hemp output was $712 million while the remaining was for indoor hemp production. Flowers, grains, fiber, and hemp seed production are valued at $623 million, $6.0 million, $41.4 million, and $41.5 million, respectively. In 2019, U.S hemp was cultivated for all uses on more than 64,000 hectares, mainly for CBD. In 2021, only 21,915 hectares of industrial hemp were planted in the U.S., and 13,549 hectares were harvested. This significant reduction in just two years resulted from overproduction and price declines of up to 90% (Sebastian et al. 2023). In 2021, farmers harvested a total outdoor area of 6,467 hectares for floral hemp, 3,341 hectares for grain hemp, and 5,136 hectares for fiber hemp. The total production of floral hemp, grain hemp, and fiber hemp was 8,952 tons, 1,983 tons, and 15,082 tons, respectively. Hemp production is currently legal in 47 states (USDA NASS 2022).

Alternate Uses of Industrial Hemp

Grain production

A burgeoning sector of the economy is the production of hemp plants for their seeds, which have numerous uses in supplements, cosmetics, and food (Farinon et al. 2020). Farmers can select the hemp seed most appropriate for their intended purpose from various distinctive attributes, such as size, oil content, and disease resistance. Farmers usually plant at least 150,000 plants per acre and utilize specified fertilizer rates to maximize grain yield. When the soil temperature reaches a specific level, farmers directly sow hemp seeds in the field. Standard agronomic practices for irrigation and weed control are used to promote good plant growth (Wortmann 2019).

Farmers can harvest the hemp seeds once they reach their maximal oil content and are fully developed. Farmers typically harvest seventy percent of the mature seeds when cutting the plants with harvesting tools such as grain combines or specialty hemp harvesters. The seeds must be rinsed and dried within six hours following harvest to prevent moisture-related issues. Seed cleaners are used to eliminate weed seeds, immature seeds, and green debris from seeds before further processing to ensure high-quality seeds (Wortmann 2019).

Fiber production

Another essential element of the hemp industry is manufacturing hemp fiber, with bast and hurd fibers harvested from the stalks of fiber hemp plants. Bast fibers are used in various products, including paper, textiles, cordage, and insulation, because they are longer and of superior quality relative to hurd fibers (Robinson 1996). Hurd fibers are shorter and used for fiberboard, paper additives, animal bedding, and plastic additives. Due to their affordability and favorable environmental effects, hemp fibers are becoming increasingly popular in building materials and automobile interiors (Grégorio et al. 2020).

Growers consider the portions of the plant that will be harvested while choosing hemp fiber cultivars. To boost fiber yield, fiber varieties are often planted at higher seeding rates per acre and in denser stands. Sickle bar mowers are a common tool for harvesting fiber crops because they can handle tall plants. To separate the bast and hurd fibers from the stalks after cutting, a procedure known as retting is required. The most typical technique is "field retting," which entails exposing the plants to rain. This exposure helps to separate the fibers and make them easier for processing. After retting, hemp fiber is bundled into sizable rounds or squares, dried, and stored. Unlike hemp grain, fiber can be dried outside without requiring climate-controlled spaces. Proper drying and storage procedures guarantee the quality and utility of hemp fiber (Wortmann 2019).

Insects Associated with Industrial Hemp in the Southeastern United States

Hemp and pollinators

As previously mentioned, hemp is wind pollinated. Enormous amounts of pollen are typically produced continuously for several weeks, yet the plants do not produce nectar. Numerous bee species may frequently visit cultivars of fiber or seed in search of pollen. Hemp in late summer can be a significant pollen source for honeybees and several native bee species.

Honeybees were the most common species caught during bee trapping in hemp in North America. A 2015–2016 study for grain and fiber hemp in Colorado discovered that long-horned bees (Hymenoptera: Apidae: *Eucerini*), particularly *Melissoides* spp., made up over half of the total catches. Other commonly capture bees were bumblebees, *Bombus* spp., and digger bees, *Anthophora* spp. Solitary bees from other families comprised a small part of the total captures; five genera of bees in the family Halictidae were found, and smaller numbers of Megachilidae and Andrenidae bees were also captured (Cranshaw et al. 2019).

Earlier studies have suggested that bees are attracted to pollen produced by male plants, but do not visit female plants (O'Brien and Arathi 2019, Flicker et al. 2020, Dalio 2012). Pollen is a significant resource for bee colonies because of lipids, proteins, vitamins, and minerals required for brood development (Dalio 2012). Two studies conducted in 2019 documented how hemp pollen can support the bee population during a shortage of flower resources and that a wide range of bee species will visit hemp in the field (O'Brien and Arathi 2019, Flicker et al. 2020). The bee species found visiting hemp from a University of Cornell study included *Bombus impatiens*, *Apis mellifera*, *Lasioglossum* spp, *Ceratina* spp, and *Helictus* spp. (Flicker et al. 2020).

Natural enemies

Predators, parasites, parasitoids, and diseases, collectively called "natural enemies," frequently prey on natural organisms and cause significant mortality rates. In biological control strategies, pests can be suppressed by using natural enemies or agents (often referred to as "beneficials") (Braley 2021).

Organisms with a broad diet and the ability to eat a variety of prey species are known as generalist predators. Due to their high adaptability, these predators may flourish in various situations by utilizing multiple food sources (Sanchez and Gillespie 2022). They frequently hunt opportunistically, changing their feeding habits in response to the number and diversity of available prey. The capacity of generalist predators to tolerate or take advantage of various ecological niches is one of their key traits. They do not have specialized hunting or feeding methods for a particular species of prey; instead, they have a wide range of adaptations that enable them to catch and eat a variety of organisms (Bernays 1988). Generalist predators will stay in the area for extended periods while pests' populations fluctuate throughout the season (Sanchez and Gillespie 2022).

Assassin bugs (Reduviidae)

Assassin bugs are part of the Reduviidae family and are one of the largest predatory land Hemipterans (Ambrose 2000). Assassin bugs have a long, three-segmented, needle-like beak and a tall, slender head with broad, beady eyes (O'Neal et al. 2015). Assassin bugs often have blackish, brown, or reddish bodies. Adults and nymphs feed on soft-body insects, such as aphids and caterpillars. The most common assassin bug species that can be found in hemp are *Zelus* spp. and *Sinea diadema* (Fabricius) (Schreiner and Cranshaw 2020).

Big-eyed bugs (Geocordiae)

In North America, roughly 19 species of big-eyed bugs are classified under the genus *Geocoris* (Champlain and Sholdt 1967). These insects have large heads and short, oval bodies ranging from 2.7 to 5 mm (Merrill and Sweet 2000). They can be distinguished by their large eyeballs, which protrude over the front of their heads, and short antennae (Merrill and Sweet 2000). Big-eyed bug adults and nymphs consume leafhoppers, mites, thrips, whiteflies, aphids, caterpillars, and eggs (Schreiner and Cranshaw 2020).

Damsel bugs (Nabidae)

The damsel bug is a generalist predator common in many agricultural systems (Braman 2000). Damsel bugs are true bugs (Hemiptera) and members of the Nabidae family (Schreiner and Cranshaw 2020). They are smaller than assassin bugs but have wider forelegs to help hold prey (Cranshaw 2004). Damsel bug adults and nymphs consume their prey by sucking their bodily fluids through needlelike mouthparts (Braman 2000). They consume aphids, beetles, caterpillars, mites, thrips, true bugs such as *Lygus* species, and occasionally engage in intraguild predation on other natural enemies (Schreiner and Cranshaw 2020).

Minute pirate bugs (Anthocoridae)

In hemp fields, the minute pirate bug *Orius insidiosus* (Say) is a frequent predator that hunts small arthropods (Schreiner and Cranshaw 2020). Minute pirate bugs are generalist predators, and both larvae and adults feed on small prey, including thrips, spider mites, insect eggs, and aphids (Lattin 2000). Adult minute pirate bugs are rectangular to oval with flattened tops and protruding eyes. The length of adult *Orius* species varies from 2–5 mm. Nymphs are rectangular to pear-shaped bodies and are frequently brown, orange, reddish, or yellow. Nymphs and adults eat their prey by sucking bodily fluids through their mouthparts resembling needles. When food is scarce, they can also consume pollen and nectar (O’Neal et al. 2015).

Stilt bugs (Berytidae)

Stilt bugs, in the family Berytidae, are generalist predators (Braman 2000). The average adult stilt bug measures over 6.35mm, brown to brick-red coloration, and has thin antennae extending halfway down the body's length. The smaller nymphs might be yellowish-green or green (O’Neal et al. 2015). Nymphs and adults of stilt bugs eat small insects, but as they develop and grow, they primarily devour insect eggs (Braman 2000).

Green lacewings (Chrysopidae)

Green lacewings are generalist predators commonly found in many agricultural systems. They have soft bodies, green coloration, and yellow eyes (Schreiner and Cranshaw 2020). Their wings are transparent, lacy, and adorned with tiny veins, while their long antennae resemble hair.

The small, rectangular eggs laid by green lacewings are white and are attached to stalks resembling hair to prevent cannibalistic behavior among the hatching larvae (Rosenheim et al. 1999). The larvae of green lacewings have sickle-shaped mandibles, an alligator-like appearance, and move swiftly. They are spindle-shaped and have prominent forward-extending jaws (Braley 2021). Green lacewing larvae and adults consume various pests, such as aphids, thrips, spider mites, and tiny caterpillars and carbohydrate-rich substances such as flower nectar or pollen. (O’Neal et al. 2015).

Lady beetles (Coccinellidae)

Convergent lady beetle, *Hippodamia convergens*, adult wing coverings usually are orange to red with 12 to 13 black markings and measure. The larva is shaped like an alligator and are dark gray to blackish blue with four bigger orange spots on the back and two smaller ones (Rodriguez-Saona and Miller 1995). Convergent lady beetles are generalist predators frequently observed in hemp (Schreiner and Cranshaw 2020). Convergent lady beetle adults and larvae are ferocious predators of various prey, including aphids, scales, mites, and thrips (Ahmed et al. 2009).

Seven-spotted lady beetles, *Coccinella septempunctata*, have two white or light-colored spots on either side of the initial portion between the head and thorax. The body is oblong and dome-shaped. Eggs are tiny and spindle-shaped. Before they pupate, larvae resemble alligators, are dark gray with orange dots on segments one and four, and develop to be the same length as adults (Flint 1998). Older larvae may travel up to 10 meters in search of prey. *C septempunctata* adults and larvae are destructive predators that consume aphids, scale insects, insect eggs, tiny caterpillars, and spider mites (O’Neal et al. 2015).

Multicolored Asian lady beetle, *Harmonia axyridis*, measure around 6 mm long and 5 mm wide and are firmly oval and convex at maturity. They come in a wide range of hues and patterns, but the majority are from orange to red, with few to no black specks (Flint 1998). Adults could have a two-to-three-year lifespan. *H. axyridis* adults and larvae are ferocious predators that consume aphids, scale insects, insect eggs, tiny caterpillars, and spider mites. Aphid consumption ranges from 100 to 300 per day for adults, while during the larval stage, up to 1200 aphids may be consumed daily (O’Neal et al. 2015).

Long-legged flies (Dolichopodidae)

Long-legged fly adults are predatory, while the larvae, are not. The larvae lack a distinct head, which is unique to adults, and have a creamy white appearance. Gnats, bark beetles, and mites are among the prey items that long-legged fly adults eat. They also consume common pests, including mosquitoes, aphids, and thrips (Schreiner and Cranshaw 2020). Adults frequently hunt for prey while sitting on foliage in partially shaded environments. They use their mouthparts to hold, penetrate, and remove internal fluids from their prey upon catching (Bortolotto et al. 2021)

Syrphid flies (Syrphidae)

Adult hoverflies, also found in hemp, consume flower nectar and are not predatory, while the larvae eat soft-body insects such as aphids and small caterpillars. (Flint 1998). During development, one larva may eat up to 300 to 400 aphids per day due to their insatiable appetite (O’Neal et al. 2015).

Tachinid flies (Tachinidae)

Many pest caterpillars, including armyworms, cutworms, leafrollers, and loopers, are parasitized by tachinids. A single egg is usually laid directly on or inside the body of a caterpillar by tachinids (Falcon-Brindis et al. 2022). The developing larva feeds inside the host, consuming non-essential organs before emerging from the dormant caterpillar or pupa. Two weeks later, the mature fly appears. Every year, there are two to three generations (Braley 2021).

Spiders (Araneae)

Spiders, significant generalist predators in agroecosystems, are a sign of a healthy ecosystem (Braley 2021). Spiders help to control several pests that attack hemp, such as caterpillars, young stink bugs, Lygus bugs, aphids, and other insects (Schreiner and Cranshaw 2020). One important predatory family is crab spiders (Thomisidae), which have many colorations that allow them to camouflage into their environment. They are distinguished by a front pair of elongated legs and a bulbous abdomen (Cranshaw 2004). Crab spiders are ambush hunters, and it is common to see them waiting quietly for passing prey on leaves or close to flower insects (Schreiner and Cranshaw 2020). Wolf spiders (Lycosidae) are enormous and are gray, brown, or black. They are primarily nocturnal, active hunters that crawl around on the soil surface (Cranshaw 2004). Jumping spiders (Salticidae) are abundant in hemp (Schreiner and Cranshaw 2020). They are active hunters and can jump short distances of less than 2.5 cm (Cranshaw 2004). Numerous significant crop pests, such as the boll weevil, spotted cucumber beetle, and other beetles, Lygus bugs, stink bugs, leafhoppers, midges, mosquitoes, and other flies are preyed upon by jumping spiders. Long-jawed orb weavers (Tetragnathidae) from the genus *Tetragnatha* are some of the most prevalent spider species discovered weaving webs in hemp (Schreiner and Cranshaw 2020).

Additionally, the Long-jawed orb weaver spiders weave sticky webs with concentrically spaced patterns to entrap tiny flying insects (Schreiner and Cranshaw 2020). Lynx spiders (Oxyopidae) have elongated bodies and many long hairs on their legs. They hide in vegetation and trap passing insects. The most common species in the southern United States is the green lynx spider, *Peucetia viridans* (Cranshaw 2004).

Predatory mites (Phytoseiidae)

There are various species of predatory mites that are used as biological control agents. The most prevalent predatory mites in cropping systems may be *Neoseiulus* species (Olaniyi et al. 2021). *N. californicus, N. cucumeris, and N. fallacis* are used to control pest mites and are commercially raised and sold for mass release (Braley 2021). The larvae have six legs, are transparent or translucent, and are inactive. Nymphs and adults have eight legs. Nymphs and adults have glossy, pear- to oval-shaped bodies. Both adults and nymphs are active hunters and predators (Devasia and Ramani 2020).

N. californicus will eat various prey items, but prefer spider mites, Tetranychidae. Although all stages of spider mites are consumed by adult *N. californicus*, nymphs, eggs, and larvae are preferred (O'Neal et al. 2015). Strawberries and greenhouse crops have both been known to release *N. californicus* for biological control purposes. The most common pest mite for which *N. californicus* is released is the two-spotted spider mite, *Tetranychus urticae*, which infests various crops in outdoor and indoor production systems (Olaniyi et al. 2021).

Parasitoid wasps

The term "parasitoid" refers to parasitic insects that attack and kill other insects. The biology of parasitoids differs from that of many other insects (O'Neal et al. 2015). Although most females can affect the sex of their progeny by managing egg fertilization, reproduction is typically sexual. Unfertilized eggs produce males, while females are produced by fertilized eggs (i.e. arrhenotoky). Typically, females deposit their eggs inside the host, where the larvae will eat, grow, and pupate (i.e. endoparasitism). Additionally, female parasitoids can inject venom through their ovipositor, paralyzing or immobilizing their hosts, or puncture them to consume their bodily contents. After oviposition, several species permit the host to continue its growth and development (Braley 2021). Ichneumonidae, Braconidae, and Chalcidae are common parasitoids of caterpillars. Further, there are commercially available Trichogrammatidae wasp parasitoids frequently utilized for biological control (Cranshaw 2004).

Pest Insects

In recent years, arthropod surveys have been conducted on hemp (Cranshaw et al. 2019). Many insects can cause damage to the plant, which can cause significant yield and quality loss. The extent of the damage depends on where insect feeding is concentrated, such as leaves, flowers, seeds, or stems (Cranshaw et al. 2019, Schreiner and Cranshaw 2020). The following categories of pests can cause damage: defoliators, chewing/sucking pests, stem borers, and root feeders (Cranshaw et al. 2019, Reay-Jones 2019, Schreiner and Cranshaw 2020, Ajayi and Samuel-Foo 2021, Britt et al. 2021). Table 1.1 describes insects, damage location, and category in the southeastern United States (Cranshaw et al. 2019, Reay-Jones 2019, Schreiner and Cranshaw 2020, Ajayi and Samuel-Foo 2021, Britt et al. 2021).

Two-spotted spider mites (Acari: Tetranychidae)

Two-spotted spider mites, *Tetranychus urticae* (Koch), are a significant pest in greenhouses and specialty crops, as well as row crops (Górski et al. 2016, Shaabow et al. 2019, Grammenos et al. 2021, Olaniyi et al. 2021). It is a major pest in greenhouse and field hemp production (McPartland 1996, McPartland et al. 2000, Cranshaw et al. 2019, Schreiner and Cranshaw 2020, Grammenos et al. 2021). In indoor production, high populations of two-spotted spider mites are a major problem because of favorable conditions in the greenhouse, but once transplanted into the field, populations do not appear to be sustained (Cranshaw et al. 2019, Grammenos et al. 2021).

Two-spotted spider mites are small, roughly 0.5 millimeters. They have oval-shaped bodies and are yellow-green, sometimes red or brown. They have two dark spots on each side of their body. Females use webbing to stick the eggs on the underside of the leaves and can lay 50 to 100 eggs in their lifetime. Spider mites have a 12 to 15-day life cycle depending on environmental conditions, and only the adults feed on the plants. They can produce several generations in a 2-to-3-month period resulting in large populations. Two-spotted spider mites can overwinter in leaf litter, weedy areas, or beneath tree bark because these areas provide protection (McPartland 1996, McPartland et al. 2000, Cranshaw et al. 2019, Grammenos et al. 2021, Hirsch and Kesheimer 2021d, Kesheimer 2022).

Underneath the leaves of hemp plants, two-spotted spider mites consume plant sap using their piercing-sucking mouthparts. Spider mites suck the chlorophyll out of the hemp plant, blocking photosynthesis. Signs of spider mites consist of heavy webbing and "stippling," which is the grey or yellow discolored spots on the surface of the leaves. Two-spotted mites can cause whole leaves to become discolored, and the plant can eventually die (McPartland 1996, McPartland et al. 2000, Schreiner and Cranshaw 2020, Hirsch and Kesheimer 2021d, Kesheimer 2022).

Cannabis aphids (Aphididae)

Cannabis aphids (*Phorodon cannabis*) are monophagous insect pests that can significantly damage fields and greenhouses in the United States. In addition to the U.S., cannabis aphids are found in central and southwest Asia, central and southern Europe, and North Africa. Cannabis aphid colors are pale yellowish green without stripes, yellowish green with one or three longitudinal darker green stripes, or pink with or without stripes. Cannabis aphids are monecious holocyclic, and experience sexual reproduction for at least a portion of its life cycle (Cranshaw et al. 2019).

Cannabis aphids are fluid feeders which means they feed on plant phloem using their piercing-sucking mouthparts. As the cannabis aphids feed, they produce a sticky excrement called honeydew, which leaves a deposit of shiny spots on the surface of the leaves. Honeydew can promote the growth of a black, sooty mold that can attract ants and protect the aphids from predatory insects (Cranshaw et al. 2019 Knight 2022).

Hemp russet mites (Eriophyidae)

Hemp russet mites (*Aculops cannabicola*) are a pest in greenhouse and outdoor hemp production and have long, cylinder-shaped bodies with beige coloration and four legs (McPartland et al. 2000). They use their piercing-sucking mouthparts to feed on the outer layer of leaves. Hemp russet mites undertake arrhenotokous reproduction, where females lay unfertilized eggs that produce male offspring. Next, the female is fertilized by the male offspring (Hayes 2022). The female then produces eggs that result in female progeny.

Adult hemp russet mites measure between 110 and 210 micrometers. The outside edge of the leaves will curl upward when damaged by hemp russet mites. The damaged leaves have a drab appearance and are yellow or brown. Yellow buds may be present in severe infestation (McPartland et al. 2000).

Whiteflies (Aleyrodidae)

Worldwide, whiteflies (Aleyrodidae: Hemiptera) are one of the major economically significant groups of pests with a vast host range. The most common pest of greenhouse hemp is *Bemisia tabaci* biotype A. In hemp, the damage from whiteflies may look like aphid damage (McPartland et al. 2000, Milenovic et al. 2022). Adult whiteflies congregate on the undersides of the leaves (McPartland et al. 2000). The whiteflies of adults are small, ranging from 1.5875 mm to 2.5 mm with powdery-looking white wings (McPartland et al. 2000, Milenovic et al. 2022). The first nymphal instars are called “crawlers” and are the most damaging stage (McPartland et al. 2000). The later instars are oval-shaped and flat with reduced legs and antennae and are immobile. The adults have wings and can move from plant to plant. Whiteflies use their piercing-sucking mouthparts to suck the phloem of plants and are the vector of many plant viruses (McPartland et al. 2000, Milenovic et al. 2022). To date, no whitefly vectored viruses have been noted in hemp.

Fungus gnats (Sciaridae)

Fungus gnats are primarily a pest of indoor-grown hemp. Adults are black with long legs and antennae but are not damaging. The damaging life stage, the larvae, are located near the top of the soil. The larval stage uses their chewing mouthparts to feed on roots and fungus. Adults do not feed on plant material. The signs of fungus gnats include stunted plant growth in seedlings, and significant damage can cause plant death (McPartland et al. 2000).

Grasshoppers and crickets (Acrididae and Gryllidae)

Economical pests of outdoor hemp include crickets (Gryllidae) and grasshoppers (Acrididae). *Melanoplus* is the most prevalent genus of grasshoppers in Alabama. They spend the winter underground as eggs and hatch in the spring from late March to early June. Grasshoppers chewed through plant matter using their chewing mouthparts (Kesheimer 2022). The tops of plants may become defoliated because of grasshopper damage. In immature seedlings, leaf feeding can cause significant damage (McPartland et al. 2000, Schreiner and Cranshaw 2020, Kesheimer 2022). Field crickets are black with shorter legs and longer antennae than grasshoppers. Field crickets also have chewing mouthparts to bite through leaves and stems. They can cause significant damage to the stem by chewing through the whole stalk of the plant (McPartland et al. 2000, Schreiner and Cranshaw 2020)

Fire ants (Formicidae)

Red imported fire ants (*Solenopsis invicta*) are one of the major pests in subtropical hemp production. Fire ants can remove bark and create tunnels in hemp stems. Fire ants may cause discoloration and wilting, which may mimic disease symptoms, particularly Southern blight (Hirsch and Kesheimer 2021b, Kesheimer 2022).

Termites (Rhinotermitidae)

Termites can be a pest in hemp, especially in subtropical regions (McPartland et al. 2000). The workers are light beige colored and do not have wings or eyes. The soldiers are beige and have enlarged jaws and heads. Usually, termites feed on decaying wood matter but will feed on living plants. In Alabama, they have been found to feed on the hemp stem (Kesheimer 2022).

Caterpillars (Noctuidae)

Armyworms (*Spodoptera frugiperda*) and yellow striped armyworms (*Spodoptera ornithogalli*), both belong to the Noctuidae family. While these pests are known to feed on various crops like corn, sorghum, cotton, and vegetables, they can also pose a threat to hemp plants. When infesting hemp, they can cause significant damage to the leaves and flowers which causes defoliation, stunted growth, and reduced yield (Cranshaw et al. 2019, Hirsch and Kesheimer 2021a, Hirsch and Kesheimer 2021e, Kesheimer 2022). The most damaging pest of outdoor hemp is *Heilicoverpa zea* Boddie. The corn earworm is the most economically significant Lepidopteran pest in agricultural crops in the southeastern United States. It feeds on a wide variety of crops including corn, soybean, and cotton (Reay-Jones 2019). *H. zea* is a polyphagous, multivoltine insect pest native to the Americas. The larva stage of *H. zea* feeds on the buds and flowers of hemp, larvae mainly damage hemp cultivars grown for CBD production (Cranshaw et al. 2019, Reay-Jones 2019, Ajayi and Samuel-Foo 2021, Britt et al. 2021, Hirsch and Kesheimer 2021a, Kesheimer 2022). In the southern U.S., *H. zea* overwinters as pupae. The larvae are very aggressive and cannibalize other larvae (Cranshaw et al. 2019, Reay-Jones 2019, Ajayi and Samuel-Foo 2021, Britt et al. 2021).

Integrated Pest Management

Integrated pest management (IPM) strategies are valuable tools for reducing the reliance on pesticides while still controlling pest populations (Kogon 1975). IPM strategies are a comprehensive approach to managing host stressors such as pests, pathogens, and viruses that are economically and ecologically sustainable (Gray et al. 2009). These methods include various strategies to control these pest populations, such as biological control, host-plant resistance breeding, and cultural techniques (Gray et al. 2009). While IPM is widely used in other crops, such as corn, cotton, and soybeans, its application in hemp requires further research. Since hemp is a new crop with little information and diverse pest populations, IPM will be a significant part of providing economically and ecologically sustainable agronomic solutions for growers (Cranshaw et al. 2019, Britt et al. 2021).

IPM Strategies for Hemp Production

Mechanical control

Physical and mechanical measures either directly kill pests or render their surroundings uninhabitable. These include barriers like screens or fences to keep animals and insects out, traps for pest animals and insects, mulches for weed control, steam sterilization for soil disease management (Department of Primary Industries and Regional Development 2018) Physical techniques for insect control in hemp, including hand removal, are frequently employed by growers (Britt et al. 2021).

Chemical control

The use of pesticides in hemp in the United States has caused uncertainty and made it challenging to build efficient pest management techniques for the crop. The main problem is the ongoing disagreement between the Controlled Substance Act of 1970, which continues to classify all *Cannabis sativa* plants, including hemp, as Schedule I substances, and the 2014 Farm

Bill, which allowed hemp production. The legal issue has hampered federal regulatory actions that could have allowed for the registration and supervision of pesticides for hemp. It is the responsibility of individual states to regulate the use of pesticides on cannabis crops. As a result, there has been a difference in how state regulatory organizations have dealt with pesticide use in hemp (Cranshaw et al. 2019).

While there are federally registered pesticides for hemp, no registered pesticides can be used in hemp cultivation in states that have not adopted the necessary regulatory framework (Cranshaw et al. 2019). According to Cranshaw et al. 2019, growers in these states have a few options. They can forego the use of pesticides altogether, use pesticides illegally, use products excluded from registration requirements under Section 25(b) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), or use products that make no mention of being pesticides, like neem oil marketed as a "leaf shine" product or soap/detergent products marketed as a "plant wash."

On the other hand, some states have created laws that permit the application of specific certified pesticides in cannabis crops. There are currently more than 100 pesticides registered for hemp in Alabama (Kesheimer 2023). Most states that have already legalized marijuana for medical and/or recreational use and expanded their marijuana laws to include all *Cannabis sativ*a crops. These states require that active chemicals in registered pesticides be exempt from tolerance criteria on food crops to comply with federal laws. This leaves specific microbial insecticides derived from plants, horticultural oils, and insecticidal soaps as the only insect control options (Cranshaw et al. 2019).

Another requirement relates to the pesticide label's language, which must allow for general use instructions rather than tightly defining the places of use. This view permits the use of pesticides on unnamed crops, including hemp. As a result, a patchwork of permitted products, often unrelated to the active ingredient, has been created. For instance, Colorado permits some *Beauveria bassiana* products containing pyrethrins but forbids products with a similar formula and different label instructions (Cranshaw et al. 2019).

When used with other pest control techniques, including crop rotation and eradicating volunteer plants, the pesticides permitted by states following this model can successfully manage various arthropod pest issues in hemp. However, there is frequently a dearth of effective pesticides for other pests, including plant diseases and weeds. In these situations, conducting new research to comply with registration criteria is necessary (Cranshaw et al. 2019).

Cultural control

Several cultural control methods are being researched in hemp production. Cultural control is the exploitation of abiotic and biotic factors to make the environment unsuitable for pest populations (Kogon 1975). Abiotic factors include variety selection, sanitation, irrigation, and fertility management. Fertility management in other crops, such as corn, soybeans, and cotton, is well researched, but there is little information on hemp production. Nitrogen rates are the main concern for growers because they can influence plant growth (Anderson et al. 2021). There are few studies regarding fertilization recommendations for CBD hemp; most of the research focuses on fiber and grain hemp and marijuana cultivars (Anderson et al. 2021)

Fertility management

The term "fertility management" refers to a group of procedures and methods used to enhance the soil's overall fertility and nutrient content for strong plant growth (Kogon 1975). It incorporates techniques including soil testing, nutrient balancing, and organic or synthetic fertilizers to ensure that plants have access to the vital nutrients required for their development. Because it directly affects crop productivity and sustainability, fertility control is crucial (Selim

2020). Fertility management promotes optimal plant growth by keeping the soil's nutrient levels appropriate, which increases crop yields and boosts agricultural output (Kogon 1975). Additionally, it is essential for long-term soil health and fertility preservation and for limiting the environmental effects of improper nutrient management by encouraging effective nutrient use and decreasing nutrient losses (Carrera et al. 2003). The economic viability of farming enterprises depends on using proper fertility management techniques. Farmers can increase their return on investment by maximizing nutrient availability in the soil (Stewart et al. 2020). Healthy and more productive crops result from balanced nutrient levels, which lower the chance of yield losses and boost the general profitability of agricultural systems (Carrera et al. 2003). Additionally, by ensuring that nutrients are used effectively and minimizing the need for additional fertilizer applications, fertility control strategies can help reduce input costs (Selim 2020). Reducing nutrient runoff and pollution, protecting natural resources, and promoting long-term soil fertility not only helps the farmer monetarily but also advances sustainable agriculture methods (Bennett et al. 2021).

Insect and nitrogen interactions

Nutrition is essential for a plant’s growth, upkeep, and reproductive processes, and it dramatically impacts whether a plant is resistant to pests or susceptible to them (Bala et al. 2018). While many chemical elements are involved in plant nutrition, only 17 are considered critical for healthy plant development and growth, with each nutrient having a significant impact. Insects who consume plants for food need these nutrients for their growth, tissue upkeep, reproduction, and energy (Boswell et al. 2008).

Individual insect performance has been found to benefit from one crucial nutrient, nitrogen, because of changes in host plant chemistry brought on by nitrogen deposition. High levels of nitrogen in plants can sometimes lead to a decrease in the production of defense chemicals (Bala et al. 2018). Another essential plant nutrient, potassium, confers a high resistance level to insect pests. Increased potassium levels improve secondary chemical metabolism, lessen carbohydrate buildup, and lessen insect pest damage to plants. Additionally, phosphorus makes plants less suitable as hosts for several insect pests (Sardans and Peñuelas 2021). It has been demonstrated that secondary macronutrients and micronutrients, including calcium, zinc, and sulfur, can lower insect populations (Bala et al. 2018).

By changing the nutrient makeup of crops, fertilization practices might indirectly affect plants' resistance to insect pests. These modifications by fertilization procedures affect plants' susceptibility to various insect pests. Techniques to improve plant resistance to phytophagous insects are being developed in response to the rising demand for healthier food options (Bala et al. 2018). Nitrogen is important because it can influence an insect's growth and development on the plant (Behie and Bidochka 2013). Nitrogen consumed by plant-feeding insects such as corn earworms can have bottom-up effects on their fitness, including host plant selection, survival, fecundity, and population dynamics (Wang et al. 2022). Reducing nitrogen availability in the host plant tissue can make it less desirable for corn earworms and other pests in the family Noctuidae (Ajayi and Samuel-Foo 2021). For example, a study by Wang et al. 2022 found that different nitrogen rates increase the herbivory of fall armyworm, *Spodoptera frugiperda*. In this study, *S. frugipeda* size, survival, growth, and development increased in all nitrogen treatments compared to the control groups (Wang et al. 2022).

Physiological effects of nitrogen in hemp

Nutrient management is essential for plant growth and development as nitrogen is a mineral critical to plant development and metabolism (Marschner 2012). This is no different in *Cannabis sativa* (Anderson et al. 2021). Nitrogen is a component of proteins, chlorophyll, nucleic acids, and other essential molecules in plants. Without adequate nitrogen, plants may show stunted growth, yellowing of leaves, and reduced yield (Maathuis 2009, Marschner 2012, Finnan and Burke 2013, Anderson et al. 2021). Nitrogen is essential in metabolism in the synthesis of macromolecules such as nucleic acids and proteins, as well as other types of molecules that play a role in response to external stressors (Marschner 2012). Nitrogen also impacts the phenylpropanoid pathway, a metabolic hub from which essential molecules such as monolignols, flavonoids, and other polyphenols are formed (Landi et al. 2019). The development and growth of plants are greatly influenced by the number of macronutrients in the soil (Masclaux-Daubresse et al. 2010).

A recent study found that nitrogen positively correlates to chlorophyll content in marijuana cultivars (Anderson et al. 2021). Over-fertilizing marijuana cultivars can lead to salt accumulation in the roots causing nutrient deficiencies and decreased yield (Anderson et al. 2021). In hemp fiber and seed production, plant height, biomass, and seed yield noticeably increased with higher nitrogen rates. Another study conducted on fiber hemp showed that increased fresh and dried biomass yields are related to higher fertilizer rates (Anderson 2021). Studies have shown that the effect of nitrogen supply on the canopy's size and leaf area index (LAI) determine how effectively plants use nitrogen during photosynthetic processes (PNUEc) (Tang et al. 2017). Tang et al. 2017 show that canopy size and LAI decreased when nitrogen supply declines.

According to Aubin et al. 2015, the effects of nitrogen, phosphorus, and potassium fertilization on the biomass and seed output of the two hemp cultivars, CRS-1 and Anka, were examined in experiments carried out in Québec, Eastern Canada. The findings showed a considerable influence on the cultivar and a connection between fertilizer and the environment. With 200 kg N/ha, a more than two-fold increase in seed yield was achieved, and the contents of cellulose and hemicellulose were only slightly affected. The study suggested employing nitrogen fertilization at a rate of >200 kg N/ha, which is greater than the normal rate utilized in Western Canada (150 kg N/ha) (Aubin et al. 2015). These studies emphasize the importance of considering the environment and geographic location before making agronomic suggestions about nitrogen fertilizer for hemp cultivation (Aubin et al. 2015).

The effects of nitrogen fertilization on photosynthesis, fiber, and seed oil content in a hemp cultivar were investigated in a study carried out in Latvia (Maļceva et al. 2011). The findings demonstrated that within a week of application, high dosages of N (100 kg/ha in the form of NH4NO3) boosted photosystem II activity as measured by the Performance Index (PI). The high dosage also increased chlorophyll content relative to unfertilized plants and the fiber output was 8% lower in plants treated with high levels of nitrogen. Despite the decline, the seed oil content did not significantly vary with each fertilization rate. This result indicates a preference for the biosynthesis of amino acids and proteins over oil production (Maļceva et al. 2011).

It is well known that the nitrogen plants take up from the soil is essential for their initial growth. Additionally, nitrogen is essential as a component of several secondary metabolites that plants make; the availability or lack of nitrogen in soils affects not only the biomass output of plants but also the synthesis and final yield of specific molecules (Landi et al. 2019). For example, in poppy (*Papaver somniferum* L.) split nitrogen applications boosted alkaloid production, which led to increased opium production when the plant was blooming (Lošák and Richter 2004). Nitrogen may affect secondary metabolites in hemp, such as THC and CBD, given the impact it can have on other plant components.

In 2021, Anderson et al. conducted a study that investigated the impact of different nitrogen rates on cannabinoids in indoor-grown CBD hemp cultivars. The study found that 50 parts per million (ppm) nitrogen was the optimal fertilizer rate, while higher fertilizer rates dramatically inhibited THC concentrations, plant development, and biomass accumulation. THC levels were compatible (<0.3%) with increased fertilizer rates (> 300 ppm N), but when combined with biomass reductions, the yields of cannabinoids were very low. Furthermore, compared to THC and CBG (> 450 ppm N), CBD content showed greater sensitivity to increased fertilizer rates (> 300 ppm N) (Anderson et al. 2021). A recent study conducted in 2020 found that nitrogen could affect CBD yield under field conditions; nitrogen rates between 140 and 190 kg nitrogen/hectare increased CBD yield (Atoloye et al. 2022). Another study conducted in 2019 and 2020 found that nitrogen rates of 157 and 191 kg nitrogen/hectare increased biomass but had no effect on CBD or THC concentrations (Short et al. 2021).

Biological Control

Biological control aims to reduce pesticide use or eliminate pest insect population growth and damage. Natural enemies are used in various ways depending on the target pest, host, environmental conditions, and pest life cycle (Kogon 1975). There are three main methods of biological control: classical/importation, augmentative, and conservation biological control (Braley 2021).

Classical biological control, often called importation biological control, is a technique used in agriculture and pest management to reduce the number of pests or invasive species. It entails bringing natural enemies or predators from the insect's native range to where the pest is wreaking havoc. Insects, mites, nematodes, or diseases are natural enemies often specialized to attack or feed on the pest species and can be used in classical biological control (Wraight and Hajek 2009). In pest management and agriculture, augmentative biological control suppresses insect populations by exploiting natural enemies. The approach focuses on introducing or increasing populations of pest-controlling organisms like predators, parasites, or diseases (Plouvier and Wajnberg 2018).

Conservation biological control

Conservation biological control (CBC) is used to enhance populations of natural enemies that are already present in the ecosystem by providing resources for food and shelter (Gray et al. 2009). CBC has shown that increasing natural enemy populations in diverse agroecosystems through natural enemy exploitation of food supplies and alternate hosts in non-crop vegetation is successful (Snyder 2019). In an integrated pest management plan, a sustainable method such as CBC can help cut down on pesticide use. The foundation of CBC is preventing habitat loss and environmental disruption brought on by intensive agricultural production to help preserve natural enemies, resulting in pest suppression (Begg et al. 2017).

CBC provides a more suitable habitat for natural enemies by making resources available to grow and sustain natural populations. At the same time, pests have yet to infest or significantly increase in the field (Perdikis et al. 2011, Arnold et al. 2019). CBC can enhance predatory Hemipterans such as assassin bugs (Reduviidae) and big-eyed bugs (Geocoridae); these are generalist predators that can prey on pests, while flower resources provide an additional food source (Perdikis et al. 2011).

Biological control of *Helicoverpa zea*

Corn earworm management is complex because of resistance due to the lack of effective transgenic and chemical control methods (Peterson et al. 2018, Reay-Jones, 2019, Britt et al. 2021). This fact, paired with the confusion surrounding chemical control in cannabis, suggests that biological control may be an alternative solution for *H. zea* in hemp. Different biological control agents are used to control corn earworms in other agricultural systems (Jonsson et al.

2008). Some examples of generalist predators include minute pirate bugs (Anthocoridae), assassin bugs (Reduviidae), big-eyed bugs (Geocoridae), and ladybugs (Coccinellidae) (Torres et al. 2004, Cranshaw et al. 2019, Peterson et al. 2018, Reay-Jones 2019, Britt et al. 2021, Lemay et al. 2022).

Spiders are generalist predators that feed on several soft-body insects, including corn earworms (Lemay et al. 2022). A biological control study found that big-eyed bugs, *Geocoris spp*., and striped lynx spiders (SLS), *Oxyopes salticus* (Hentz), at optimum density could reduce the populations of *H. zea* (Lemay et al. 2022). Another study found that predator *Geocoris floridanus* could decrease the number of *H. zea* and beet armyworms, *Spodoptera exigua*. (Torres et al. 2004). Coccinellidae has regularly observed predators of *H. zea* eggs in sweet corn (Lattin 2000). Specifically, *Colemegilla maculata* are generalist predators and ferocious feeders, which makes them a valuable predatory insect to use as a biocontrol agent (Seagraves and Yeargan 2009).

A polymerase chain reaction (PCR) molecular analysis conducted by Peterson et al. (2018) to determine the frequency of predation of corn earworms and *O. insidiosus* found high predation of corn earworm eggs and larvae caused by *O. insidiosus* (Peterson et al. 2018). Assassin bugs can prey on insects up to three times their size, making them a suitable biological control agent for corn earworms (Grundy and Maelzer 2002, Fiedler and Landis 2007). The enzyme they secrete while feeding melts corn earworm organs and allows the predator to drink their melted body contents (Fiedler and Landis 2007). Assassin bugs are often found in the same environments as corn earworms, which makes them a potential predator against corn earworms in hemp.

Native plants as a conservation biological control strategy

Blooming time for floral resources is an important component of providing stable food sources for predatory insects, allowing them to survive longer in cropping systems. Prey populations can fluctuate during the growing season, especially during the fall (Jonsson et al. 2008). Many beneficial insects leave cropping systems when food sources are low, and habitat diversity of floral resources can provide beneficial insects with alternative food, encouraging them to remain longer (Perdikis et al. 2011).

There is no reason to believe that perennial native plants cannot perform as well as annual exotics, even though most guidelines propose annual plants that are not local to the management region. There are various advantages of using native perennial plants to manage habitats including local ecology has been adapted to by these species, they can be utilized to rehabilitate threatened habitats and increase natural biodiversity, and they are also less prone to spread than exotic annuals. Additionally, compared to annual species, which must be established annually, their perennial nature offers places for natural enemies to overwinter, leading to a one-time seed or plant purchase. This was demonstrated by planting 24 native perennial plants next to corn and soybean fields that attracted high numbers of natural enemies (Fiedler and Landis 2007).

Some native plants that can be used in the Southeastern states are purple coneflower (*Echinacea purpurea*), butterfly milkweed (*Asclepias tuberosa*), red shade yarrow (*Achillea millefolium*), and black-eyed-Susan (*Rudbeckia hirta* L.). Long bloom times, local biodiversity, non-invasiveness, and commercial availability are all benefits of these wildflowers (Stantion and Jenkins 2020).

Long purple coneflower (Asteraceae: *Echinacea purpurea*) is an herbaceous perennial native to central and eastern United States (Burlou-Nagy et al. 2022). It can be identified by its purple and pink flowers, with a bloom time from April to September (Stantion and Jenkins 2020). Butterfly milkweed, (Apocynaceae: *Asclepias tuberosais*) is an herbaceous perennial with orange flowers that bloom from June to August (Fishbein 1996). Black-eyed Susan, (Asteraceae: *Rudbeckia hirta*) is a perennial native to the eastern United States but has become endemic throughout North America. It has distinct yellow flowers with a bloom time from June to October (North Carolina State Extension 2022). Common yarrow (Asteraceae: *Achillea millefolium*) is a perennial plant native to North America. It has white, pink, or red flowers and a bloom time from April to October. All these wildflower species can be grown in full sun or part shade and are drought tolerant (Stantion and Jenkins 2020).

Summary

In conclusion, Integrated Pest Management (IPM) may play a crucial role in hemp cultivation, but further research is desperately needed. By implementing IPM practices, farmers can minimize synthetic pesticides, suppress insect pests, and reduce insect-related yield losses. IPM for hemp involves a combination of cultural, biological, and chemical control methods tailored to a region's specific pest and disease pressures. This approach promotes sustainable hemp production and reduces environmental risks associated with pesticide use.

Proper fertility management is also essential for successful hemp cultivation. Hemp has specific nutrient requirements, and maintaining optimal soil fertility levels is crucial for plant growth, health, and productivity. Organic practices such as crop rotation, cover cropping, and compost or organic fertilizers are commonly employed in hemp fertility management. However, given the unique regulatory nature of hemp cultivation, care must be taken to ensure hemp crops remain below the legal THC limit while still maximizing CBD production. Further research is needed to identify the best fertility practices for hemp in the southeast.

Using perennial native plants as a conservation biological control strategy can provide numerous benefits to hemp crops. Perennial native plants attract and support a diverse range of beneficial insects, such as pollinators and natural enemies of pests. These beneficial insects contribute to pest control by preying on or parasitizing pest species. By incorporating perennial native plant species into and around hemp fields, farmers can enhance biodiversity, promote ecosystem services, and reduce reliance on synthetic pesticides.

Objective

Overall, adopting sustainable practices like IPM, proper fertility management, and incorporating perennial native plants can contribute to the long-term success of hemp cultivation. These strategies prioritize ecological balance, reduce environmental impacts, and promote natural pest control, benefiting both farmers and the surrounding environment. This study aims to investigate the interrelationships among nitrogen levels, the potency of growth chemicals, and arthropod diversity. Specifically, it seeks to examine the impact of variety selection and biological control on multiple aspects, including plant growth, plant chemistry, insect diversity, insect damage, and yield. Furthermore, the study aims to evaluate the effectiveness of various insect predators and mites as biological control agents in a greenhouse hemp environment.

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Table 1.1

Insect	Damage (CBD Hemp)	Location	Category
Corn earworm *Heilicoverpa zea*	Leaves and flowers	Field	Chewing/ Defoliators pest
Two-spotted spider mite *Tetranychus urticae Koch*	Under leaves	Greenhouse	Sucking-piercing pest
Cannabis aphid (*Phorodon cannabis*)	Under Leaves	Field and greenhouse	Sucking-piercing pest
Red imported fire ant *Solenopsis invicta*	Stems	Field	Chewing pest
Yellow-striped armyworm *Spodoptera ornithogalli*	Leaves and Flowers	Field	Chewing/ Defoliators pest
Eurasian hemp borer *Grapholita delineana*	Stems	Field	Stem borer pest
Hemp russet mite *Aculops cannibicola (Farkas)*	Under Leaves	Field and greenhouse	Chewing pest
Pentatomidae Stink bugs	Leaves	Field	Sucking-piercing pest
Green peach aphid *Myzus persicae*	Under leaves	Field and greenhouse	Sucking-piercing pest
Fungus gnats Sciaridae	Roots	Greenhouse	Sucking-piercing pest
Crickets Grylloidea	Stems	Field	Chewing pest

Chapter 2

Exploring the Relationship Between Nitrogen, Chemical Potency, And Arthropod Populations in Southeastern Hemp

Abstract

Hemp, *Cannabis sativa L.*, has a long history of cultivation and is currently experiencing a modern resurgence in production. This is due to the recent United States Farm Bills and increased interest in hemp and its byproducts. In the U.S. and specifically in Alabama, hemp cultivation primarily focuses on the flower component of the plant, cannabidiol (CBD). However, growers must adhere to legal regulations limiting tetrahydrocannabinol (THC) content to 0.3% or less. Despite the growing interest in hemp production, there is a lack of comprehensive information regarding agronomic practices in today's environment. This knowledge gap poses significant challenges for growers as they risk losing their crops due to environmental factors or exceeding the legal THC limit.

To address this issue, a study examined the impact of different nitrogen rates on hemp growth, CBD levels, and THC content. Variety BaOx was grown in the field with different at-plant nitrogen treatments, including 0, 57, 85, 112, or 183 kg/hectare of nitrogen. Plant height and stem width were measured weekly after transplantation. Leaf tissue and flower samples were collected to assess nutrient levels and the potency of plant cannabinoids. Arthropod samples were conducted weekly and caterpillar damaged assessed. Harvest was conducted at the end of season to assess yield.

The results indicated that the nitrogen treatments did not significantly affect plant height or width. In terms of potency, plots that received middle nitrogen rates (85, 112 kg/hectare) resulted in higher CBD and THC content, but statistical significance was not observed in 2021. In 2022, the 0 and 57 kg/hectarenitrogen rates resulted in the highest CBD levels. Analysis of

plant tissue showed no impact of the treatments on nitrogen concentration in the leaves, and no nitrogen deficiencies were observed in either year. Additionally, the highest nitrogen rate of 183 kg/hectare exhibited some insect damage in either year. There we no significant differences in both years.

These findings suggest that the nitrogen treatments employed did not substantially affect hemp plant growth, and even the lowest rates tested did not result in nitrogen deficiencies. However, we found that nitrogen did influence THC and CBD levels. Moreover, nitrogen levels may impact insect damage, which, in turn, can affect flower quality. It is important to note that severe weather conditions may have influenced the results, potentially explaining the absence of statistical significance in the data.

This study emphasizes the need for further experimentation, as there are currently no recommended standard nitrogen rates for hemp cultivation. Additionally, the potential impact on CBD and THC levels highlights the importance of fertility management as an integrated pest management strategy for outdoor hemp production.

Introduction

Hemp (*Cannabis sativa* L.) is one of the earliest cultivated plants. Hemp had not been grown commercially for decades because of the Marijuana Tax Act and other restrictive laws surrounding the crop (Cherney and Small 2016). The United States legalized hemp farming through the 2014 and 2018 Farm Bills (U.S. H.R.2642 - Agricultural Act of 2014 113th Congress 113-333, U.S. H.R. 2 –115th Congress 15-334). Its metabolites, such as cannabidiol (CBD), have been mainly responsible for the comeback over the last several years (Cherney and Small 2016, Williams 2020). However, agronomic recommendations for producing CBD are absent in the southeastern United States. Most fertility management techniques used in other crops like corn, soybeans, and cotton are widely studied and understood. However, there are little data available for CBD hemp production. Most fertility recommendations focus on grain and fiber hemp production (Anderson et al. 2021).

Nitrogen rates are of particular concern to growers due to its potential to affect plant development and the consequent need for nutrients (Anderson et al. 2021). Also of concern is the fact that hemp is subject to high pest pressure. The most damaging outdoor pest of hemp is corn earworm, *Helicoverpa zea* (Cranshaw et al. 2019, Ajayi and Samuel-Foo 2021). These two variables create a significant issue for producers since these factors can alter the cannabinoids in hemp as well as plant development, nutrient uptake, and plant health (Anderson et al. 2021). Along with this problem, there is a high likelihood that many biotic and abiotic factors, such as pest insects, disease, and improper nutrition, may lead growers to lose their hemp crop. These lack of data presents a challenge, and without this knowledge, growers may spend money on expensive inputs without seeing a return on their investment (Cranshaw et al. 2019).

Nitrogen is essential for the metabolism of plants, which includes the synthesis of chlorophyll, nitrogenous bases in nucleic acids, and proteins, all of which affect crop physiology

(Landi et al. 2019). Nucleic acids, chlorophyll, and proteins are essential plant chemicals in insufficient supply in hemp, inhibiting the growth of the plant's stem, leaves, and side branches as well as the buildup of biomass (Eliašová et al. 2004, Figueiredo et al. 2008). The accumulation of other mineral nutrients in plants, such as calcium, iron, and zinc, is influenced by nitrogen supply. Similarly, decreased growth at low nitrogen levels is caused by a reduced intake of certain macro- and micronutrients (Saloner and Bernstein 2020).

Cannabinoids are a class of chemical substances mostly present in *Cannabis sativa* (McPartland et al. 2000, Small 2015). Tetrahydrocannabinol (THC) and cannabidiol (CBD) are the two most widely used cannabinoids (Small 2015). Nitrogen is essential for *C. sativa* plants during vegetative and blooming stages (Landi et al. 2019, Bevan et al. 2021). The ability of *C. sativa* plants to produce cannabinoids may be influenced by nitrogen availability (Landi et al. 2019, Saloner and Bernstein 2022). Studies have indicated that a lack of nitrogen can cause plants to produce fewer cannabinoids (Landi et al. 2019, Bevan et al. 2021, Saloner and Bernstein 2022). *C. sativa* plants focus on allocating limited resources toward vital tasks like growth when there is a nitrogen shortage rather than producing secondary compounds like THC (Landi et al. 2019, Bevan et al. 2021, Saloner and Bernstein 2022). Growers must be mindful of THC which cannot legally exceed 0.3% and will result in total crop destruction. Some studies suggest excessive nitrogen can lead to higher THC and CBD (Landi et al. 2019, Atoloye et al. 2022).

Terpenoids are fragrant substances present in various plants, including *C. sativa*, and they play a role in the distinctive flavor and scent profiles of various strains. Terpenoid synthesis in *C. sativa* can be influenced by nitrogen availability (Chacon et al. 2022). Terpenoids are essential in plants dense against herbivores (War et al. 2012) and may protect the plant from fungal diseases and infestations of insects (Isah et al. 2018, Chacon et al. 2022). The overall sensory properties of the plant may be impacted by changed terpenoid profiles caused by nitrogen availability (War et al. 2012, Chacon et al. 2022).

Environmental factors such as light, temperature, and pH also play crucial roles in the complicated interactions between cannabinoids and nitrogen (Eliašová et al. 2004, Figueiredo et al. 2008). This strain of *C. sativa* and its genetics can also affect how it reacts to nitrogen availability, affecting terpenoids and cannabinoids (Booth et al. 2020). To maximize desired chemical profiles and plant health in *C. sativa*, proper nitrogen control is essential (Saloner and Bernstein 2020).

Plants with high nitrogen levels may experience changes in their chemical makeup. More readily available nitrogen can result in more significant concentrations of some substances, such as proteins and amino acids (Landi et al. 2019). These adjustments to plant chemistry may affect interactions between insects and plants, such as herbivory, deterrence, and attraction. Some studies have demonstrated that an increase in nitrogen can modify the synthesis of defensive chemicals in plants or make some herbivorous insects more attracted to them, thereby changing the dynamics of predator-prey relationships (Fürstenberg-Hägg et al. 2013, Kersch-Becker et al. 2017).

Insect populations can be impacted by nitrogen in both direct and indirect ways (Behie and Bidochka 2013). Increased nitrogen availability can improve plant growth and production because nitrogen is a crucial ingredient for plant growth (Behie and Bidochka 2013, Bala et al. 2018). As a result, plant resources like leaves, flowers, and seeds may grow larger and more plentiful, directly benefiting herbivorous insects that consume these plants (Behie and Bidochka

2013, Bala et al. 2018). In most circumstances, nitrogen is the principal plant nutrient restricting an insect's ability to grow to its full potential (Behie and Bidochka 2013, Bala et al. 2018).

Insects adapted to feed on nitrogen-rich plants may experience population increases when their food sources become more abundant (Behie and Bidochka 2013, Bala et al. 2018). Except in a few rare cases where nitrogen fertilizer application decreases herbivore performance, nitrogen fertilizer generally promotes herbivore eating preferences, food consumption, survival, growth, and population density (Bala et al. 2018). The insect orders that most significantly depend on nitrogen are Hemiptera, Thysanoptera, Diptera, and Lepidoptera (Bala et al. 2018). Within Lepidoptera, pest insects, including corn earworm, *Helicoverpa zea*, and fall armyworm, *Spodoptera frugiperda*, require nitrogen for their reproduction and development. Consumed nitrogen can affect insects' host plant selection and survival, reproduction, development, and population dynamics (Wang et al. 2022). For example, nitrogen is suggested to increase the growth rate and survival *of S. frugiperdaa* (Wang et al. 2022). Given the effect nitrogen may have on plant chemistry and pest dynamics, this study aims to explore the effects of nitrogen on hemp, *Cannabis sativa*, development, CBD and THC production, and insect damage and diversity.

Materials and Methods

Field Methods

Transplanting

One thousand two hundred feminized hemp variety BaOx were ordered from Triangle Hemp in Raleigh, North Carolina (34.53322° N, 83.04279° W). The seeds were sowed in a greenhouse at the Plant Science Research Center in Auburn, Alabama (32.5882919 ° N, -85.4885295° W) on April 15, 2021. Seeds were placed into 30 cell count trays and used PRO-MIX 'BX' (Rivière-du-Loup City, Québec, Canada) general peat-based growing medium potting soil. Trays were put under a misting system; each cell received water every 30 minutes for 30 seconds every day for six weeks. Seedlings were hand transplanted into raised beds with clay, alkaline soil and white plastic mulch at E.V. Smith Research Center in Shorter, Alabama (32.445628, -85.890104) on June 4, 2021. Between-row spacing was 1.83 meters, and in-row spacing was 0.61 meters. Each plot was separated with a 3.1-meter buffer. On June 15, 2021, severe heat and drought caused seedling death, so additional transplants were made into the field. Drip irrigation was used as needed based on standard agronomic practices. Weeds were mechanically removed from all plots every week.

On April 15, 2022, hemp was sown in the greenhouse using the same methods as 2021. On June 6, seedlings were hand transplanted in the field with the same row and plot spacing in 2021. In late June 2022, extreme heat caused 50% of plant mortality in the field. New seedlings were transplanted as replacements. The same irrigation and weed control practices were used as 2021.

Nitrogen Trial

Four nitrogen rates were applied in 2021 and five rates in 2022 in a randomized complete block design with four replications. In 2021, there were ten plants in each plot, and in 2022, the number of plants decreased to five. The plots were treated with varying amounts of Ultrasol Multipurpose Plus 20-20-20 (SQM North America) nitrogen fertilizer, including 0 (only 2022), 57, 85, 112, or 183 kg/hectare. The nitrogen was a split application with a portion of the nitrogen applied before transplant when the beds were formed with white plastic mulch. The second applications were made on July 22, 2021. No second application was made in 2022. All other macronutrients and micronutrients were applied pre-plant based on soil test results based on field corn: phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), iron (Fe), boron (B), chlorine (Cl), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo).

Hemp Plant Growth and Leaf Tissue

Beginning on June 18, 2021, plant height and plant stem width were measured for 10 consecutive weeks. All height was measured from the base of the plant to the apical meristem. Measuring calipers were used to measure the diameter of the stem at the base of the plant at the soil line. On September 15, 2022, prior to the harvest, the height of three plants from each plot was measured. A meter stick was utilized to measure the distance from the base of the plants to their tallest apical meristems (the tips of the main stems). Additionally, a plant mortality assessment was conducted for each plot to determine if any plants had died or were no longer viable.

Leaf tissue samples were collected at three growth phases—pre-flowering on July 14, 2021, flowering on August 26, 2021, and post-flowering on September 2, 2021. Twenty to thirty fully matured leaves were taken from each plot. Leaf samples were sent to Waters Agricultural Laboratories, Inc in Camilla, Georgia for analysis of plant nutrient rates. Starting on July 5, 2022, measurements of plant height and stem width were conducted for six consecutive weeks using the same methods as described earlier. Leaf tissue samples were collected at three different stages of growth: pre-flowering (August 9, 2022), flowering (September 9, 2022), and post-flowering (September 13, 2022). The methods mentioned previously were employed for observing and collecting leaf tissue samples.

Arthropod sampling

Arthropod sampling was conducted weekly from July 28, 2021, to October 1, 2021, using a black vinyl drop cloth (85.2 cm x 96.96 cm) (Great Lakes IPM™, Vestaburg, Michigan, USA). Heavy-duty 38cm muslin sweep net sweeping net (Forestry Suppliers, Inc., Jackson, Mississippi, USA) was used to sample each plot. One plant was randomly selected in each plot to conduct a drop cloth sample. A drop cloth was placed at the base of the plant with the wooden rod adjacent to the plant stem. The plant was shaken gently five times into the drop cloth with enough force to dislodge any arthropods. All dislodged arthropods were collected using either an aspirator or hand collecting. Ten figure-eight sweeps were conducted per plot with a sweep net. All contents from the sweep net were placed into Ziploc bags (16.5cm x 14.9cm) (S.C. Johnson & Son Inc, Cincinnati, Ohio) and kept in a cooler for transport to the laboratory. Arthropod samples were kept in a -20°C freezer before they were identified to the lowest taxonomic level possible. Arthropod sampling was carried out weekly from July 27, 2022, to September 8, 2022, using the same drop cloth sweet net to sample each plot. The same sampling methods from 2021 were used in 2021.

Cannabinoid Testing

Prior to harvest, floral samples were collected for potency analysis on three dates: September 1, 2021, September 14, 2021, September 21, 2021, and September 28, 2021. Flowers were randomly selected from one from each plot for cannabinoids. Sampling procedures followed the Alabama Department of Agriculture and Industries' (ADAI) standard operating procedures (SOP) for pre-harvest THC sampling. The top 20 centimeters of the plant's primary stem was clipped, secured in a paper bag, and removed for analysis. Samples were sent to ACS

Laboratory, Sun City Center, Florida for analysis. A panel of eleven cannabinoids was tested, including: tetrahydrocannabinol (THC), delta-8-Tetrahydrocannabinol (Delta 8-THC), tetrahydrocannabinol acid (THCA), tetrahydrocannabivarin (THCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerolic acid (CBGA), and cannabinol (CBN).

On September 7, 2022, floral samples were taken in preparation for the harvest in order to determine their potency. Flowers were randomly selected from each plot for cannabinoid analysis, following the sampling procedures outlined in the Alabama Department of Agriculture and Industries' (ADAI) standard operating procedures (SOP) for pre-harvest THC sampling. The same methods employed in 2021 were used. A panel of ten cannabinoids, including: tetrahydrocannabinol (THC), delta-8-Tetrahydrocannabinol (Delta 8-THC), tetrahydrocannabinol acid (THCA), tetrahydrocannabivarin (THCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerolic acid (CBGA), and cannabinol (CBN) was tested.

Plant damage and caterpillars

On September 3 and 10, 2021, caterpillar numbers and damage were assessed on five buds randomly selected in each plot. Buds consists of the inflorescence on a single stem that is approximately 7.62 cm. A damage rating scale of 0 – 5 was used (Figure 2.1). From July 18, 2022, to September 9, 2022, caterpillar damage were assessed on five randomly selected buds in each plot. The same methods and damage scale described earlier were utilized for this assessment.

Harvest

In 2021, hemp plants were not harvested due to damage from disease and weather events. On September 16, 2022, three plants from each plot were harvested at the base of the plant, where the stem meets the soil by a Bond steel bypass lopper (Bond Manufacturing, Antioch, California, USA). The fresh weight of plants (stem, leaves, and buds) was measured using a Taylor hanging scale (Uline, Pleasant Prairie, Wisconsin, USA). Additionally, the width of each plant stem was assessed using measuring calipers. After weighing, harvested plants were transported to a barn at the Organic Farm on EVS Research Station Center in Shorter, Alabama (32.445628, -85.890104). Harvested plants were hung upside down for 14 days on Grip-Rite (0.0508 centimeters diameter) black annealed steel 16 gauge tie wire (Prime Source, Irving, Texas, USA). Plants were loaded onto a Taylor hanging scale on September 30, 2022, and the dry weight of each plant was recorded.

In 2022, harvested buds were deemed either marketable or unmarketable. In 2022, flower bud fresh weights were measured using a digital scale (VWR International LLC, Radnor, Pennsylvania, USA). On October 16th, the dry weight was measured using a digital scale mentioned above.

Statistical Analysis

Analyses for 2021 and 2022 was conducted using RStudio 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria). Each year was analyzed separately due to variations in dates and the number of plants in each plot. A generalized linear model and Tukey's HSD was used to identify significant differences plant growth, plant nutrients, chemical potency, and yield between rates. A generalized linear model with a Poisson distribution and Tukey's HSD was used to identify significant differences insect damage, arthropod family richness and abundance between different rates. All graphs were created using Excel (Microsoft Corporation, Redman, WA, USA).

Results

Plant Measurements

In 2021 and 2022, there were no significant effects of nitrogen rate on plant height (2021: P = 0.1992, 2022: P = 0.7845) or plant width (2021: P = 0.1992, 2022: P = 0.8671). In 2021 and 2022, there were significant effects of date on plant height (2021: P < 0.0001, 2022: P < 0.0001) and plant width (2021: P < 0.0001, 2022: P < 0.0001).

At harvest in 2022, the amount of nitrogen applied did not impact the height of the plants (P = 0.585). The rates of 112 and 85 pounds per acre resulted in significantly taller plants. Regarding stem diameter, the nitrogen rate in 2022 had no significant effect (P = 0.8670). The 183 pounds per acre rate exhibited a significantly larger stem diameter compared to the rates of 0, 57, 85, and 112 pounds per acre.

Leaf tissue analyses

In 2021 and 2022, there were no significant effects of nitrogen rate on nutrient concentrations in the leaves (2021: P = 0.8770, 2022: P = 0.8230) (Table 2.5). In 2021 and 2022, there were no significant effects of nitrogen rate treatment on phosphorous (2021: P = 0.7130, 2022: P = 0.1380), potassium (2021: P = 0.9980, 2022: P = 0.0089) calcium (2021: P = 0.9180, 2022: P = 0.4850), sulfur (2021 P =0.9320, 2022: P = 0.6680), magnesium (2021: P = 0.9320, 2022: P = 0.944), boron (2021: P = 0.9320, 2022: P = 0.0555), zinc (2021: P = 0.1460, 2022: P = 0.4040), manganese (2021: P = 0.6010, 2022 P = 0.5350), iron (2021: P = 0.7930, 2022: P = 0.9950), or copper (2021: P = 0.1370, 2022: P = 0.7860) concentrations in the leaves (Tables 2.5, 2.6).

In 2022, there was a significant effect of nitrogen rate treatment on potassium concentrations in the leaves (P = 0.0089). Rate 0 had significantly higher potassium compared to the other rates (P = 0.0015). In 2021 or 2022, there were no nutrient deficiencies detected in any of the micro- or macronutrients across any of the treatments (Tables 2.5, 2.6).

Cannabinoid concentrations

Overall, for trial one in 2021, nitrogen rate did not have a significant effect on THC percentage on a dry weight basis (P = 0.1798). Overall, 85 and 112 kg/hectare rate had a higher THC percentage compared to the 57 and 183 kg/hectare rates (P = 0.0434). On the first date nitrogen did not have significant effect on THC percentage on a dry weight basis (P = 0.9729). On this date 85 and 112 kg/hectare rate had a higher THC percentage compared to the 57 and 183 kg/hectare rates (Table 2.7) (Figure 2.3)

Overall, for trial one in 2021, nitrogen rate did not have a significant effect on CBD percentage on a dry weight basis (P = 0.6598). The 112 kg/hectare rate had a higher CBG percentage compared to the 57, 85, and 183 kg/hectare rates. On the first date nitrogen did not have significant effect on CBD percentage on a dry weight basis (P = 0.1717). On this date 85 and 112 kg/hectare rate had a higher CBD percentage compared to the 57 and 183 kg/hectare rates. CBN was not detected in the flower samples in 2021 (Table 2.7) (Figure 2.2).

Overall, trial one in 2021 date had a significant effect on THC (P = 0.0121), CBD (P = 0.0010) and CBG (p = 0.0071) percentage on a dry weight basis. On September 1 ,2021 had significantly higher THC, CBD and CBG compared to September 14, 21, and 28 (Table 2.7).

Overall, for trial two in 2022, nitrogen rate did not have a significant effect on CBD percentage on a dry weight basis (P = 0.4918). There also were no significant differences between nitrogen and THC in 2022 (P = 0.7319). There were no significant differences detected between nitrogen rates in CBC (P = 0.412), CBDA (P = 0.529), CBG (P = 0.721), THCA (P = 0.674), or CBGA (P = 0.716) percentages on a dry weight basis (Table 2.8). CBDV, CBN, and THCV were not detected in the flower's samples (Table 2.8), (Figures 2.4 and 2.5)

Plant damage

In 2021, nitrogen rate did have a significant effect on plant damage (P = 0.0503). The 85 and 183 kg/hectare had significantly higher damage compared to the 57, and 112 kg/hectare rates (Table 2.9) (Figure 2.6). In 2022, the rate did not have a significant effect on plant damage (P = 0.8892) (Table 2.10) (Figure 2.7).

Arthropod abundance and abundance

2021

A total of 1,255 arthropods were captured in sweep nets and drop cloth in 2021 comprised of 82 families and a total of 1,581arthropods were captured sweep nets and drop cloths in 2022 comprised of 59 families (Table 2.11). In 2021, the nitrogen rate did not have a significant impact on arthropod family richness (P = 0.7437). In 2021, the study found that the application rates of 183 and 85 kg/hectare rates higher arthropod family richness compared to the rates of 57 and 112 kg/hectare rates. Among all the rates evaluated, the application rates of 57 and 112 kg/hectare rates showed the lowest arthropod family richness but these results were not statically significant. In 2021, date had significant effect on arthropod family richness (P < 0.0001) with August 25 having significantly higher arthropod family richness then decreased on all subsequent sample dates (Table 2.12)

The abundance of arthropods in 2021 was not significantly influenced by the nitrogen rate (P = 0.3981) (Table 2.13). In 2021, the study found that the application rates of 183 kg/hectare rates higher arthropod abundance compared to the rates of 57, 85 and 112 kg/hectare rates (Table 2.13.). In 2021, date had no significant effect on arthropod abundance (P = 0.681) with August 25 having the highest arthropod abundance decreased on all subsequent sample dates.

A total of 456 pest insects were captured in 2021 comprised of 31 families. The most abundant pest insects were Ceratopogonidae, Chrysomelidae and Drosophilidae. Nitrogen rate did not have significant impact arthropod incidental abundance (P = 0.8732). Rate 183 did have higher arthropod incidental abundance (Table 2.14) . A total of 426 pest insects were captured in 2021 comprised of 8 families. The most abundant pest insects were Acrididae, Cicadellidae and Noctuidae. The nitrogen rate did not have a significant effect on the pest arthropods abundance (P = 0.3900). Rate 85 had the highest number of pest arthropods compared to the other rates, while rate 57 had the lowest (Table 2.14). In 2021 the nitrogen rate did not have a significant effect on the predatory arthropods abundance s (P = 0.3900). Rates 57 112 and 183 had the highest number of predatory arthropods while rate 85 had the lowest. However, predatory insects were low in numbers compared to the other categories, except for parasitoids. A total of 257 predatory arthropods were captured in 2021 comprised of 19 families. The most abundant predatory arthropods were Anyphaenidae, Coccinellidae, Dolichopodidae, Geocoridae and Reduviidae (Table 2.14). The nitrogen rate did not have a significant effect on the parasitoid insects abundance (P = 0.6417). Rate 183 had the higher number of parasitoid insects compared to the other rates, while rate 57 had the lowest. However, parasitoid insects were relatively low in numbers compared to pests, incidental arthropods, and predatory arthropods. A total of 116 parasitoids insects were captured in 2021 comprised of 10 families. The most abundant parasitoids were Braconidae, Ichneumonidae, Scelionidae and Tachinidae (Table 2.14).

2022

In 2022, nitrogen rate did not have a significant effect on arthropod family richness (P = 0.3952). Rate 183 had the highest arthropod family richness while rate 0 had the lowest. Date did have a significant effect on arthropod family richness with August 15, 2022, having the highest arthropod family richness (P < 0.0001). (Table 2.15). In 2022, nitrogen rate did have a significant effect on arthropod abundance (P < 0.0001). Rate 183 had significantly higher arthropod abundance while rate 0 had the lowest. Date did have a significant effect on arthropod abundance with August 10, 2022, having the highest arthropod abundance (P < 0.0001) (Table 2.16).

A total of 704 incidental arthropods were captured in 2022 comprised of 16 families. The most abundant incidental arthropods were Ceratopogonidae, Chrysomelidae, Drosophilidae and Membracidae. The nitrogen rate did have a significant effect on the incidental arthropods abundance (P < 0.0001). Rate 112 had the significantly higher incidental arthropods abundance compared to the other rates, while rate 0 had the lowest (Table 2.17).

A total of 268 pest insects were captured in 2021 comprised of 8 families. The most abundant pest arthropods abundance was Acrididae, Miridae, Formicidae and Noctuidae. In rate 0, 57, 85 and 112. The nitrogen rate did not have a significant effect on the pest insect abundance (P = 0.9997). Rate 112 had the highest pest insect abundance compared to the other rates, while rate 0 had the lowest (Table 2.17).

A total of 312 predatory arthropods were captured in 2022 comprised of 18 families. The most abundant predatory arthropods were Dolichopodidae, Geocoridae, Reduviidae and Syrphidae. The nitrogen rate did not have a significant effect on the Predatory category of arthropods (P = 0.6595). Rate 112 had the highest number of predatory arthropods compared to the other rates, while rate 57 had the lowest (Table 2.17).

A total of 297 parasitoids insects were captured in 2022 comprised of 9 families. The most abundant parasitoids were Chalcididae, Ichneumonidae, Scelionidae and Tachinidae (Table 2.17). Rate 112 had the highest parasitoid insects abundance compared to the other rates, while rate 0 had the lowest (Table 2.17).

Harvest

Plant biomass and Marketability

The nitrogen rate in 2022 also did not have a significant influence on the wet plant weight. (P = 0.9978) (Table 2.18). Similarly, the nitrogen rate did not have a significant effect on the dry plant weight (P = 0.7469) (Table 2.19). Furthermore, the nitrogen rate did not have significant impact the on wet marketable bud weight (P = 0.5967) (Table 2.20). Regarding unmarkable wet bud weight in 2022, the nitrogen rate did not have a significant effect (P = 0.8966) (Table 2.21). The nitrogen rate also did not have a significant effect on the dry marketable bud weight (P = 0.4633) (Table 2.22). Similarly, the nitrogen rate did not have a significant effect on the dry unmarketable bud weight (P = 0.4426) (Table 2.23). Lastly, the nitrogen rate did not have a significant impact on the marketable proportion of three buds from three plants (P = 0.7709) (Figure 2.8)

Discussion

The study investigated the effects of nitrogen rates on various aspects of plant growth, nutrient concentrations, cannabinoid percentages, arthropod abundance, and plant biomass marketability in field trials conducted in 2021 and 2022. We hypothesized that higher nitrogen rates will lead to increased plant growth, chemical potency, and arthropod diversity. We found some of these relationships were significantly affected by nitrogen, while others were not.

Plant Growth

Plant height and width were not significantly influenced by nitrogen rate, but date had significant effects on both parameters. In 2021, the middle and highest nitrogen rates resulted in the tallest plants, while in 2022, the rates of 57 and 183 kg/hectare had the greatest plant height. Stem height and width were also affected by nitrogen rate, with higher rates resulting in taller and wider stems. In both experiments we did not see any treatments that had visible deficiency from nitrogen. Also, plants in the higher nitrogen treatment did not have dark green, shiny leaves with down curled leaves, which is an indication of nitrogen toxicity (Anderson et al. 2021). We did see a trend in decreased height and width in the two middle rates of nitrogen which resulted in slightly shorter plants compared to rates 183, 57, and 0. Similarly, Anderson et al. 2021 observed a decrease in plant height with decreasing fertilizer rates (300 ppm to 600 ppm) (Anderson et al. 2021) which can explain why we saw these results.

In a similar study using marijuana cultivars found a reduction in plant growth in fertilizer greater than 150 ppm nitrogen. In this study it is thought that increasing nitrogen supply levels will increase the osmotic potential of leaf tissue sap, indicating a response to salt. This salinity response is characterized by an initial quick response to high salinity levels, followed by a slow accumulation of salts within plants, which ultimately results in limited growth at later stages. High salt concentrations from the nitrogen could have contributed to smaller plants (Saloner and

Bernstein 2020). Our results in both experiments could potentially be attributed to high salinity levels or soil type. To delve deeper into this correlation, we propose conducting a greenhouse experiment using potting soil, identical methods and nitrogen rates, but this time converting them into parts per million (PPM).

Plant Nutrients

Leaf tissue analyses showed no significant effects of nitrogen rate on nutrient concentrations, and no nutrient deficiencies were detected across treatments. The nutritional value of plants can be affected by the availability of nitrogen. Plants with higher nitrogen levels typically have more nitrogen in their tissues, which provides more nutrition for insects that eat plants (Behie and Bidochka 2013). No difference were observed between higher rates of nitrogen in the leaf tissue. Extreme weather conditions, such as heavy rainfall, might have influenced our results. To address this potential factor, we suggest conducting a greenhouse experiment with the same leaf tissue test and nitrogen rates used previously.

Chemical Potency

The study found no consistent impact of nitrogen rate on THC and CBD percentages in both trials. However, date had a significant impact on CBD and THC in 2021. Cannabis plants have different mechanisms for producing CBD and THC. While the availability of nitrogen can affect the total amount of cannabinoids produced, changes in the levels of CBD and THC may not follow a similar pattern. Even though there were no statistically significant differences, there were trends suggesting that the amount of nitrogen did influence CBD and THC concentrations. The final cannabinoid makeup can also be influenced by the specific genetics of the cannabis strain and other environmental conditions (Hussain et al. 2021). We recommend conducting an experiment using various varieties while maintaining the same rates.

Insect Damage

Nitrogen rate did not significantly affect plant damage in either year. Higher nitrogen levels in plants typically promote greater biomass, increased leaf area, and overall growth. This abundance of plant material serves as a plentiful food source for herbivorous insects, potentially leading to elevated insect populations and greater herbivory rates (War et al., 2012). Notably, research indicates that *H. zea* prefers plants with higher nitrogen content, as evidenced by a significant difference in insect damage (Biswas et al. 2009, Li et al. 2021, Wang et al. 2022). The robust health of the higher nitrogen rate plants might have enabled them to fend off insects more effectively. One study suggested that THC and CBD concentrations might be impacted insect herbivory (Jackson et al. 2021). There were significant effects on insect damage in the higher rates of nitrogen. It is possible for nitrogen to alter the plant's defense making it susceptible to insect feeding. The insect feeding could have triggered immune response resulting in decreasing cannabinoid production.

Insect Diversity

In 2021, arthropod family richness and abundance were not influenced by nitrogen rate. In 2021 date had a significant effect on arthropod family richness and abundance. In 2022, nitrogen did not have a significant effect on arthropod family richness. In 2022, nitrogen did have a significant effect on arthropod abundance with rate 183 having the highest. Date had a significant effect on arthropod family richness and abundance. In 2021 nitrogen rate did not have a significant effect on incidental, pest predatory arthropods or parasitoids insects. In 2022 nitrogen rate did have a significant effect on incidental, pest predatory arthropods.

Nitrogen did not have a significant effect on insect family richness and abundance. However, in CBD hemp, there is typically a high insect diversity and abundance. A wide range of insect families can be observed in CBD hemp fields. Incidental insects were highly abundant in both years, including herbivorous insects such as Chrysomelidae and Membracidae. These insects might prefer higher rates but do not cause economic losses for growers. The other most common incidental insect families were Ceratopogonidae and Drosophilidae which are flies that feed on nectar.

A total of 8 families of pest insects were collected, including Noctuidae, which is the family corn earworm belongs to, a major pest in CBD hemp. The corn earworm feeds on the valuable buds of the plant, causing damage to the marketable portions. In this study, nitrogen rate did not influence pest insects but there was a trend where the highest rates 85, 112 and 183 had overall higher numbers of insects. The difference in pest abundance between the two years could be attributed to the health of the plants. In 2022, it is possible that the plants in Rate 183 were not as healthy as those in the other rates. Therefore, the reduced abundance of pest in Rate 183 in 2022 might be due to the less favorable condition of the plants in that treatment.

In 2021 there were lower numbers of predatory arthropods and parasitoid insects which may explain the higher numbers of corn earworms. There was an increase in predatory arthropods and parasitoid insects in the year 2022 which could have decreased the abundance of corn earworm. The most common predatory arthropods found were: Anyphaenidae, Coccinellidae, Dolichopodidae, Geocoridae , Reduviidae and Syrphidae. The most common parasitoid insects were: Braconidae Chalcididae, Ichneumonidae, Scelionidae and Tachinidae. Hemp fields are known to harbor a rich diversity of predatory arthropods and parasitoids, which are instrumental in reducing pest populations. Predatory insects, including ladybugs, assassin bugs, big-eyed bugs, spiders, and parasitic wasps, play a crucial role in natural pest management within hemp ecosystems. These beneficial insects actively prey on and control populations of pest insects such as the corn earworm, helping to regulate their numbers.

The presence of a diverse community of predatory arthropods and parasitoids in hemp fields offers a sustainable and environmentally friendly approach to pest control. Rather than relying solely on chemical interventions, using the natural predation and parasitism abilities of these insects can contribute to pest management. This approach aligns with the principles of integrated pest management (IPM), which emphasizes the use of multiple tactics, including biological control, to minimize the need for synthetic pesticides.

By supporting populations of predatory arthropods and parasitoids, hemp growers can promote a healthier and more balanced ecosystem within their fields. This natural pest management strategy can contribute to sustainable agriculture practices while reducing reliance on chemical inputs, benefiting both the crop and the environment. Balancing insect diversity and abundance in hemp cultivation is crucial for sustainable and successful crop production. Growers need to carefully monitor insect populations, identify pests and beneficial insects, and take appropriate action when pest populations exceed thresholds that may cause significant damage. Additionally, implementing practices that enhance the habitat for beneficial insects, such as providing flowering plants as additional food sources or creating refuge areas, can help maintain a more balanced insect community in hemp fields.

Overall, managing insect diversity and abundance in flowering hemp requires a proactive and holistic approach that considers the specific pests and beneficial insects in the local ecosystem. By implementing effective IPM strategies and fostering a balanced insect community, growers can mitigate pest damage, reduce reliance on chemical pesticides, and support the overall health and productivity of their hemp crops.

Harvest Parameters

Harvest data showed no significant effects of nitrogen rate on plant biomass and marketability in 2022. Our results could have been effected by different environmental conditions, genetics or high salinity levels that were previously talked about.

Conclusions

Overall, the study suggests that while nitrogen rates may influence some aspects of plant growth and arthropod abundance but maybe not have consistent effects on cannabinoid concentrations and plant biomass marketability. Fertility management is crucial in agricultural practices, including for Alabama growers. Properly managing fertility levels, such as nitrogen, in crops is essential for optimal plant growth and development. As mentioned previously, increased plant nitrogen levels can increase biomass, leaf area, and overall growth. However, this can also attract herbivorous insects, potentially resulting in increased insect populations and higher levels of herbivory. For Alabama growers cultivating crops such as cannabis, fertility management becomes particularly important when considering the production of CBD and THC, two prominent cannabinoids found in cannabis plants. While the specific effects of nitrogen levels on CBD and THC production may vary depending on the strain and other factors, evidence suggests that nitrogen availability can influence the quality and potency of these cannabinoids.

The importance of insect feeding and damage depends on the specific pests present in the area and their impact on crop health. Insects can cause substantial damage to plants, including cannabis, by feeding on leaves, stems, and flowers. This damage can affect the overall health and yield of the crop, as well as potentially impacting the quality and cannabinoid content of the flowers. To address insect damage, farmers can utilize diverse integrated pest management techniques. These methods involve monitoring pest populations, implementing cultural practices, employing biological controls, and, when required, applying suitable pesticides. By adopting these strategies, growers aim to effectively manage pests while minimizing adverse effects on the environment and the quality of their crops.

Before applying nitrogen to their fields, it is advisable for growers to have their soil fertility tested. This allows them to assess the current nutrient levels and determine the appropriate amount of nitrogen needed. Starting with a lower rate of nitrogen and gradually supplementing nitrogen if necessary is also recommended. This approach ensures that the plants receive adequate nutrition while minimizing the risk of excessive nitrogen levels, which can have negative consequences such as environmental pollution and reduced crop quality. By conducting soil fertility tests and adopting a cautious approach to nitrogen application, growers can optimize their fertility management practices and support the healthy growth and development of their crops while minimizing potential risks associated with nutrient imbalance.

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Tables

Table 2.1

2021: Mean Plant Height (cm) +/- Std. Error

	2021 Sample Date										
Rate	18-Jun	25-Jun	29-Jun	6-Jul	13-Jul	20-Jul	30-Jul	6-Aug	13-Aug	20-Aug	27-Aug
57	26 +/- 2.1	33 +/- 3.0	37 +/- 3.0	49 +/- 3.0	60 +/- 3.0	70. +/- 3.0	77 +/- 3.0	83+/- 3.0	82+/- 2.1	85 +/- 3.0	84 +/- 3.0
85	28 +/- 1.7	36+/- 1.7	41+/- 1.7	49+/- 1.7	62 +/- 1.7	71 +/- 1.7	78 +/- 1.7	83 +/- 1.7	84 +/- 1.2	81 +/- 1.7	84+/- 1.7
112	25 +/- 3.3	32 +/- 3.3	39 +/- 3.3	46 +/- 3.3	60 +/- 3.3	84+/- 3.3	77 +/- 3.3	82 +/- 3.3	84 +/- 2.3	84 +/- 3.3	84 +/- 3.3
183	28 +/- 3.4	35 +/- 3.4	40+/- 3.4	50+/- 3.4	60 +/- 3.4	71 +/- 3.4	80 +/- 3.4	87+/- 3.4	86 +/- 2.4	85+/- 3.4	91 +/- 3.4

The mean ± standard error of the plant height (cm) measure from the top of the apical meristem to the base of the plant at the soil

Table 2.2

2021: Mean Stem Width (mm) +/- Std. Error

2021 Sample Date											
Rate	18-Jun	25-Jun	29-Jun	6-Jul	13-Jul	20-Jul	30-Jul	6-Aug	13-Aug	20-Aug	27-Aug
57	4.9+/- 1.7	7.8+/- 1.7	14 +/- 1.7	12 +/- 1.7	17 +/- 1.7	19 +/- 1.7	25+/- 1.7	22 +/- 1.7	31 +/- 1.2	29 +/- 1.7	30 +/- 1.7
85	5.2+/- 3.4	7.0+/- 3.4	16+/- 3.4	14+/- 3.4	14+/- 3.4	27+/- 3.4	24+/- 3.4	23+/- 3.4	26+/- 2.4	27+/- 3.4	29+/- 3.4
112	4.8+/- 1.7	8.1+/- 1.7	15+/- 1.7	11+/- 1.7	14+/- 1.7	18+/- 1.7	26+/- 1.7	23+/- 1.7	28+/-1.2	28+/- 1.7	29+/- 1.7
183	5.1+/- 1.9	6.8+/- 1.8	15+/- 1.8	13+/- 1.8	17+/- 1.8	17+/- 1.8	22+/- 1.8	22+/- 1.8	30+/- 1.2	29+/- 1.8	29+/- 1.8

The mean ± standard error of the plant width (mm) measure from the diameter of the stem at the base of the plant at the soil line

Table 2.3

2022: Mean Plant Height (cm) +/- Std. Error

2022 Sample Date							
Rate	5-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug	15-Sep
0	39 +/- 4.9	46 +/- 4.9	56+/-3.4	68+/-4.9	67 +/- 4.9	73+/- 4.9	68+/- 4.9
57	41+/- 3.1	49 +/- 3.1	60 +/- 3.1	69 +/- 3.1	73+/- 2.2	85 +/- 3.1	68 +/- 3.1
85	38+/-6.3	41+/-6.3	56+/-6.3	63+/-6.3	67+/-4.5	74+/-6.3	82+/-6.3
112	37+/-4.9	45+/-4.9	55+/-4.9	63+/-4.9	68+/-3.5	73+/-4.9	80+/-4.9
183	41+/-4.2	48+/-4.2	59+/-4.2	66+/-2.9	37+/-4.2	77+/-4.2	61+/-4.2

The mean ± standard error of the plant height (cm) measure from the top of the apical meristem to the base of the plant at the soil.

Table 2.4

2022: Mean Stem Width (mm) +/- Std. Error

	2022 Sample Date						
Rate	5-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug	15-Sep
0	6.3+/- 1.9	9.7 +/- 1.9	11 +/- 1.9	14+/- 1.9	17 +/- 1.3	21 +/- 1.9	25 +/- 1.9
57	6.3+/- 1.9	9.7+/- 1.9	11+/- 1.9	14+/- 1.9	17+/- 1.3	21+/- 1.9	26 +/- 1.9
85	5.6+/- 2.1	7.9+/- 2.1	9.7+/- 2.1	13+/- 2.1	16+/- 1.5	18+/- 2.1	21+/- 2.1
112	5.5+/- 2.3	7.8+/- 2.3	10+/- 2.3	14+/- 2.3	16+/-1.6	17+/- 2.3	22+/- 2.3
183	6.4+/-2.0	7.6+/-2.0	14+/-2.0	2.0+/-2.0	16+/-1.4	20+/-2.0	33+/-2.0

The mean ± standard error of the plant width (mm) measure from the diameter of the stem at the base of the plant at the soil line

Table 2.5

2021 Leaf tissue analysis

Nutrient	Rate	Concentration Mean +/- Std. Error
N%	57	3.8±0.3
	85	3.8±0.4
	112	4.1±0.4
	183	4.0±0.4
P%	57	0.2 ±0.02
	85	0.3±0.03
	112	0.2±0.03
	183	0.2±0.03
K%	57	1.3±0.1
	85	1.4±0.2
	112	1.4±0.2
	183	1.4± 0.2
Mg%	57	0.6±0.03
	85	0.7±0.04
	112	0.6±0.04
	183	0.6 ±0.04
Ca%	57	4.4 ±0.2
	85	4.4±0.3
	112	4.4±0.3
	183	4.6±0.3
S%	57	4.4±0.02
	85	4.4±0.03
	112	4.4±0.04
	183	4.6±0.04

The mean ± standard error of the plant micronutrient and macronutrient in leaf tissue analysis.

Table 2.5

2021 Leaf tissue analysis

Nutrient	Rate	Concentration Mean +/- Std. Error
B%	57	25±2.6
	85	25±3.7
	112	24±3.8
	183	27±0.04
Zn%	57	27±2.3
	85	29±3.3
	112	31±3.3
	183	29 ±3.3
Mn PPM	57	94±7.0
	85	107±9.9
	112	100±10
	183	100±10
Fe PPM	57	99±7.4
	85	88±10
	112	92±10
	183	93 ±10
Cu PPM	57	8.2±0.3
	85	7.3±0.5
	112	8.6±0.5
	183	7.9 ±0.5
	0	3.9±0.2
	57	3.9±0.3

The mean ± standard error of the plant micronutrient and macronutrient in leaf tissue analysis.

Table 2.6

2022 Leaf tissue analysis

The mean ± standard error of the plant micronutrient and macronutrient in leaf tissue analysis.

Nutrient	Rate	Concentration Mean +/- Std. Error
N%	85	4.1±0.3
	112	4.0±0.3
	183	4.2±0.3
P%	0	0.3±0.2
	57	0.2±0.3
	85	0.3±0.3
	112	0.2±0.3
	183	0.2 ±0.3
K%	0	0.7±0.07
	57	0.7±0.10
	85	1.3±0.10
	112	1.2±0.3
	183	1.1±0.1
Mg%	0	0.7±0.07
	57	0.7±0.1
	85	0.7±0.1
	112	1.2±0.3
	183	0.7 ±0.1
Ca%	0	0.2± 0.03
	57	0.2 ± 0.03
	85	0.2 ± 0.03
	112	0.2 ± 0.03
	183	0.2± 0.03
S%	0	0.2±0.01
	57	0.2±0.01
	85	0.2±0.01

	112	0.2±0.01
	183	0.2±0.01

The mean ± standard error of the plant micronutrient and macronutrient in leaf tissue analysis.

Table 2.6

2022 Leaf tissue analysis

Nutrient	Rate	Concentration Mean +/- Std. Error
B%	0	26±2.1
	57	26±3.0
	85	24±3.0
	112	24±3.1
	183	24±3.2
Zn%	0	26±2.1
	57	26±3.0
	85	29±3.0
	112	24±3.1
	183	24±3.2
Mn PPM	0	181±11
	57	180±16
	85	187±16
	112	195±16
	183	166±16
Fe PPM	0	106±70
	57	107±10
	85	110±10
	112	107±10
	183	105±10
Cu PPM	0	9.4±0.5
	57	8.9±0.7
	85	8.5±0.7
	112	8.6±0.7
	183	8.6±0.7

The mean ± standard error of the plant micronutrient and macronutrient in leaf tissue analysis.

Table 2.7

Cannabinoid concentrations 2021

Rate	Sample Date	THC	CBD	CBG	Other	Total
57	1-Sep-21	0.38±0.04	8.9±1.0	0.2±0.03	0.2±0.0	10±0.7
	14-Sep-21	0.23±0.03	5.7±1.0	0.2±0.03	0.060±0.005	6.3±1.0
	21-Sep-21	0.30±0.01	6.9±1.1	0.1±0.03	0.070±0.005	7.4±1.1
	28-Sep-21	0.33±0.05	6.6±0.4	0.1±0.01	0.23±0.01	7.4±0.4
85	1-Sep-21	0.5±1.1	12±3.3	0.4±0.1	0.47±0.09	13±3.6
	14-Sep-21	0.270±0.031	5.6±0.7	0.29±0.03	0.06±0.02	6.2±0.8
	21-Sep-21	0.280±0.008	6.7±1.3	0.18±0.02	0.08±0.06	7.2±1.3
	28-Sep-21	0.29±0.09	6.8±2.4	0.26±0.06	0.17±0.06	7.5±2.6
112	1-Sep-21	0.53±0.09	11±2.0	0.4±0.1	0.46±0.07[c]	13±2.3
	14-Sep-21	0.41±0.03	8.1±0.7	0.4±0.1	0.10±0.01	9.1±0.8
	21-Sep-21	0.42±0.02	7.5±0.5	0.29±0.09	0.11±0.01	8.4±0.8
	28-Sep-21	0.27±0.04	6.0±0.8	0.25±0.06	0.21±0.05	6.8±1.0
183	1-Sep-21	0.36±0.01	8.2±0.3	0.30±0.04	0.34±0.01	9.2±0.4
	14-Sep-21	0.37±0.03	7.4±0.4	0.43±0.04	0.10±0.02	8.4±0.5
	21-Sep-21	0.41±0.05	8.2±2.0	0.23±0.05	0.13±0.02	9.0±2.1
	28-Sep-21	0.39±0.04	8.7±1.4	0.18±0.02	0.28±0.06	9.5±1.5

Table 2.8

Cannabinoid concentrations 2022

Nitrogen Rate					
Cannabinoid	0	57	85	112	183
CBC	0.11± 0.03	0.10± 0.05	0.07 ± 0.05	0.02± 0.05	0.057±0.053
CBDA	6.3± 1.2	6.5± 0.8	5.0 ±1.2	4.7± 1.2	5.9± 1.2
CBGA	0.4± 0.1	0.3±0.1	0.4±0.1	0.2± 0.1	0.3± 0.1
Other cannabinoids	0.11± 0.03	0.10±0.05	0.07±0.15	0.04 ± 0.15	0.08± 0.15
THC-A	0.208± 0.032	0.21±0.04	0.16±0.04	0.16 ±0.04	0.20± 0.04
Total CBD	7.8± 1.2	8.0±1.7	6.0±1.7	5.3±1.7	7.0±1.7
Total CBG	0.4± 0.1	0.3±0.1	0.4±0.1	0.25±0.18	0.3±0.1
Total THC	0.14±0.04	0.13± 0.05	0.10± 0.05	0.12±0.05	0.17± 0.05

Table 2.9

Plant damage 2021

Rate	Mean damage rating across 5 buds ± S.E.M in 2021
57	0.6±7.0^{a}
85	1.2±7.0^{a}
112	0.6±5.0^{a}
183	1.3±5.7^{b}

S.E.M= Standard Error of Mean

Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Table 2.10

Plant damage 2022

Rate	Mean damage rating across 5 buds ± S.E.M in 2021
0	0.18±0.18a
57	0.2±0.24a
85	0.19±0.26a
112	0.24±0.24a
183	0.25±0.24a

S.E.M= Standard Error of Mean

Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Table 2.11

Arthropod families and classification

Family	Year Found	Arthropod Classification
Acrididae	2021, 2022	Pest
Aeolothripidae	2021, 2022	Pest
Agelenidae	2021, 2022	Incidental
Anthicidae	2021, 2022	Incidental
Anthocoridae	2021, 2022	Predatory
Anyphaenidae	2021, 2022	Predatory
Aphididae	2021, 2022	Pest
Aphrophoridae	2021, 2022	Incidental
Araneidae	2021	Predatory
Berytidae	2021, 2022	Predatory
Bibionidae	2021, 2022	Incidental
Braconidae	2021, 2022	Parasitoid
Calliphordae	2021	Incidental
Carabidae	2021, 2022	Predatory
Ceratopogonidae	2021, 2022	Incidental
Cercopoidae	2022	Incidental
Chalcididae	2021, 2022	Parasitoid
Chamaemyiidae	2021, 2022	Predatory
Chironomidae	2021, 2022	Incidental
Chrysomelidae	2021, 2022	Incidental
Cicadellidae	2021, 2022	Pest
Coccinellidae	2021, 2022	Predatory
Coreidae	2021, 2022	Incidental
Culicidae	2021, 2022	Incidental
Curculionidae	2021, 2022	Incidental
Diapriidae	2021	Parasitoid
Dictyopharidae	2021	Incidental
Dolichopodidae	2021, 2022	Predatory
Drosophilidae	2021, 2022	Incidental

Ectobiidae	2021	Parasitoid
Elateridae	2021	Incidental
Erebidae	2021	Incidental
Erotylidae	2021	Incidental
Encyrtidae	2021, 2022	Parasitoid
Figitidae	2021	Parasitoid
Formicidae	2021, 2022	Pest
Geocoridae	2021, 2022	Predatory
Hemerobiidae	2021	Incidental
Ichneumonidae	2021	Parasitoid
Labiduridae	2021	Incidental
Lasiocampidae	2021	Predatory
Latridiidae	2021, 2022	Incidental
Lycosidae	2021, 2022	Predatory
Lygaeidae	2021, 2022	Incidental

Table 2.11

Arthropod families and classification

Family	Year Found	Arthropod Classification
Megaspillidae	2021	Parasitoid
Membracidae	2021, 2022	Incidental
Mirdae	2021, 2022	Pest
Muscidae	2021	Incidental
Nabidae	2021	Predatory
Nitdulidae	2021	Incidental
Noctuidae	2021, 2022	Pest
Oxyopidae	2021, 2022	Predatory
Pentatomidae	2021, 2022	Pest
Phalacridae	2021	Incidental
Platygastridae	2021	Parasitoid
Reduviidae	2021, 2022	Predatory
Rhopalidae	2021	Incidental
Rhyparochromidae	2021	Incidental
Salticidae	2021, 2022	Predatory
Scarabaeidae	2021, 2022	Incidental
Scatopsidae	2021	Incidental
Scelionidae	2021	Parasitoid
Silvanidae	2021, 2022	Incidental
Staphylinidae	2021	Predatory
Stratiomyidae	2021, 2022	Incidental
Syrphidae	2021, 2022	Predatory
Tachinidae	2021, 2022	Parasitoid
Tetragnathidae	2021, 2022	Predatory
Tetrigidae	2021	Incidental
Tettigoniidae	2021, 2022	Incidental
Thomisidae	2021	Predatory
Thripidae	2021, 2022	Pest
Trichogrammatidae	2021, 2022	Parasitoid

Ulidiidae	2021	Incidental
Vespidae	2021	Predatory

Table 2.12

Arthropod family richness by date in 2021

Nitrogen Rate				
2021 Sample Date	57	85	112	183
28-Jul	23	24	15	27
4-Aug	18	11	20	17
11-Aug	25	24	23	23
18-Aug	22	21	23	24
25-Aug	34	33	34	44
1-Sep	19	12	16	18
3-Sep	8	6	9	8
9-Sep	28	17	22	26
1-Oct	20	23	30	22

Arthropod abundance - the number of families in each rate

Table 2.13

Arthropod abundance by date in 2021

Nitrogen Rate				
2021 Sample Date	57	85	112	183
28-Jul	33	54	24	57
4-Aug	26	13	28	25
11-Aug	47	50	43	45
18-Aug	43	32	28	30
25-Aug	50	40	59	80
1-Sep	26	16	19	23
3-Sep	8	6	15	10
9-Sep	37	33	29	34
1-Oct	33	52	59	40

Arthropod abundance - the number of individuals in each rate

Table 2.14

Insect classification and abundance 2021

Nitrogen Rate				
Insect Classification	57	85	112	183
Incidental	124	84	111	137
Parasitoid	26	32	26	32
Pest	87	126	104	112
Predatory	66	57	66	69

Arthropod abundance - the number of individuals in each classification for each nitrogen rate

Table. 2.15

Arthropod family richness by date2 022

Nitrogen Rate					
2022 Sample Date	0	57	85	112	183
26-Jul	15	19	20	27	26
4-Aug	18	11	20	14	18
10-Aug	18	19	23	22	15
15-Aug	22	22	22	29	22
26-Aug	17	16	23	17	20
1-Sep	26	28	34	28	35
8-Sep	18	16	18	13	20
12-Sep	6	5	4	5	4

Arthropod abundance - the number of families in each rate

Table 2.16

Arthropod abundance by date in 2022

Nitrogen Rate					
2022 Sample Date	0	57	85	112	183
26-Jul	29	42	33	52	57
4-Aug	23	13	25	27	20
10-Aug	33	46	84	71	55
15-Aug	31	39	34	86	42
26-Aug	29	28	42	27	31
1-Sep	48	59	67	92	96
8-Sep	41	35	32	28	37
12-Sep	6	6	4	9	6

Arthropod abundance - the number of individuals in each rate

Table 2.17

Insect classification and abundance 2022

Insect Classification	0	57	85	112	183
Incidental	101	116	154	188	145
Parasitoid	41	59	71	57	69
Pest	45	50	52	63	58
Predatory	64	54	59	63	72

Arthropod abundance - the number of individuals in each classification for each nitrogen rate

Table 2.18

Plant wet weight (grams)

Rate	Mean wet weight (g) ± S.E.M of three plants
0	1145±0.0014
57	1155±0.0208
85	1167± 0.0207
112	1240± 0.0204
183	1115± 0.0210

S.E.M= Standard Error of Mean

Table 2.19

Plant dry weight (grams)

Rate	Mean dry weight (g) ± S.E.M of three plants
0	400±0.025
57	480±0.033
85	305± 0.037
112	191± 0.043
183	319±0.037

S.E.M= Standard Error of Mean

Table 2.20

Marketable wet bud weight (grams)

Rate	Mean marketable wet bud weight(g)± S.E.M. of three buds from three plants
0	83±0.054
57	21±0.120
85	53±0.087
112	58±0.085
183	45±0.092

S.E.M= Standard Error of Mean

Table 2.21

Unmarkable wet bud weight (grams)

Rate	Mean unmarketable wet bud weight (g) ± S.E.M of three buds from three plants
0	31±0.088
57	77±0.0105
85	61±0.108
112	64±0.108
183	64±0.108

S.E.M= Standard Error of Mean

Table 2.22

Markable dry bud weight (grams)

Rate	Mean marketable dry bud weight (g) ± S.E.M of three buds from three plants
0	35±0.084
57	10±0.178
85	22±0.135
112	19±0.140
183	11±0.168

S.E.M= Standard Error of Mean

Table 2.23

Unmarkable dry bud weight (grams)

Rate	Mean unmarketable dry bud weight (g) ± S.E.M of three buds from three plants
0	2.8 ±0.29
57	4.6±0.37
85	17±0.31
112	13±0.32
183	8.8±0.33

S.E.M= Standard Error of Mean

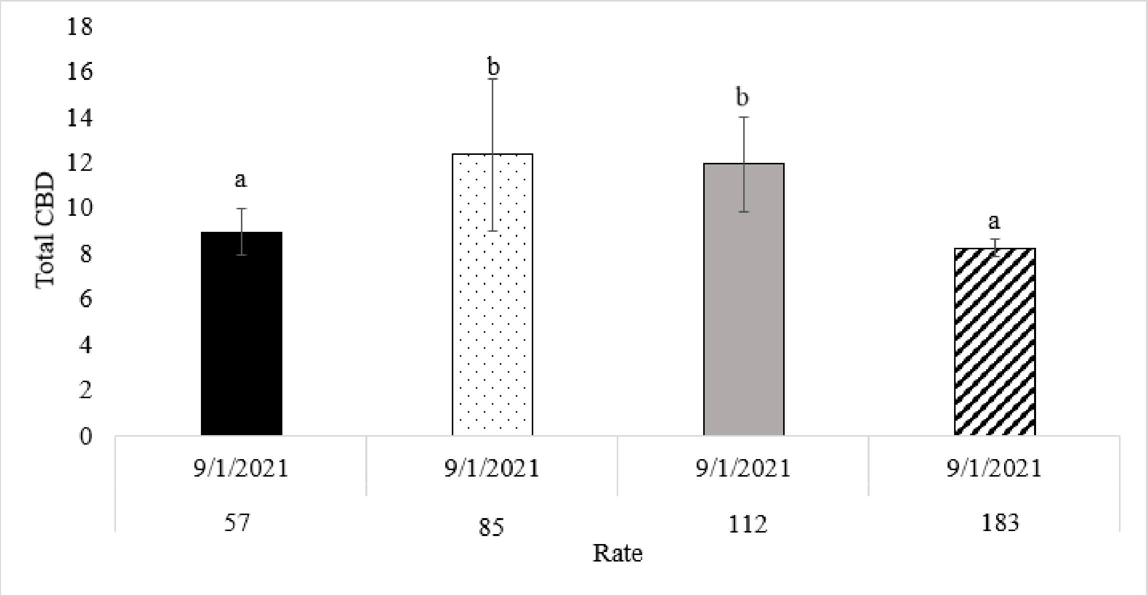
Figures

Figure 2.1

Damage Scale (0 to 5)

Figure 2.2

CBD September 1, 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test

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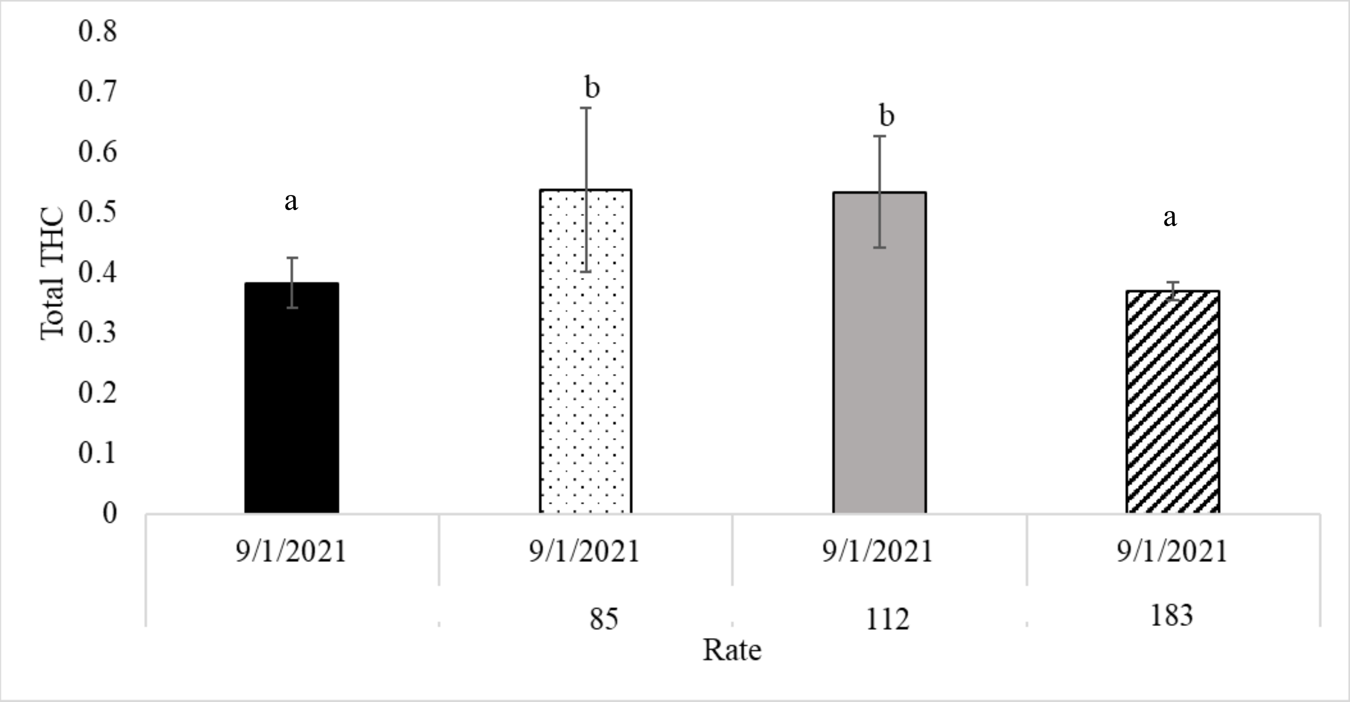
Figure 2.3

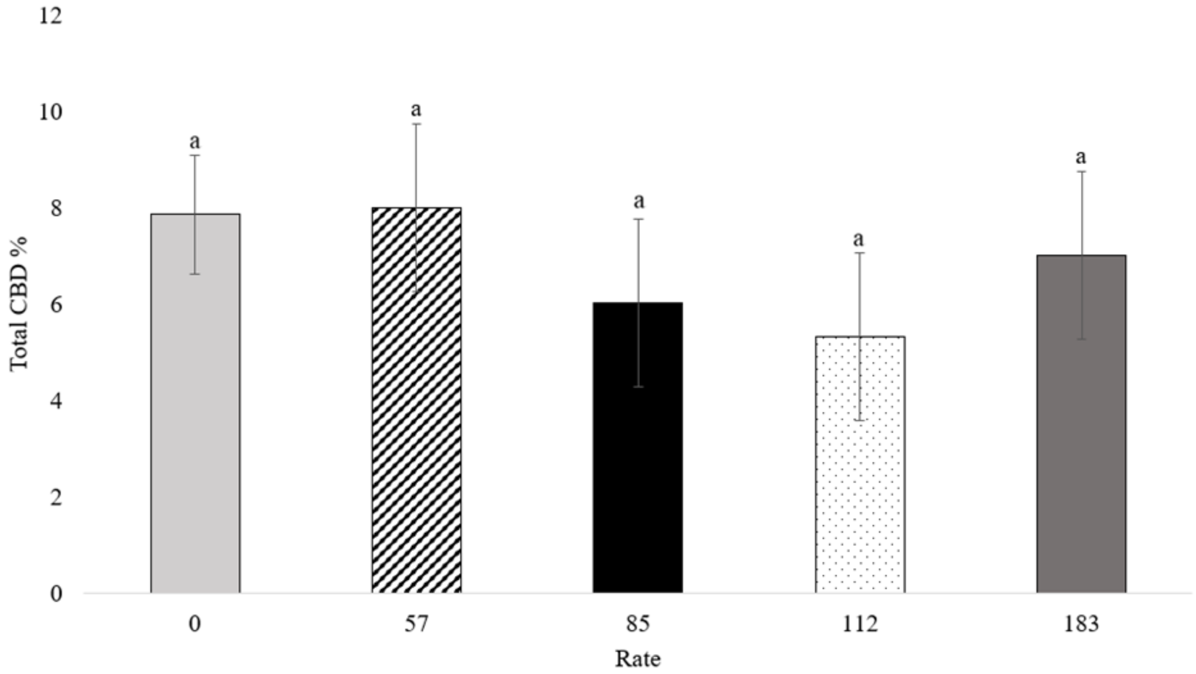
THC September 1, 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 2.4

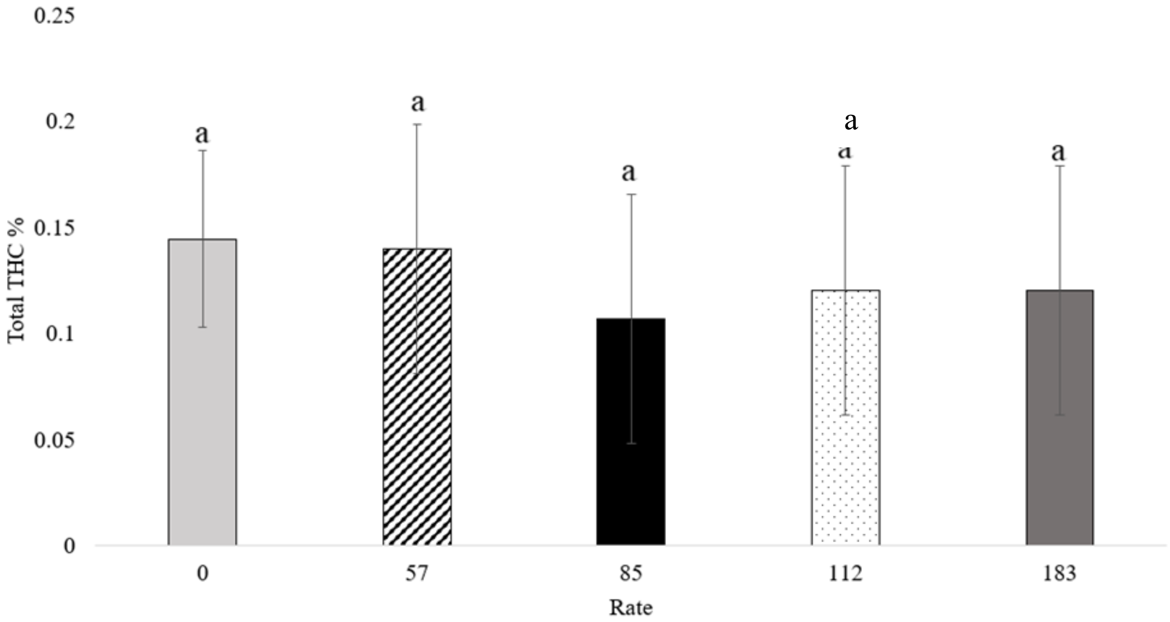
CBD 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey’s HSD post hoc test.

Figure 2.5

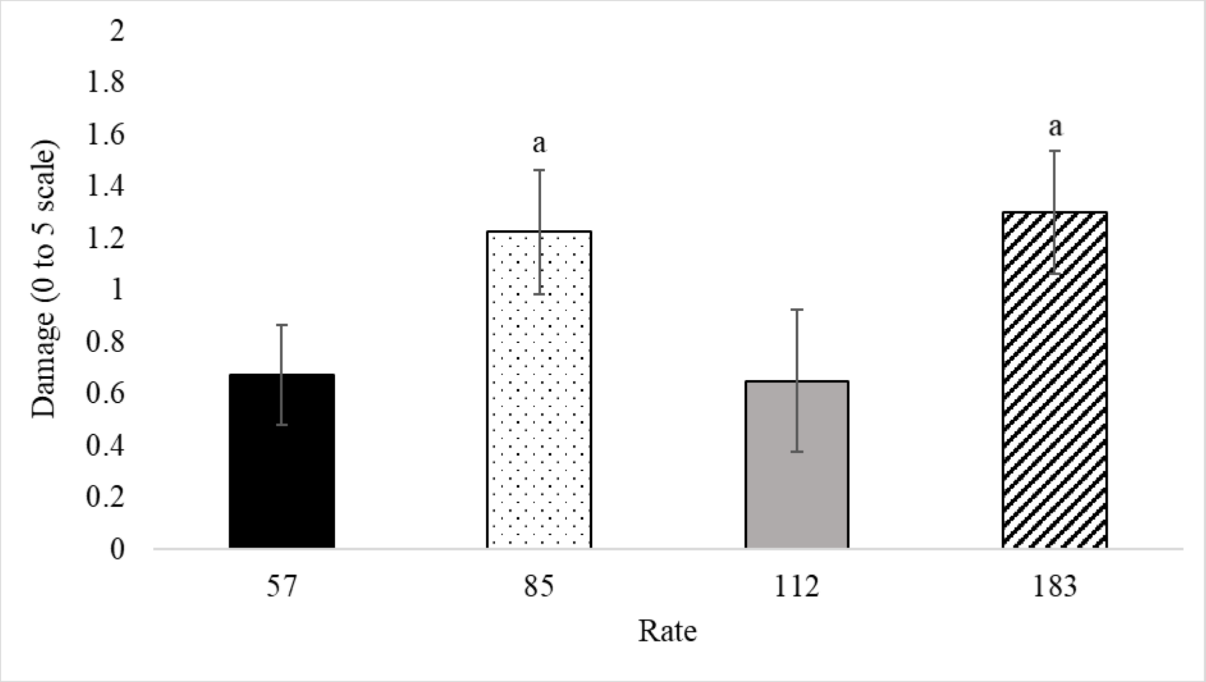
THC 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 2.6

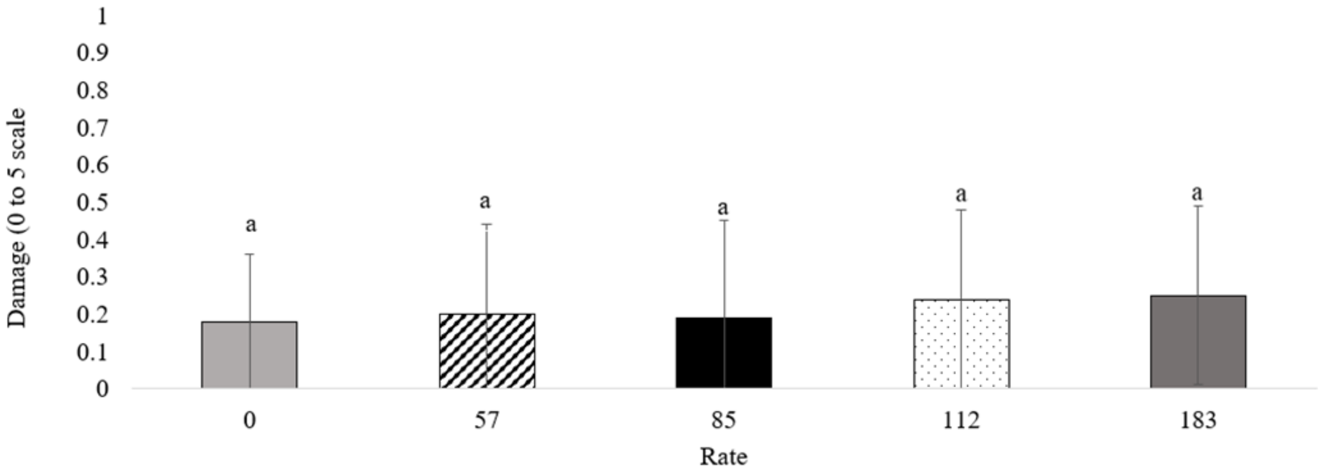
2021 Plant damage



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 2.7

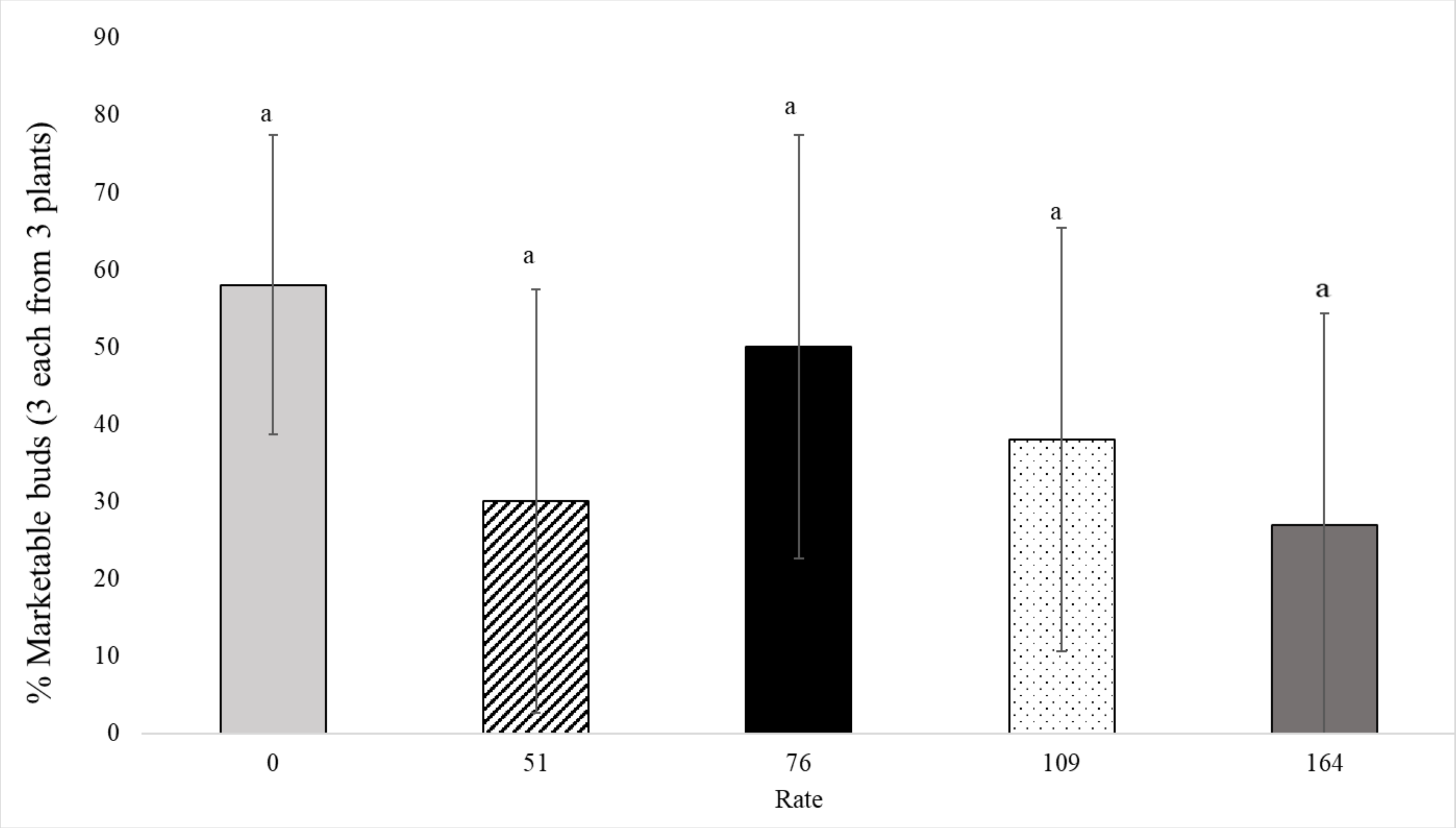
Plant Damage 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 2.8

% Markable buds



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Chapter 3

Varietal Selection for Outdoor Floral Hemp in East Central Alabama

Abstract

Hemp, *Cannabis sativa L*, has a long history as one of the oldest cultivated plants. However, due to restrictive laws like the Marihuana Tax Act, commercial hemp production declined for several decades. The situation changed with the passage of the 2014 and 2018 Farm Bills in the United States, which legalized hemp production. In the past seven years, there has been a resurgence in hemp cultivation, primarily driven by the demand for its byproducts, particularly cannabidiol (CBD). CBD is widely used for human consumption and is often marketed as a wellness product. This has led to increased pressure on growers to reduce their reliance on chemical pesticides. To make informed decisions and avoid unnecessary costs, growers need accurate information about pest management in hemp. Various insect pests pose a threat to hemp, with corn earworm, *Helicoverpa zea*, being one of the most damaging pests in outdoor cultivation. Previous research in other crops, such as cotton and hops, has shown that management strategies such as variety selection can influence insect damage and crop yields. Therefore, the objective of this study was to explore the potential of cultural control strategies, specifically varietal selection, in reducing pest-related losses in CBD hemp. A field experiment was conducted at the E.V. Smith Research Farm in Shorter, Alabama to evaluate four different CBD hemp varieties: BaOx, Southern Luck, Belle, and Cat Daddy. We assessed plant growth, insect damage and diversity, and chemical potency at harvest. The results of this field experiment revealed that variety selection had significant effects on plant measurements, cannabinoid potency, insect populations, and crop yield. In 2021, there were significant effects of variety on plant height and plant width. In 2021, significant differences between varieties were found in THC percentage before harvest but not in 2022. All varieties tested higher than the legal THC

limit in 2021. In 2021, significant differences in damage ratings were observed between varieties, but not in 2022. In 2021, variety had a significant effect on pollinator abundance but this effect was not seen in 2022. In 2021 or 2022, variety did not have a significant effect on arthropod abundance per sweeping sample. No significant differences were found in the fresh weight and dry weight of harvested plants or harvested flowers among the four varieties. This information will help identify management strategies for hemp growers, enabling them to make informed decisions and optimize their production practices.

Introduction

In hemp ecosystems, insects play a crucial role, acting both as pests and beneficial organisms (Cranshaw et al. 2019). Hemp, *Cannabis sativa* L., known for its versatile applications like fiber, seeds, and cannabinoids such as CBD (cannabidiol), is influenced by various insect species. While some insects pose challenges as pests, others contribute to the overall health and productivity of hemp crops. Understanding the diverse insect diversity within hemp cultivation is essential for implementing effective pest management strategies and maintaining a sustainable ecosystem (McPartland et al. 2000). Additionally, pollinators play a critical role in ensuring the reproductive success of hemp plants, despite their wind-pollination characteristics (O'Brien and Arathi 2019).

Hemp cultivation faces the threat of insect pests that can cause significant damage to the plants. Hemp aphids, *Phorodon cannabis*, for example, feed on hemp plant sap, resulting in stunted growth and reduced yields. The hemp russet mite, *Aculops cannabicola*, is a microscopic pest that discolors, stunts, and deforms leaves and buds, compromising the overall plant health. Hemp aphids and hemp russet mites are major pests of indoor production, while corn earworm, *Helicoverpa zea*, is a major pest of outdoor hemp production (McPartland et al. 2000).

To minimize the damage caused by pests, it is important to implement efficient pest management practices, such as integrated pest management (IPM). This approach combines cultural practices, biological control techniques, and the judicious use of insecticides when necessary (Gray et al. 2009). Cultural control tactics are especially important in proactive pest management, where producers can make informed decisions prior to planting. One effective cultural control strategy is variety selection.

Variety selection plays a crucial role in IPM (Kogon 1975). Just like other crops such as cotton, soybean, and corn, selecting the right varieties is essential due to the potential production advantages they offer (Gray et al. 2009). Each variety possesses distinct genetic characteristics that influence yield quality, insect abundance, and adaptation to different climatic conditions (Kogon 1975). These factors are equally significant in hemp agriculture. Furthermore, variety selection is vital in hemp farming due to the unique plant chemistry and potential benefits for output.

Many cultivars have been bred and chosen specifically for higher CBD content to facilitate the extraction of CBD-rich oil or the production of other CBD-infused products. By selecting high-CBD cultivars and meeting the market demand for CBD, farmers can increase their potential CBD yield and thus profit (Marinotti and Sarill 2020). Simultaneously, it is crucial to select varieties low in total delta-9 tetrahydrocannabinol (THC) to ensure compliance with legal regulations. THC, the psychoactive component in cannabis, must remain below a specified threshold (0.3% THC in the United States) for hemp to be legally recognized as such (Ely et al. 2022). By choosing low-THC varieties, farmers can adhere to the rules, avoiding legal complications and potential crop destruction (Mead 2019).

Understanding the relationship between CBD production and pollinator diversity is crucial because the presence of male plants in proximity to female CBD-producing plants can have a negative impact on flower production. In cannabis cultivation, it is common practice to separate male and female plants to prevent unwanted pollination, especially in the case of high-quality CBD flower production (O’Brien and Arathi 2019, Flicker et al. 2020)

When a male cannabis plant releases pollen, it can travel through the air or be carried by pollinators, including bees, to nearby female plants. If the pollen from a male plant reaches the female flowers of CBD-producing plants, it can lead to seed production rather than the desired seedless flower production. The formation of seeds diverts energy and resources from the development of CBD-rich flower buds, resulting in a decrease in overall flower production. Additionally, the presence of seeds can negatively affect the quality and market value of CBD products. Seedless flowers are generally preferred for CBD production because they contain higher concentrations of cannabinoids, including CBD (Small 2015).

Variety selection also has implications for managing pest pressure in crops. Certain varieties possess characteristics that deter or repel specific pests, including organic chemical compounds or physical traits that make the plants less attractive or vulnerable to pests (Fürstenberg-Hägg et al. 2013). For example, some cultivars may produce specific terpenes with natural insect-repellent properties or possess trichomes that prevent pests from feeding (Boncan et al. 2020). Additionally, varieties that are well-adapted to the local climate and growing conditions generally exhibit better overall plant health and vigor. Such strong and healthy plants are more resilient to pest pressure and can recover better from pest damage. Farmers can enhance plant resilience and minimize the impact of pests by selecting cultivars that are suitable for the environmental conditions of their location (Cook 1988).

Gaining a comprehensive understanding of the intricate insect diversity within hemp ecosystems is crucial for the implementation of sustainable farming practices. This knowledge empowers farmers and researchers to develop targeted pest management strategies that minimize harm to beneficial insects (Scherr and McNeely 2008). Moreover, preserving insect diversity in hemp fields fosters a balanced and resilient ecological system while contributing to the overall biodiversity of the surrounding area. The interplay between pests, beneficial insects, and pollinators in hemp habitats underscores the complex relationship between insects and this versatile plant (Saunders et al. 2016, Cranshaw et al. 2019). By comprehending the diverse roles insects play in hemp farming, farmers can enhance crop health, efficiently control pests, and contribute to the sustainable and environmentally conscious production of hemp (Kaur and Kander 2023).Variety selection is a crucial tool that hemp growers can employ as part of integrated pest management to bolster pest control efforts (Kogon 1975). The aim of this study is to explore the effects of variety selection on various aspects of plant growth, plant chemistry, insect diversity and damage, and yield. By examining these factors, we seek to identify potential management strategies that can be utilized by growers.

Methods

Planting

In 2021 and 2022, three varieties from The Hemp Mine (Fair Play, South Carolina, USA and one variety from Triangle Hemp (Raleigh, North Carolina, USA [34.53322° N, 83.04279° W]) were used for the field experiment conducted at E.V. Smith Research Center (Shorter, Alabama [32.445628° N, -85.890104 ° W]]). Varieties Cat Daddy, Belle, and Southern Luck were received as rooted cuttings from The Hemp Mine and hand transplanted into the field on June 11, 2021, and June 27, 2022. Variety BaOx was received as seeds from Triangle Hemp. Seeds were placed into 30 cell count trays and used PRO-MIX 'BX' (Rivière-du-Loup City, Québec, Canada) general peat-based growing medium potting soil. Trays were put under a misting system; each cell received water every 30 minutes for 30 seconds every day for six weeks. Seedlings were hand transplanted into raised beds with clay, alkaline soil and white plastic mulch at E.V. Smith Research Center. BaOx plants were hand transplanted into the field on June 18, 2021. In 2021, plots consisted of one row of 10 plants each replicated four times in a randomized complete block design (RCBD). In 2022, plots consisted of one row of five plants each replicated four times in a RCBD. All plots received 183 kg/ha of nitrogen fertilizer (Ultrasol Multipurpose Plus 20-20-20, [SQM North America]). The nitrogen was applied as described in Table 3.1.

In-season data collection

Beginning in August 2021 and July 2022, plant height and plant stem width were measured weekly. All height was measured from the base of the plant to the apical meristem. Measuring calipers were used to measure the diameter of the stem at the base of the plant at the soil line. On September 3 and 10, 2021, caterpillar damage was assessed on five buds randomly selected in each plot using a 0 – 5 rating scale (Table 3.2). In 2022, weekly caterpillar damage assessments were conducted from July through harvest. Buds consisted of the inflorescence on a single stem that is approximately 7.62 cm. Arthropod sampling was conducted using a sweet net and drop cloth following the methods from Chapter 2. Drop cloth sampling was conducted first in the plots, followed by sweep net sampling after at least one-half hour. Arthropod sampling was conducted weekly in both years, beginning in July 2021 and August 2022.

Pollinator sampling

Pollinator sampling was conducted weekly from July 20, 2021, to October 1, 2021, for all varieties with one elevated trap per plot (Figure 3.1). The traps were yellow 532 mL Solo cups (Reynolds Consumer Products, Inc, Lake Forest, Illinois, USA) filled with 50/50 propylene glycol: water solution (Nexeo Solutions LLC Doraville, Georgia, USA). Cups were affixed to a 122 cm tall wooden stake. At the end of each sampling period, the contents of each trap was brought to the laboratory for identification. In 2022, pollinator sampling was conducted biweekly from August 12, 2022, to September 26, 2022.

Pre-harvest and harvest data collection

Prior to harvest, floral samples were collected for potency analysis on four dates: September 1, 2021, September 14, 2021, September 21, 2021, and September 28, 2021. In 2022, floral samples were taken on one date, September 7, 2022. Flowers were randomly selected from one plant from each plot. Sampling procedures followed the Alabama Department of Agriculture and Industries' (ADAI) standard operating procedures (SOP) for pre-harvest THC sampling. The top 20 cm of the plant's primary stem was clipped, secured in a paper bag, and removed for analysis. Samples were sent to ACS Laboratory, Sun City Center, Florida, USA for analysis. A panel of eleven cannabinoids was tested in 2021, including: A panel of eleven cannabinoids was tested in 2021, including: tetrahydrocannabinol (THC), delta-8-tetrahydrocannabinol (Delta 8-THC), tetrahydrocannabinol acid (THCA), tetrahydrocannabivarin (THCV), cannabidiol (CBD), cannabidiolic acid (CBDA), cannabidivarin (CBDV), cannabigerol (CBG), cannabigerolic acid (CBGA), and cannabinol (CBN). In 2022, the same panel of cannabinoids was tested with the exception of Delta 8-THC.

Harvest data were not collected in 2021 due to excessive plant damage from weather and disease. On September 22, 2022, prior to harvest, the height of two plants from each plot was measured using the same method described previously. Two hemp plants per plot were harvested on September 23, 2022. Plants were cut at the base of the plant where the stem meets the soil using a steel bypass lopper (Bond Manufacturing, Antioch, California, USA). Fresh weight was recorded from harvested plants using a Taylor hanging scale (Uline, Pleasant Prairie, Wisconsin, USA). Harvested plants were hung upside down for 14 days on 16 gauge (0.05 centimeters) black annealed steel tie wire (Grip-Rite, Prime Source, Irving, Texas, USA).

Following fresh weight measurement, one bud (as described above) was removed from the top, middle, and bottom of the plant. Each bud was assessed for damage and marketability using a 0-3 damage scale based on Britt et al. 2021, with 0,1 deemed marketable and 2,3 unmarketable. Fresh weight of each bud was recorded at harvest using a digital scale (VWR International LLC, Radnor, Pennsylvania, USA). Buds were placed in brown paper bags and brought to Plant Science Research Center Greenhouse (Auburn, Alabama, USA [32.5882919, -85.4885295]) for drying. On September 30, 2022, dry weight of whole plants was recorded with a hanging scale and on October 16, 2022, dry weight of individual flower buds was recorded with a digital scale.

Statistical Analysis

Analyses for 2021 and 2022 was conducted using RStudio 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria). Each year was analyzed separately due to variations in dates and the number of plants in each plot. A generalized linear model and Tukey’s HSD was used to identify significant differences plant growth, chemical potency, and yield between rates. A generalized linear model with a Poisson distribution and Tukey's HSD was used to identify significant differences insect damage, pollinators and arthropod populations, all graphs were created using Excel (Microsoft Corporation, Redman, WA, USA).

Results

Plant growth

In 2021, there were significant effects of variety on plant height (2021: $P < 0.0001$) and plant width (2021: $P = 0.0101$) (Table 3.3) and (Table 3.2) and (Figures 3.3, 3.4). In 2022, there were significant effects of variety on plant height (2022: $P = 0.0003$), but not plant width (2022: $P = 0.0757$). In both years, Southern Luck had significantly higher plant height and wider plant stems (Tables 3.1 and 3.2) (Figures 3.3 and 3.4) and (Table 3.3 and 3.4) (Figures 3.5 and 3.6).

2021 Cannabinoid concentrations

In 2021, flower samples were taken on four dates for potency analysis (September 1, September 14, September 21, September 28, 2021). There were no significant differences between varieties in THC or CBD percentage immediately prior to harvest on September 28. Potency analyses in 2021 revealed all varieties tested higher than the legal 0.3% THC limit on all four sample dates (Table 3.5) (Figures 3.8 and 3.9).

In 2021, there were significant differences between varieties in both THC percentage ($P = 0.0027$) and CBD percentage ($P = 0.0138$) on a dry weight basis. BaOx and Cat Daddy had the highest CBD and THC percentage on a dry weight basis and Belle and Southern Luck had the lowest CBD percentage on a dry weight basis. Variety did have a significant effect on CBG percentage on a dry weight basis ($P = 0.0212$). In 2021 BaOx and Cat Daddy had the highest CBG percentage on a dry weight basis and Belle and Southern Luck had the lowest CBG percentage on a dry weight basis. In 2021 variety did not have a significant effect on other Cannabinoids ($P =0.6959$). In 2021 variety did not have a significant effect on total cannabinoids ($P = 0.01722$). CBN was not detected in the flower samples in any variety in 2021 (Table 3.5).

2022 Cannabinoid concentrations

In 2022, there were no significant differences between varieties in either THC percentage (P = 0.4401) or CBD percentage (P = 0.3890) on a dry weight basis. Potency analyses in 2022 revealed no varieties tested higher than the legal 0.3% THC limit. There were no significant differences detected between varieties in CBC (P = 0.4450), CBDA (P = 0.3594), CBG (P = 0.0650), THCA (P 0.3935), or CBGA (P = 0.0610) percentages on a dry weight basis. Overall, Southern Luck had the highest percentages of THC, CBD, CBC, CBDA, CBG, THCA, and CBGA. In 2022, CBDV, CBN, and THCV were not detected in flower samples in any variety (Table 3.6) (Figures 3.9 and 3.10).

Plant damage

In 2021, damage ratings varied significantly between varieties (P < 0.0001). Cat Daddy and Belle had significantly higher damage ratings than BaOx and Southern Luck, with Cat Daddy having the overall highest damage rating (Table 3.7 Figure 3.11). In 2022, damage ratings did not vary significantly between varieties (P = 0.7952). Southern Luck had the highest damage with all other varieties having an average damage rating of less than 2 (Table 3.8, Figure 3.12).

Insect populations

Pollinators

A total of 263 pollinators were captured in cups in 2021 comprised of 17 families. A total of 40 pollinators were captured in cups in 2022 comprised of 9 families (Table 3.10). In 2021, variety did have a significant effect on pollinator abundance (P = 0.0363). Belle had significantly higher pollinator abundance compared to Southern Luck, BaOx, and Cat Daddy. Pollinators found in each variety in 2021 are summarized in Table 3.11. In 2022, there was no significant effect of variety on pollinator abundance (P = 0.5661). There were lower numbers of pollinators captured in 2022 compared to 2021. Pollinators found in each variety in 2022 are summarized in Table 3.12.

In 2021, there was a significant effect of time on pollinator abundance (P < 0.0001). Pollinator abundance was the highest on the first sample date (July 13, 2021) then decreased on all subsequent sample dates (Table 3.11). In 2022, there was a significant effect of time on pollinator abundance (P < 0.0001) (Table 3.13). Pollinator abundance was the highest on the first sample dates (September 22, 2022 and September 26, 2022) then decreased on all subsequent sample dates (Table 3.14).

The most common family captured in both years was Apidae; this includes cuckoo bees, carpenter bees, digger bees, bumblebees, and honeybees. Additionally, solitary bees from the Halictidae, Megachilidae, and Andrenidae families were collected in high numbers.

Sweep samples

A total of 1,293 arthropods were captured in sweep nets in 2021 comprised of 53 families and a total of 293 arthropods were captured in 2022 comprised of 37 families (Table 3.14).

<u>2021</u>

In 2021, the variety did not have a significant effect on arthropod abundance per sweeping sample (P = 0.8179). BaOx had significantly higher arthropod abundance compared to the other varieties (Table 3.15).

Sample date had a significant effect on abundance in BaOx (P = 0.0482) and Southern Luck(P = 0.0321) but not Belle (P = 0.2333) or Cat Daddy (P = 0.1408) (Tables 3.16).

In 2021, incidental arthropod and parasitoid families exhibited the highest abundance in all varieties, while pest and predatory families showed the lowest abundance (P < 0.0001) (Table 3.17).

2022

In 2022, variety did not have any significant effect on arthropod abundance per sweeping sample ($P = 0.7731$). Cat Daddy had the highest arthropod abundance. There were lower numbers of arthropods captured in 2022 compared to 2021. Arthropods found in each variety in 2022 are summarized in (Tables 3.23).

Sample date did not have a significant effect on any of the varieties (Belle: $P = 0.6826$, Cat Daddy: $P = 0.6199$, BaOx: $P = 0.6985$, Southern Luck: $P = 0.3037$) (Table 2.23). In 2022, incidental and parasitoids arthropod families exhibited the highest abundance in all varieties per sweeping sample, while predatory and pest families showed the lowest abundance ($P < 0.0001$). (Table 3.24).

Drop cloth samples

A total of 241 arthropods were captured in drop cloths in 2021 comprised of 33 families and a total of 117 arthropods were captured in 2022 comprised of 24 families (Table 3.14).

2021

In 2021, variety did have a significant impact on arthropod abundance ($P = 0.0530$). Belle had significantly higher arthropod abundance compared to the other varieties. Sample date did not have a significant effect on any of the varieties (Belle: $P = 0.6572$, BaOx: $P = 0.8902$, Cat Daddy: $P = 0.4579$ and Southern Luck ($P = 0.0321$) (Tables 3.18 and 3.19)

In 2021, incidental and pest arthropod abundance exhibited the highest abundance in all varieties, while predatory and parasitoid families showed the lowest abundance, but these results were not statistically significant ($P = 0.0938$). (Table 3.20).

2022

In 2022, the variety did not have a significant impact on arthropod abundance (P = 0.5813). Southern Luck had the highest arthropod abundance, although this was not statistically significant (Tables3.24)

Sample date did not have a significant effect on any of the varieties (Belle: P = 0.3156, Cat Daddy: P = 0.7223, BaOx: P = 0.3825, Southern Luck: P = 0.6275) (Table 3.25)

In 2022 pest and predatory arthropods had the highest abundance in all varieties, while incidental and parasitoid families showed the lowest abundance, but these results were not statistically significant (P = 0.7211). (Table 3.26). Observed in 2021 was a higher abundance of *H.zea* found in the field compared to *Spodoptera ornithogalli*. In 2022, the opposite was found, with a higher abundance of *Spodoptera ornithogalli* in the field compared to *H.zea* (Tables 3.15, 3.18, 3.21 and 3.24)

Harvest

No significant differences between varieties were found in the wet weight (P=0.0723) or dry weight (P=0.7831) of the two harvested plants (Tables 3.27 ,3.28). Although no significant differences were observed, Cat Daddy exhibited the highest wet and dry weights among the varieties, while Belle had the lowest wet and dry weights.

Similarly, the flower bud wet weight (P=0.3096) and dry weight (P=0.5868) did not show any significant differences between the varieties (Tables 3.29, Table 3.30). BaOx had the highest wet weight, and Southern Luck had the highest dry weight. Cat Daddy displayed the lowest wet and dry weights. Furthermore, the percentage of unmarketable buds did not differ significantly between the varieties (P=0.1821). Overall, Cat Daddy had the highest percentage of unmarketable buds (Tables 3.31)

Discussion

This study investigated the effects of different hemp varieties on various plant characteristics, cannabinoid concentrations, plant damage, insect populations, and harvest outcomes in the years 2021 and 2022. The research involved four hemp varieties: BaOx, Cat Daddy, Belle, and Southern Luck. We hypnotize different hemp varieties will exhibit different growth patterns and cannabinoids and support different insect populations.

Plant Height and Width

In 2021, the hemp varieties exhibited significant differences in both plant height and width. Southern Luck consistently showed higher plant height and wider stems compared to other varieties. However, in 2022, while there was a significant effect on plant height, there was no significant impact on plant width among the varieties. This study reveals that variety significantly influences plant height and width. Southern Luck consistently exhibited higher plant height and wider stems compared to other varieties. This information is crucial for growers as it highlights the potential of Southern for achieving larger and more robust plants. Our results may have been influenced by both nitrogen levels and other environmental factors discussed earlier. To address these potential effects, we propose conducting a greenhouse experiment using the same varieties and nitrogen rates as previously discussed.

Cannabinoid Concentrations

In 2021, all hemp varieties tested higher than the legal 0.3% THC limit on all sampling dates. However, there were significant differences between varieties in THC, CBD, and CBG percentages on a dry weight basis. BaOx and Cat Daddy had the highest CBD and THC percentages, while Belle and Southern Luck had the lowest CBD percentages. In 2022, none of the hemp varieties tested higher than the legal THC limit, and there were no significant differences in THC and CBD percentages among the varieties. We found that THC and CBD percentages varied among varieties, particularly in 2021. All varieties exceeded the legal THC limit, suggesting the need for careful monitoring and management to ensure compliance with regulations. Additionally, Belle, Cat daddy and Luck Southern stood out with the highest CBD and THC percentages on a dry weight basis. But Cat daddy, Southern luck and Belle also had higher THC compared to BaOx. Because growers must be mindful of THC these varieties would also not be recommended in Alabama.

Insect Damage

This study shows significant variation in plant damage from caterpillars between varieties in 2021 but no significant differences in 2022. Cat Daddy and Belle exhibited higher damage ratings in 2021 compared to BaOx and Southern Luck. However, Southern luck had the most damage and attracted more pest insects including corn earworm and yellow stripped army worm. Southern luck would not be recommended for Alabama growers. Belle and Cat daddy also had high insect damage and attracted more pest insects including corn earworm and yellow stripped army worm. Belle and Cat daddy would also not be recommended for Alabama growers. Also, our experiments showed that in hemp cultivation, the yellow striped armyworm (*Spodoptera ornithogalli*) has emerged as a significant pest.

Insect Populations - Pollinators

Numerous pollinators thrive among the hemp varieties. The abundance of pollinators in 2021 was influenced by the hemp variety, with Belle having significantly higher pollinator abundance compared to Southern Luck, BaOx, and Cat Daddy. However, in 2022, there were no significant differences in pollinator abundance among the varieties. Pollinator diversity is a crucial aspect of cultivation, and the study demonstrates that variety has a significant effect on pollinator abundance, with Belle showing higher abundance in 2021 while Southern Luck had the highest in 2022. Understanding the relationship between CBD production and pollinator diversity is important to prevent undesired pollination and subsequent seed production, which can decrease flower production and affect the quality of CBD products. To mitigate the risk of cross-pollination, CBD producers employ strategies such as physical separation, timing, and selective breeding. These strategies help prevent male plants from reaching female CBD-producing plants and diverting energy and resources towards seed production. Cat Daddy, Southern luck and Belle would not recommend because these varieties do attract more pollinators than BaOx. This can be a risk to growers that also produce fiber and CBD hemp. The relationship between pollinators and hemp needs to be further explored.

Insect Populations

Many arthropods thrive among the hemp varieties. In 2021, BaOx had significantly higher arthropod abundance compared to other varieties, but in 2022, there were no significant differences in arthropod abundance among the hemp varieties. In 2021, Belle had significantly higher arthropod abundance compared to other varieties in drop cloth samples. However, in 2022, there were no significant differences in arthropod abundance among the varieties. While BaOx did not attract an abundance of predatory insects. Growers can enhance their fields by attracting more predatory insects by plant wildflowers. This highlights the importance of considering the susceptibility of different varieties to damage and implementing appropriate pest management strategies. The results also shed light on arthropod populations captured in floral hemp in Alabama. While variety did not have a significant effect on arthropod abundance per sweeping sample in 2021 and 2022, the data show variations in arthropod abundance among different varieties and over time. These findings underscore the importance of monitoring arthropod populations and their potential impact on plant health and yield.

Harvest parameters

No significant differences were found between the varieties in terms of wet and dry weights of harvested plants and flower buds. Cat Daddy exhibited the highest wet and dry weights, while Belle had the lowest. The percentage of unmarketable buds did not significantly differ between the varieties, with Cat Daddy showing the highest percentage. Finally, the study examines harvest characteristics, including wet and dry weights of plants and flower buds, as well as the proportion of unmarketable buds. Although no significant differences were observed among varieties, Cat Daddy, Southern luck, and Belle consistently displayed higher wet and dry weights, compared to BaOx. These findings provide insights into the potential yield and market value of different varieties. Although Cat daddy, Southern luck and Belle did have higher yield. These varieties had more THC and insect pest pressure. These varieties were not suitable for Alabama climate.

Conclusions

Overall, the study suggests that the hemp varieties had varying effects on plant characteristics, cannabinoid concentrations, insect populations, and harvest outcomes in 2021 and 2022. Southern Luck consistently displayed higher plant height and wider stems, while Cat Daddy had higher THC and CBD percentages but also showed more plant damage and unmarketable buds.

These findings provide valuable insights for hemp growers in selecting suitable varieties based on their specific goals and considerations. However, further research may be required to explore the underlying factors influencing these differences in more depth. The results of the study provide valuable insights into various aspects of plant growth, cannabinoid concentrations, plant damage, pollinator diversity, and harvest characteristics in different varieties. These findings can be discussed in relation to their implications for cultivation practices and the overall quality of the harvest.

Overall, these results highlight the complex interplay between plant genetics, environmental factors, and cultivation practices. They offer valuable information for growers to make informed decisions about variety selection, pest management, and cultivation techniques. By understanding the effects of variety on plant growth, cannabinoid concentrations, pollinator diversity, and harvest characteristics, growers can optimize their cultivation strategies to maximize crop yield, quality, and overall sustainability. Regarding plant growth, different varieties exhibit variations in growth patterns, including height and overall development, attributed to genetic differences. These variations can impact the productivity and health of plants. By carefully selecting well-adapted varieties, farmers can optimize plant growth and maximize agricultural yields (Kogon 1975). Variety selection also affects plant chemistry, as different varieties possess varying levels of bioactive compounds, such as CBD and THC (Booth et al. 2020, Boncan et al. 2020) By selecting varieties with desirable chemical profiles, farmers can potentially enhance plant defenses and improve the quality of harvested produce. Furthermore, variety selection plays a role in insect diversity and damage. Different varieties can attract or repel specific insect species, leading to variations in insect diversity within cultivated areas. Additionally, certain varieties may exhibit natural resistance or tolerance to specific pests, resulting in reduced insect damage (War et al. 2012, Fürstenberg-Hägg et al. 2013).

The choice of crop varieties is crucial in determining the overall yield. Selecting varieties well-suited to local conditions and possessing desirable agronomic traits can potentially lead to higher yields. Considering factors like climate, soil type, and pest pressure is important when choosing crop varieties for CBD hemp cultivation. Overall, the findings underscore the significant influence of variety selection on plant growth, ecosystem dynamics, and agricultural productivity. By carefully selecting appropriate varieties, farmers can optimize plant growth, enhance plant defenses, promote beneficial insect populations, and ultimately improve crop yield and quality. These insights can guide informed decision-making regarding variety selection and contribute to sustainable and efficient agricultural practices.

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Tables

Table 3.1

2021: Mean Plant Height (cm) +/- Std. Error

Hemp Variety	*2021 Sample Date*			
	6-Aug	13-Aug	20-Aug	27-Aug
BaOx	68 +/- 3.9	69+/- 2.7	81 +/- 3.9	84+/- 3.9
Belle	86 +/- 10.2	88+/- 7.2	93 +/- 10.2	92+/- 10.2
Cat Daddy	85 +/- 6.2	78 +/-4.4	79 +/- 6.2	85+/-6.2
Southern Luck	110+/- 9.4	114+/- 6.6	120 +/- 9.4	120+/- 9.4

The mean ± standard error of the plant height (cm) measure from the top of the apical meristem to the base of the plant at the soil

Table 3.2

2021: Mean Stem Width (mm) +/- Std. Error

Hemp Variety	*2021 Sample Date*			
	6-Aug	13-Aug	20-Aug	27-Aug
BaOx	13 +/- 3.9	23 +/- 2.7	23 +/- 3.9	26 +/- 3.9
Belle	18+/- 2.2	21+/- 1.5	25 +/- 2.2	26 +/- 2.2
Cat Daddy	17.+/- 2.0	19 +/- 1.4	23 +/- 2.0	24+/- 2.0
Southern Luck	22 +/-2.0	24+/- 1.4	29 +/- 2.0	31+/- 2.0

The mean ± standard error of the plant width (mm) measure from the diameter of the stem at the base of the plant at the soil line

Table 3.3

2022: Mean Plant Height (cm) +/- Std. Error

Hemp Variety	*2022 Sample Date*							
	5-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug	26-Aug	26-Sep
BaOx	5.2 +/- 10.9	6.4+/- 10.9	10.8+/- 10.9	47 +/- 10.9	27 +/-7.7	35 +/- 10.9	45 +/- 10.9	105 +/- 10.9
Belle	18 +/- 18.2	19 +/- 18.2	23+/-18.2	79+/- 18.2	40 +/- 12.8	46 +/- 18.2	56 +/- 18.2	86 +/- 18.2
Cat Daddy	18 +/- 10.0	22+/- 10.0	29 +/- 10.0	97+/- 10.0	50+/-7.1	60 +/- 10.0	85 +/- 10.0	93+/- 10.0
Southern Luck	38/- 1.2	35 +/- 1.2	37+/- 1.2	112+/- 1.2	50 +/- 1.2	54 +/- 1.2	65+/- 1.2	100 +/- 1.2

The mean ± standard error of the plant height (cm) measure from the top of the apical meristem to the base of the plant at the soil

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Table 3.4

2022: Mean Stem Width (mm) +/- Std. Error

Hemp Variety	*2022 Sample Date*							
	5-Jul	11-Jul	18-Jul	25-Jul	1-Aug	8-Aug	26-Aug	26-Sep
BaOx	1.4 +/- 3.2	1.4 +/- 3.2	2.0+/- 3.2	9.8 +/- 3.2	7.6 +/- 2.3	8.3 +/- 3.2	13.9 +/- 3.2	32. +/- 3.2
Belle	3.0 +/- 4.5	2.9 +/- 4.5	4.2 +/- 4.5	16+/-4.5	8.5 +/- 3.2	10.7 +/- 4.5	14.8 +/- 4.5	26 +/- 4.5
Cat Daddy	3.3 +/- 2.7	3.2 +/- 2.7	5.5 +/- 2.7	21 +/- 2.7	11 +/- 1.9	14+/- 2.7	18 +/- 2.7	29 +/- 2.7
Southern Luck	5.1+/- 1.2	4.5 +/- 1.2	5.5+/- 1.2	19 +/- 1.2	8.8 +/- 1.2	11.2+/- 1.2	15 +/- 1.2	27 +/- 1.2

The mean ± standard error of the plant width (mm) measure from the diameter of the stem at the base of the plant at the soil line

Table 3.5

Cannabinoid concentrations 2021

Cannabinoid (%)	*2021 Sample Date*	BaOx	Belle	Cat Daddy	Southern Luck
Total THC	1-Sep	0.32 ± 0.07	0.19± 0.02	0.39± 0.05	0.17± 0.02
	14-Sep	0.34 ± 0.07	0.34± 0.07	0.48± 0.03	0.31± 0.04
	21-Sep	0.33±0.04	0.33± 0.04	0.38 ±0.05	0.30± 0.02
	28-Sep	0.38±0.03	0.38± 0.03	0.37±0.02	0.40± 0.03
Total CBD	1-Sep	7.1 ± 1.5	4.2± 0.6	8.3± 1.0	3.6 ± 0.3
	14-Sep	7.6± 1.6	7.6± 1.6	10± 0.4	6.5 ± 0.9
	21-Sep	6.9± 1.0	6.9± 1.6	8.1±1.1	5.8± 0.5
	28-Sep	9.3± 0.6	9.3± 1.7	9.0±0.7	9.8± 0.5
Total CBG	1-Sep	0.3 ± 0.1	0.10 ± 0.02	0.26 ± 0.03	0.049 ± 0.007
	14-Sep	0.9 ± 0.3	6.9±1.0	0.57 ± 0.04	0.23± 0.02
	21-Sep	0.23± 0.06	0.23±0.06	0.25 ±0.03	0.12± 0.02
	28-Sep	0.21± 0.02	0.21 ±0.02	0.15 ±0.04	0.27± 0.03
Other Cannabinoids	1-Sep	0.25± 0.06	0.093± 0.008	0.25 ± 0.04	0.064± 0.007
	14-Sep	0.14± 0.02	1.05± 0.02	0.15± 0.01	0.06± 0.01
	21-Sep	0.10± 0.01	0.10± 0.01	0.14± 0.02	0.19 ± 0.03
	28-Sep	0.59± 0.07	0.10± 0.01	0.44± 0.12	0.67± 0.05
Total Cannabinoids	1-Sep	4.6± 0.6	9.2± 1.2	9.2± 1.2	3.9 ± 0.4
	14-Sep	9.0± 2.1	9.0± 2.1	11± 0.5	7.1 ± 1.0
	21-Sep	7.5± 1.1	7.5± 1.1	8.8± 1.2	6.4 ± 0.6
	28-Sep	10± 0.7	10.56± 0.7	10± 0.9	11± 0.6

Table 3.6

Cannabinoid concentrations 2022

Cannabinoid	BaOx	Belle	Cat Daddy	Southern Luck
CBC	0.010 ± 0.007	0.050 ± 0.006	0.038 ± 0.017	0.069 ± 0.043
CBDA	2.171 ± 0.262	5.601 ± 0.403	4.245 ± 0.944	4.917 ± 1.338
CBGA	0.075 ± 0.013	0.325 ± 0.401	0.317 ± 0.053	0.345 ± 0.088
Other cannabinoids	0.010 ± 0.006	0.050 ± 0.600	0.038± 0.017	0.069 ± 0.031
THCA	0.085 ± 0.008	0.179 ± 0.021	0.150 ± 0.034	0.157 ± 0.031
Total CBD	2.183 ± 0.283	2.635 ± 0.261	4.179 ± 0.074	5.138 ± 01.646
Total CBG	0.085 ± 0.014	0.343 ± 0.037	0.330 ± 0.052	0.373 ± 0.104
Total THC	0.100 ± 0.012	0.242 ± 0.011	0.189 ± 0.048	0.223 ± 0.071

S.E.M= Standard Error of Mean

Table 3.7

Plant damage 2021

Variety	Mean damage rating across 5 buds ± S.E.M in 2021
BaOx	0.6±0.07[a]
Belle	0.9±0.1[a]
Cat Daddy	1.1±0.1[a]
Southern Luck	0.6±0.1[a]

S.E.M= Standard Error of Mean

Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Table 3.8

Plant damage 2022

Variety	Mean damage rating across 5 buds ± S.E.M in 2022
BaOx	0.3±0.2[a]
Belle	0.7±0.3[a]
Cat Daddy	0.8±0.3[a]
Southern Luck	1.3±0.3[a]

S.E.M= Standard Error of Mean

Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Table 3.9

Pollinator Families 2021 and 2022

Family	Year Found
Andrenidae	2021
Apidae	2021, 2022
Chrysididae	2021
Colletidae	2021
Halictidae	2021, 2022
Megachilidae	2021, 2022
Muscidae	2021
Nymphalidae	2021, 2022
Papilionidae	2021
Pompilidae	2021
Scarabaeidae	2021, 2022
Scoliidae	2021, 2022
Sphecidae	2021, 2022
Syrphidae	2021
Tiphiidae	2021
Vespidae	2021

Table 3.10

2021 Pollinator abundance and variety

Pollinator Family	BaOx	Belle	Cat Daddy	Southern Luck
Andrenidae	3	11	0	9
Apidae	19	46	15	44
Chrysididae	0	2	1	0
Colletidae	1	5	0	10
Halictidae	5	1	7	5
Megachilidae	2	4	2	0
Muscidae	1	2	1	0
Nymphalidae	1	0	0	0
Papilionidae	0	0	0	1
Pompilidae	0	1	0	2
Scarabaeidae	4	2	6	7
Scoliidae	0	8	3	3
Sphecidae	0	2	0	0
Syrphidae	0	0	0	1
Tiphiidae	0	5	1	0
Vespidae	2	2	0	3

pollinator abundance - the number of individuals in each variety

Table 3.11

2021 Pollinator abundance, date, and variety

2021 Sampling Date	BaOx	Belle	Cat Daddy	Southern Luck
13-Jul	15	30	15	33
20-Jul	0	17	4	4
4-Aug	4	11	3	20
11-Aug	4	6	1	6
18-Aug	4	8	2	4
25-Aug	1	3	10	4
1-Sep	6	7	3	4
9-Sep	0	5	2	2
1-Oct	7	8	6	8

Pollinator abundance - the number of individuals in each variety

Table 3.12

2022 Pollinator abundance and variety

Pollinator Family	BaOx	Belle	Cat Daddy	Southern Luck
Andrenidae	0	0	0	1
Apidae	6	0	4	0
Chrysididae	0	0	0	0
Colletidae	0	0	0	0
Halictidae	2	1	1	0
Megachilidae	0	0	1	0
Muscidae	0	0	0	0
Nymphalidae	1	0	0	0
Papilionidae	0	0	0	0
Pompilidae	0	0	0	0
Scarabaeidae	3	4	8	5
Scoliidae	0	0	1	0
Sphecidae	1	1	0	0
Syrphidae	0	0	0	0
Tiphiidae	0	0	0	0
Vespidae	0	0	0	0

Pollinator abundance - the number of individuals in each variety

Table 3.13

2022 Pollinator abundance, sample date and variety

Date	BaOx	Belle	Cat Daddy	Southern Luck
12-Aug	0	0	1	0
19-Aug	1	0	2	2
2-Sep	4	2	6	1
22-Sep	1	1	1	2
26-Sep	7	3	7	2

Pollinator abundance - the number of individuals in each variety

Table 3.14

Arthropod Families 2021 and 2022

Family	Year Found	Arthropod Classification
Acrididae	2021, 2022	Pest
Agelenidae	2021	Incidental
Aeolothripidae	2022	Pest
Anthicidae	2021, 2022	Incidental
Anthocoridae	2021, 2022	Predatory
Aphididae	2021, 2022	Pest
Araneidae	2021, 2022	Predatory
Berytidae	2021, 2022	Predatory
Blissidae	2022	Incidental
Bibionidae	2021, 2022	Incidental
Braconidae	2021, 2022	Parasitoid
Carabidae	2021, 2022	Predatory
Ceratopogonidae	2021, 2022	Incidental
Cercopidae	2022	Incidental
Chalcididae	2021,2022	Parasitoid
Chironomidae	2021	Incidental
Chrysomelidae	2021, 2022	Incidental
Cicadellidae	2021, 2022	Pest
Coccinellidae	2021, 2022	Predatory
Crambidae	2022	Incidental
Curculionidae	2021, 2022	Incidental
Cryptophagidae	2022	Incidental
Delpacidae	2021	Incidental
Dolichopodidae	2021, 2022	Predatory
Drosophilidae	2021, 2022	Incidental
Ectobiidae	2022	Incidental
Forficulidae	2021	Predatory
Formicidae	2021, 2022	Pest

Table 3.14

Arthropod Families 2021 and 2022

Family	Year Found	Arthropod Classification
Geocoridae	2021, 2022	Predatory
Ichneumonidae	2021, 2022	Parasitoid
Halictidae	2021, 2022	Pollinator
Hesperiidae	2021, 2022	Pollinator
Latridiidae	2021, 2022	Incidental
Linyphiidae	2021, 2022	Predatory
Lycosidae	2021, 2022	Predatory
Lygaeidae	2021, 2022	Incidental
Membracidae	2021, 2022	Incidental
Mirdiae	2021, 2022	Pest
Mymaridae	2021, 2022	Parasitoid
Nabidae	2021, 2022	Predatory
Noctuidae H	2021, 2022	Pest
Noctuidae S	2021, 2022	Pest
Oxyopidae	2021, 2022	Predatory
Platygastridae	2021, 2022	Parasitoid
Pentatomidae	2021, 2022	Pest
Phlaeothripae	2021, 2022	Pest

Noctidae H = *Helicoverpa zea*

Noctidae S = *Spodoptera ornithogalli*

Table 3.14

Arthropod Families

Family	Year Found	Arthropod Classification
Reduviidae	2021, 2022	Predatory
Rhopalidae	2022	Incidental
Salticidae	2021, 2022	Predatory
Sciaridae	2022	Incidental
Scelionidae	2021	Parasitoid
Silphidae	2022	Incidental
Silvanidae	2021	Incidental
Sphecidae	2022	Predatory
Stratiomyidae	2021, 2022	Incidental
Syrphidae	2021, 2022	Predatory
Tachinidae	2021, 2022	Parasitoid
Tetragnathidae	2021, 2022	Predatory
Tettigoniidae	2021, 2022	Incidental
Theridiidae	2021, 2022	Predatory
Thomisidae	2021, 2022	Predatory
Trichogrammatidae	2021, 2022	Parasitoid
Ulidiidae	2021	Incidental
Vespidae	2022	Predatory

Table 3.15

2021 Sweeping: Arthropod abundance and variety.

Arthropod Family	BaOx	Belle	Cat Daddy	Southern Luck
Acrididae	7	13	8	23
Anthicidae	0	1	0	0
Anthocoridae	7	1	2	5
Aphididae	1	4	4	10
Araneidae	0	1	1	0
Berytidae	2	1	0	3
Bibionidae	2	5	0	1
Braconidae	0	5	3	3
Carabidae	0	1	0	3
Ceratopogonidae	57	83	40	43
Chalcidoidea	6	16	10	3
Chironomidae	4	11	19	5
Chrysomelidae	19	5	4	11
Cicadellidae	4	16	3	4
Coccinellidae	2	1	1	0
Crambidae	0	1	0	0
Delpacidae	0	0	1	0
Dolichopodidae	6	8	10	6
Doryctinae	0	0	0	1
Drosophilidae	7	6	1	1
Formicidae	3	4	1	0
Geocoridae	12	12	6	17
Halictidae	1	0	0	0
Ichneumonidae	1	7	2	0
Latridiidae	0	0	2	0
Lycosidae	0	2	0	2
Membracidae	11	5	5	5

Arthropod abundance - the number of individuals in each variety

Table 3.15

2021 Sweeping Arthropod abundance and variety.

Arthropod Family	BaOx	Belle	Cat Daddy	Southern Luck
Mirdiae	6	33	20	20
Mymaridae	1	3	5	1
Nabidae	0	1	1	0
Noctuidae H	1	13	17	8
Noctuidae S	14	13	4	1
Oxyopidae	4	10	0	4
Pentatomidae	4	5	1	0
Phlaeothripae	10	6	17	3
Platygastridae	0	5	5	0
Reduviidae	5	2	3	3
Salticidae	1	2	2	4
Scelionidae	1	0	0	4
Silvanidae	6	0	0	0
Stratiomyidae	73	74	118	75
Syrphidae	0	3	0	0
Tachinidae	3	4	1	2
Tetragnathidae	2	0	0	1
Tettigoniidae	0	0	0	1
Theridiidae	0	0	0	4
Thomisidae	0	0	1	1
Thripinae	15	5	15	10
Trichogrammatidae	1	2	1	0
Ulidiidae	1	1	0	1

Arthropod abundance - the number of individuals in each variety

Noctidae H = *Helicoverpa zea*

Noctidae S = *Spodoptera ornithogalli*

Table 3.16

2021 Sweeping: Arthropod abundance, date, and variety.

2021 Sampling Date	BaOx	Belle	Cat Daddy	Southern Luck
28-Jul	6	38	18	28
4-Aug	57	15	22	27
11-Aug	47	52	63	45
18-Aug	27	52	52	31
25-Aug	103	102	68	101
1-Sep	40	85	96	24
9-Sep	15	23	11	18
1-Oct	10	7	8	11

Arthropod abundance - the number of individuals in each variety

Table 3.17

Sweeping: 2021 Arthropod Classification by Variety

Classification	BaOx	Belle	Cat Daddy	Luck
Incidental	180	187	190	143
Parasitoid	13	42	28	14
Pest	68	90	90	79
Predatory	43	45	27	49

Arthropod abundance - the number of individuals in each variety

Table 3.18

2021 Drop cloth: Arthropod abundance and variety.

Arthropod Family	BaOx	Belle	Cat Daddy	Southern Luck
Acrididae	1	14	3	1
Agelenidae	1	0	0	1
Anthicidae	0	3	2	0
Araneidae	2	1	0	0
Berytidae	2	0	0	0
Chalcidoidae	0	0	1	0
Chrysomelidae	1	2	1	0
Coccinellidae	2	2	2	1
Curculionidae	0	1	0	0
Forficulidae	0	1	0	0
Formicidae	1	4	2	1
Geocoridae	3	11	2	9
Lasiocampidae	0	0	1	0
Linyphiidae	1	1	2	0
Lycosidae	1	1	1	1
Lygaeidae	1	0	1	1

Arthropod abundance - the number of individuals in each variety

Table 3.18

2021 Drop cloth: Arthropod abundance and variety.

Arthropod Family	BaOx	Belle	Cat Daddy	Southern Luck
Megalopygidae	0	1	0	0
Membracidae	1	0	0	0
Mirdiae	1	8	8	3
Nabidae	0	1	0	2
Noctuidae H	6	8	9	2
Noctuidae S	3	3	1	8
Oxyopidae	3	4	7	4
Pentatomidae	3	18	1	6
Phalacridae	1	0	0	0
Reduviidae	3	6	1	4
Salticidae	2	3	1	2
Silvanidae	2	0	0	1
Tetrigidae	0	0	1	0
Thomisidae	1	5	4	2

Arthropod abundance - the number of individuals in each variety

Noctidae H = *Helicoverpa zea*

Noctidae S = *Spodoptera ornithogalli*

Table 3.19

2021 Drop cloth: Arthropod abundance, date, and variety.

2021 Sampling Date	BaOx	Belle	Cat Daddy	Southern Luck
28-Jul	5	15	5	5
4-Aug	3	6	4	2
11-Aug	5	22	12	4
18-Aug	4	29	6	5
25-Aug	7	0	5	2
3-Sep	7	9	8	8
9-Sep	4	10	7	8
1-Oct	7	7	4	16

Arthropod abundance - the number of individuals in each variety

Table 3.20

Drop cloth: 2021 Arthropod Classification by Variety

Classification	BaOx	Belle	Cat Daddy	Luck
Incidental	9	5	7	9
Parasitoid	0	0	0	0
Pest	18	73	36	37
Predatory	33	53	29	42

Arthropod abundance - the number of individuals in each variety

Table 3.21

2022 Sweeping: Arthropod abundance and variety.

Arthropod Family	BaOx	Belle	Cat Daddy	Southern Luck
Acrididae	6	5	5	3
Anthocoridae	1	0	3	4
Blissidae	3	3	1	2
Broconidae	6	9	7	6
Chrysomelidae	19	6	28	12
Cicadellidae	4	3	33	2
Drosophilidae	6	15	33	25
Geocoridae	1	0	0	1
Linyphiidae	2	3	3	0
Lygaeidae	0	0	0	4
Membracidae	1	1	5	2
Mymaridae	1	0	2	0
Noctidae H	1	0	0	11
Noctidae S	1	0	6	3
Noctuidae T	0	1	0	0
Pentatomidae	1	1	0	3
Phylacridae	0	0	0	3
Reduviidae	2	0	2	0
Sciaridae	0	0	2	2
Silphidae	0	0	2	0
Vespidae	0	0	1	0

Arthropod abundance - the number of individuals in each variety

Noctidae H = *Helicoverpa zea*

Noctidae S = *Spodoptera ornithogalli*

Noctuidae T = *Trichoplusia ni*

Table 3.22

2022 Sweeping: Arthropod abundance, date, and variety.

2022 Sampling Date	BaOx	Belle	Cat Daddy	Southern Luck
4-Aug	7	8	11	15
9-Aug	14	3	16	11
15-Aug	4	16	26	13
26-Aug	7	7	12	6
1-Sep	9	7	18	21
8-Sep	14	13	20	20

Arthropod abundance - the number of individuals in each variety

Table 3.23

Sweeping: 2022 Arthropod Classification by Variety

Classification	BaOx	Belle	Cat Daddy	Southern Luck
Incidental	29	30	69	47
Parasitoid	13	10	13	27
Pest	7	9	9	6
Predatory	6	5	12	6

Arthropod abundance - the number of individuals in each variety

Table 3.24

2022 Drop cloth: Arthropod abundance and variety.

Arthropod Family	BaOx	Belle	Cat Daddy	Southern Luck
Acrididae	6	5	5	3
Aeolothripidae	1	0		0
Anthicidae	2	2	0	0
Anthocoridae	1	0	3	4
Aphidae	1	1	2	1
Araneidae	0	0	0	1
Blissidae	0	1	1	1
Chalcididae	1	0	0	0
Chrysomelidae	2	1	0	1
Cicadellidae	1	0	1	1
Curculionidae	0	1	2	0
Ectobiidae	0	0	0	1
Formicidae	0	1	0	1
Geocoridae	3	0	0	1
Lycosidae	2	0	0	0
Linyphiidae	2	2	2	2
Miridae	1	0	1	0
Nabidae	4	0	2	0
Noctidae H	0	0	0	2
Noctidae S	5	21	6	1
Pentatomidae	14	2	0	0
Reduviidae	0	2	3	1
Rhopalidae	0	0	0	1
Sphecidae	0	1	0	0

Arthropod abundance - the number of individuals in each variety

Noctidae H = *Helicoverpa zea*

Noctidae S = *Spodoptera ornithogalli*

Table 3.25

2021 Drop cloth: Arthropod abundance, sample date, and variety.

2022 Sampling Date	BaOx	Belle	Cat Daddy	Southern Luck
3-Aug	4	8	5	3
15-Aug	2	2	1	5
2-Sep	7	6	21	4
9-Sep	5	5	13	26

Arthropod abundance - the number of individuals in each variety

Table 3.26

Drop cloth: 2021 Arthropod Classification by Variety

Classification	BaOx	Belle	Cat Daddy	Southern Luck
Incidental	2	4	2	3
Parasitoid	0	0	1	0
Pest	11	11	25	28
Predatory	5	6	12	7

Table 3.27

Plant fresh weight

Variety	Mean fresh weight (g) ± S.E.M
BaOX	2625.87 ± 381.815
Belle	946.17 ± 343.787
Cat Daddy	2647.14 ± 546.614
Southern Luck	1623.01 ± 590.865

S.E.M= Standard Error of Mean

Table 3.28

Plant dry weight

Variety	Mean dry weight (g) ± S.E.M
BaOX	506.748 ± 102.277
Belle	326.020 ± 160.578
Cat Daddy	520.923± 144.018
Southern Luck	434.693 ± 217.962

S.E.M= Standard Error of Mean

Table 3.29

Bud fresh weight

Variety	Mean fresh bud weight (g) ± S.E.M
BaOX	9.264 ± 0.285
Belle	8.241 ± 2.756
Cat Daddy	5.188 ± 0.654
Southern Luck	8.217 ± 1.098

S.E.M= Standard Error of Mean

Table 3.30

Bud dry weight

Variety	Mean dry bud weight (g) ± S.E.M
BaOX	2.847 ± 0.184
Belle	2.873 ± 1.007
Cat Daddy	1.999 ± 0.228
Southern Luck	3.097 ± 0.573

S.E.M= Standard Error of Mean

Table 3.31

Unmarketable Proportion

Variety	Mean proportion of unmarketable buds ± S.E.M
BaOX	0.125 ± 0.226
Belle	0.208 ± 0.257
Cat Daddy	0.125 ± 0.226
Southern Luck	0.333 ± 0.235

S.E.M= Standard Error of Mean

Figures

Figure 3.1

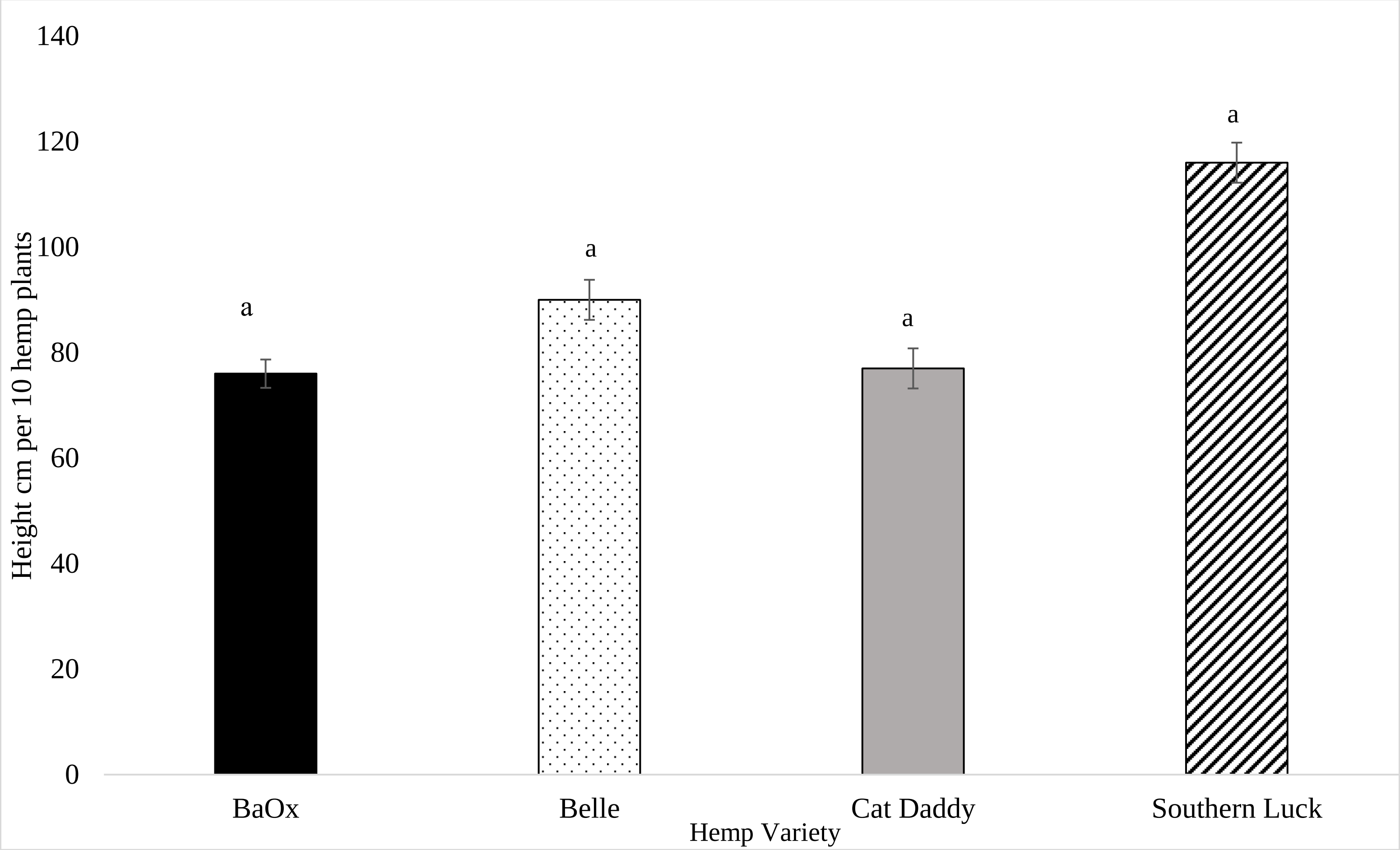
Damage Scale (0 to 5)

Figure 3.2

Elevated traps pollinators

Figure 3.3

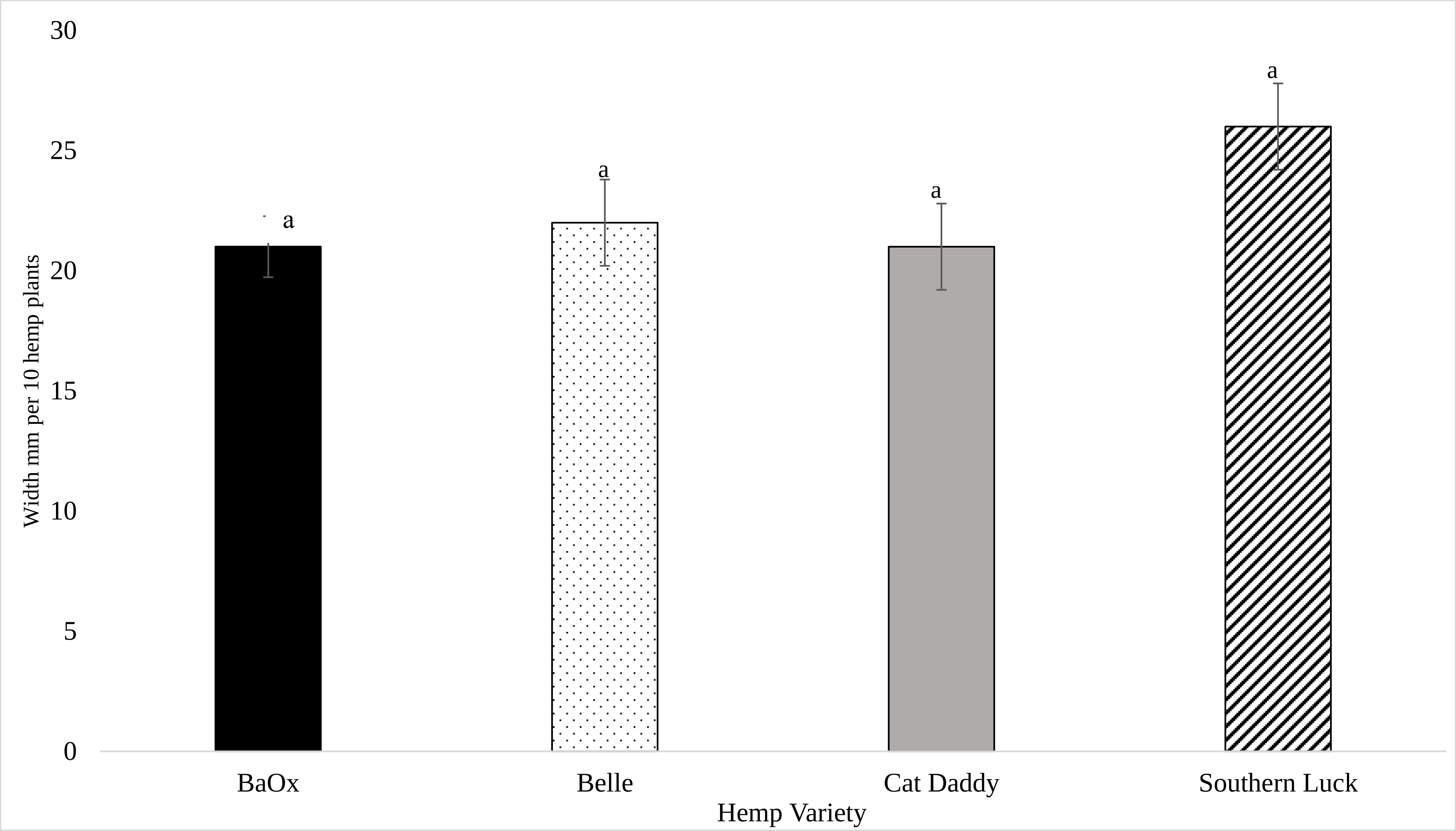
Height 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.4

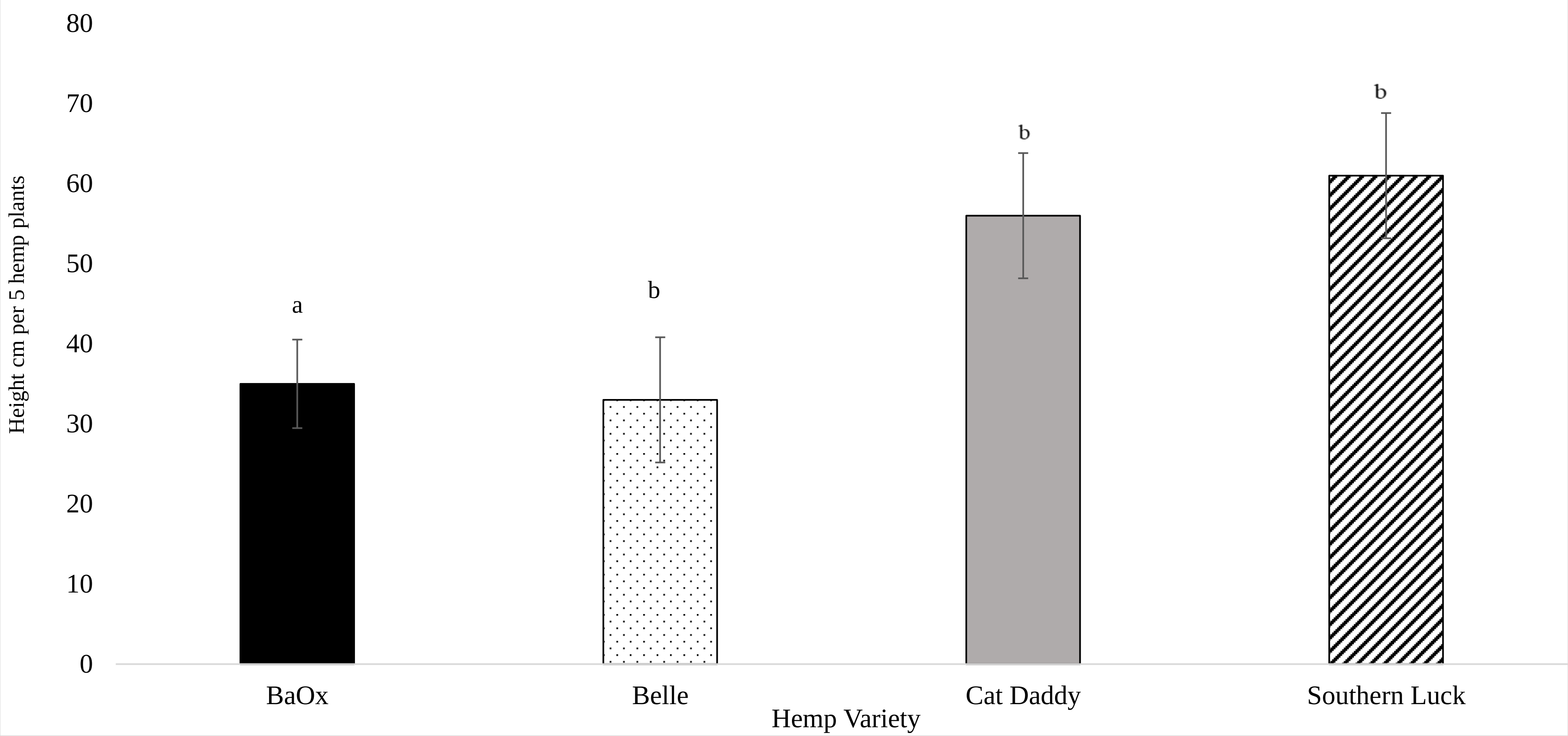
Width 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.5

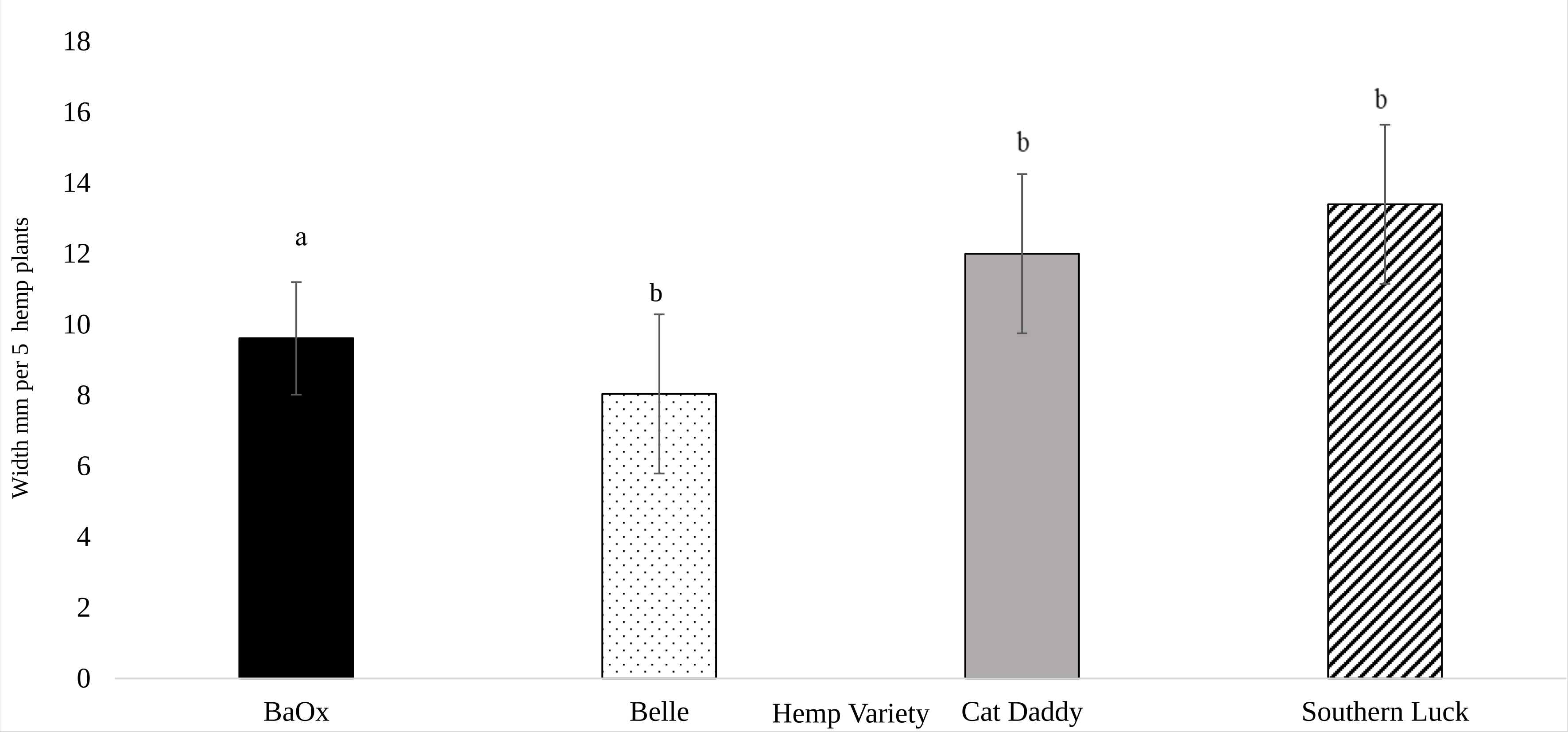
Height 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey’s HSD post hoc test.

Figure 3.6

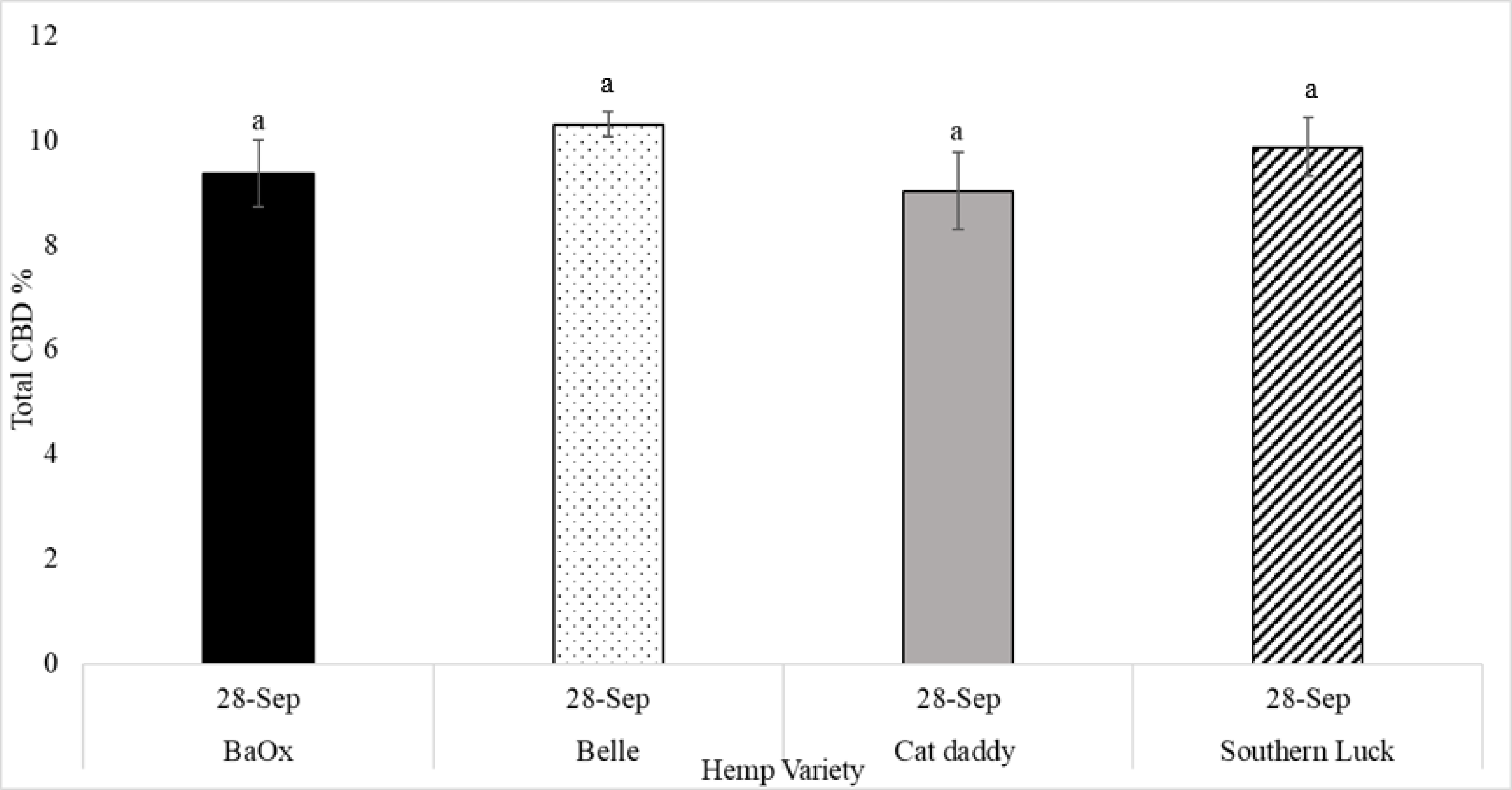
Width 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.7

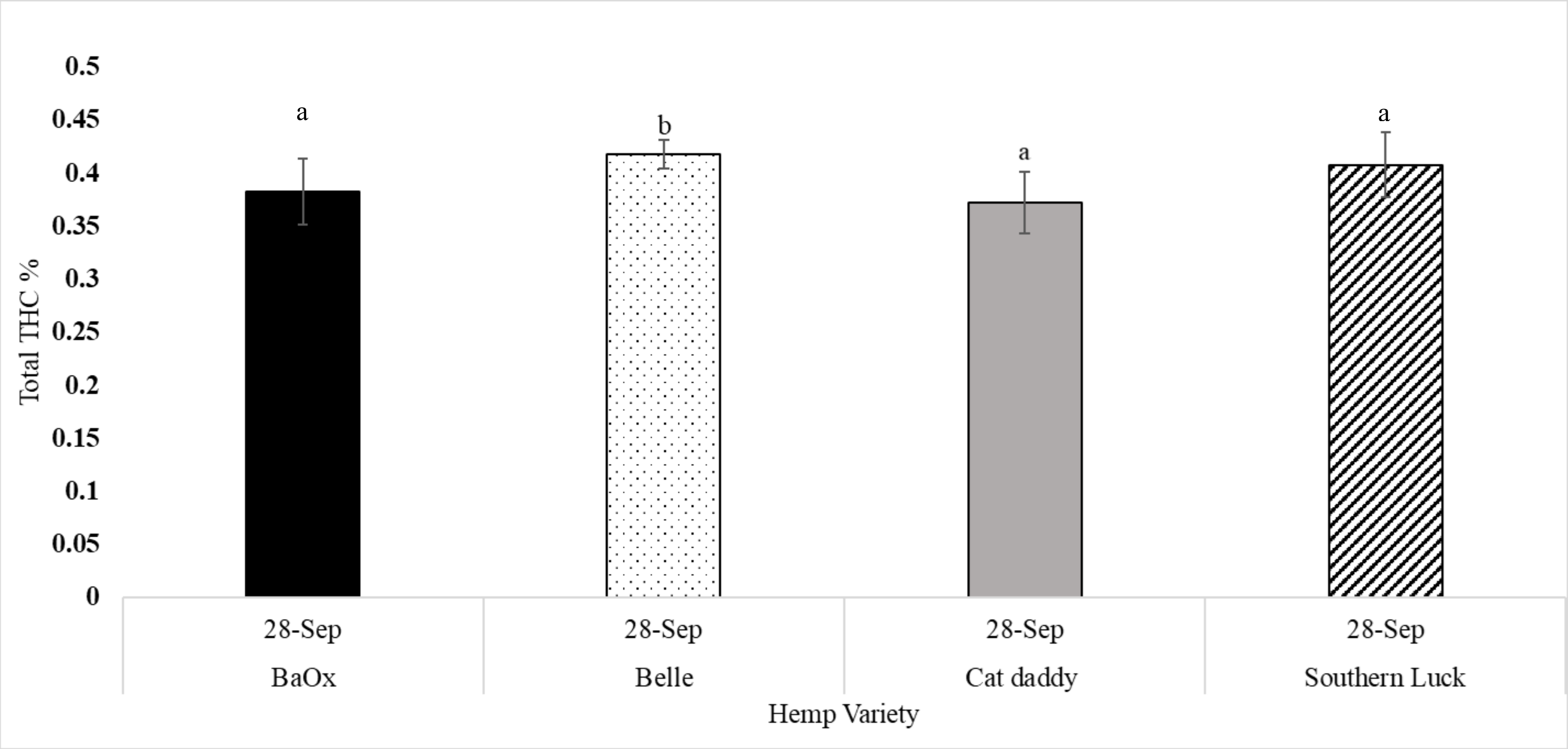
CBD September 28, 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.8

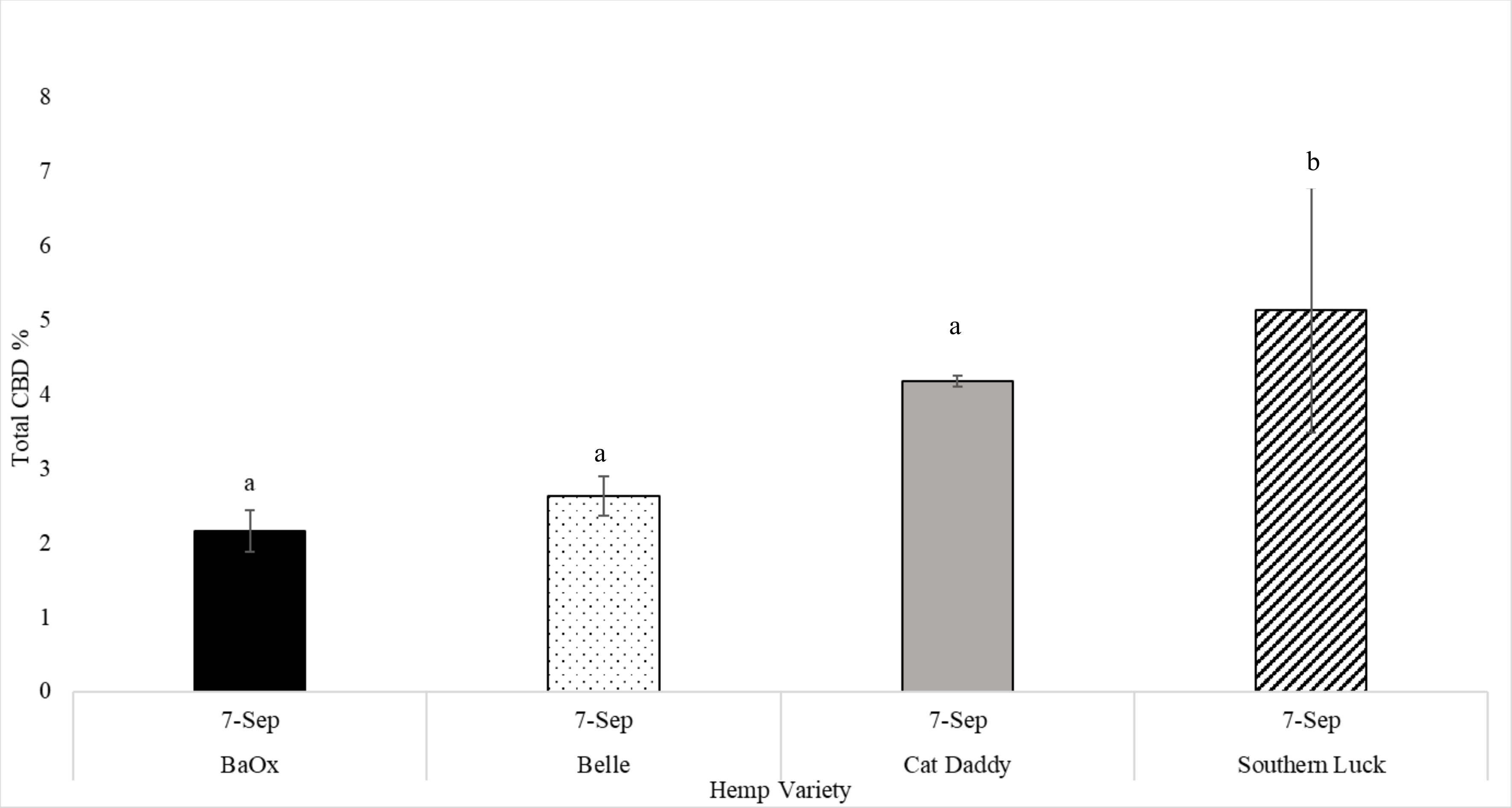
THC September 28, 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.9

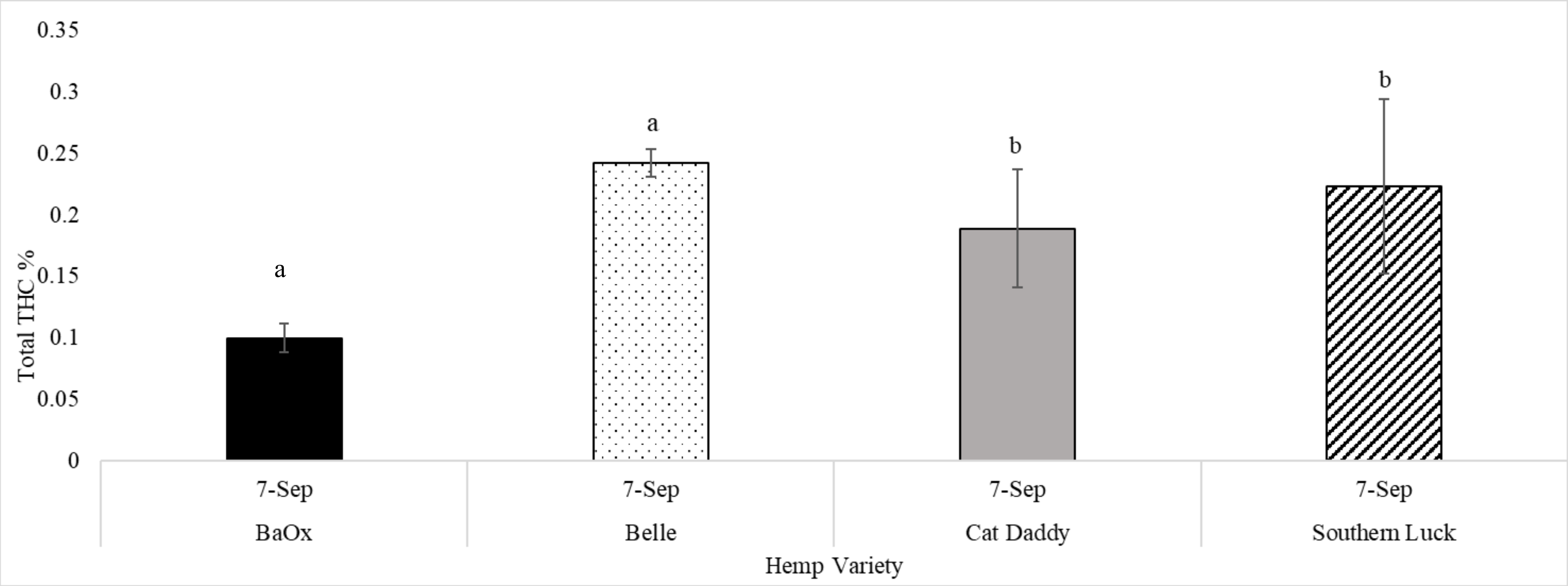
CBD 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.10

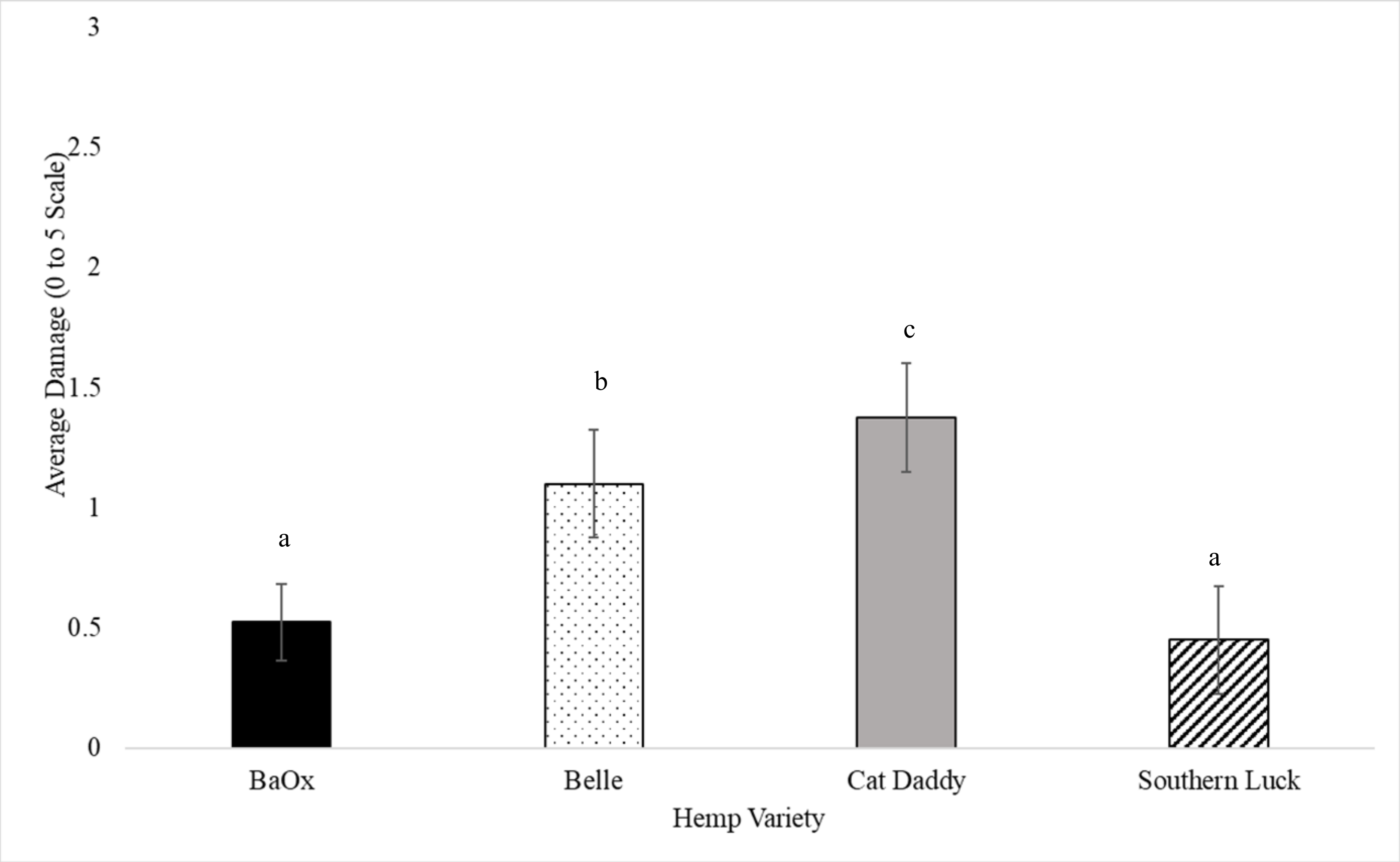
THC 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.11

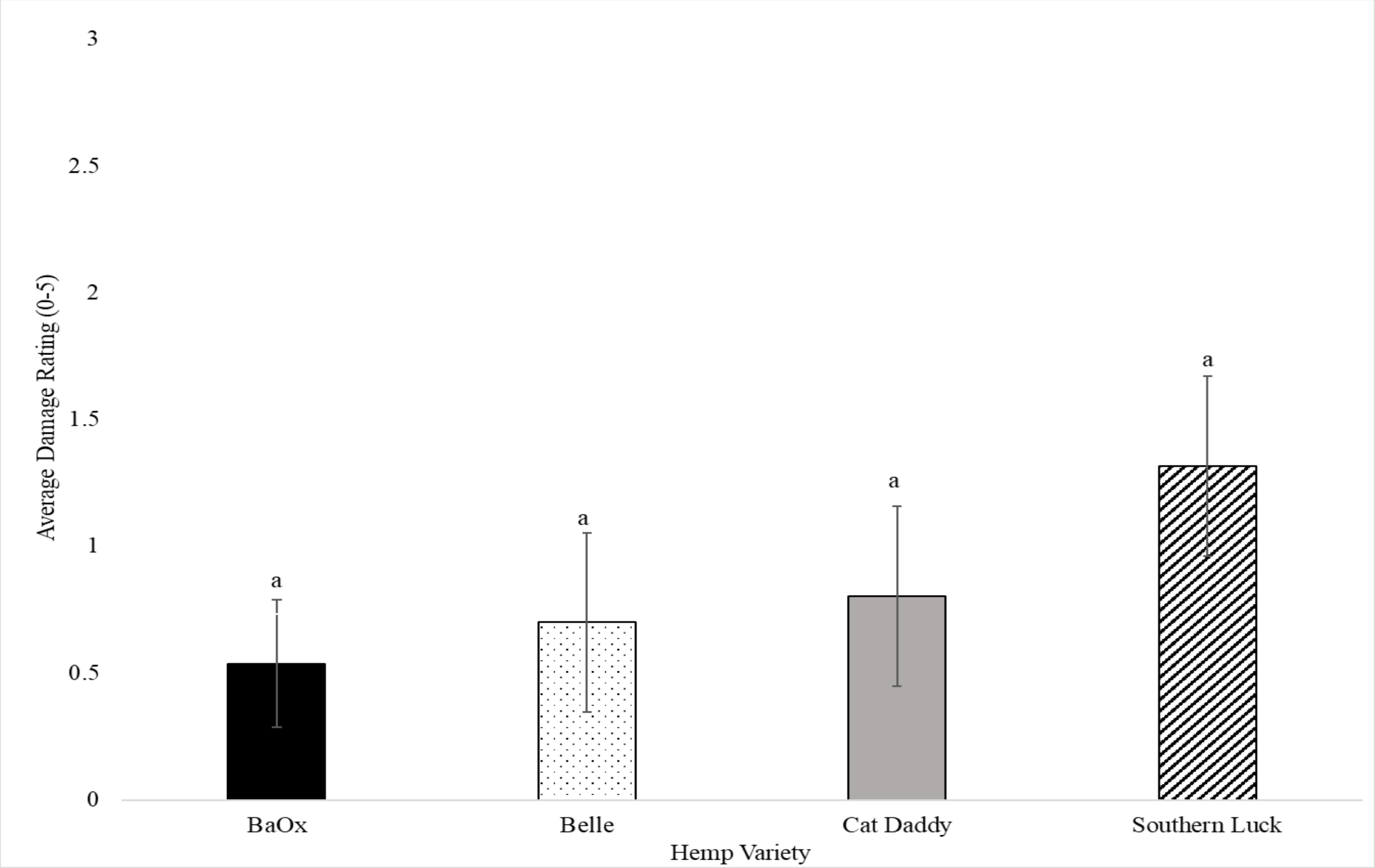
Plant Damage 2021



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.

Figure 3.12

Plant Damage 2022



Means with different letters indicate significant differences at α=0.05, via the Tukey's HSD post hoc test.