Evaluation of Blackberry Cultivar Performance Under 30% Shade and Full Sun in Central Alabama

by

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Abstract

Blackberry, the official state fruit of Alabama, has strong potential for expanded commercial production in the region. Yield, fruit quality, and environmental conditions of eighteen blackberry cultivars were evaluated over two harvest seasons (2024–2025) under full sun and 30% aluminet shade at the Chilton Research and Extension Center in central Alabama using a randomized complete block design (n = 8). Shade increased yield in 2024 but did not consistently improve yield in 2025, likely due to greater rainfall and soil moisture during the second year. Berry size was consistently greater under shade, and white drupelet disorder (WDD) incidence was reduced relative to full sun; however, shade also reduced soluble solids content and increased titratable acidity. Cultivar differences were observed for all measured variables. ‘Kiowa’, ‘Ponca’, and ‘Prime-Ark® Horizon’ produced among the greatest cumulative yields across both years, whereas ‘Columbia Star’ and ‘Eclipse’ were among the lowest-yielding and poorly adapted to central Alabama conditions. ‘Ponca’ and ‘Osage’ combined high yields with favorable fruit quality, low WDD incidence, and desirable flavor attributes. Although ‘Kiowa’ was consistently high yielding, it exhibited greater WDD incidence and lower soluble solids content than several other cultivars. Costly repairs to the shade structure were necessary during this study following storm damage, and caution should be exercised when determining whether to utilize a shade structure for blackberry production. Cultivar selection was observed to have a more consistent influence on yield, fruit quality, and WDD, and is likely a more economically impactful decision compared to utilizing shade structures in central Alabama.

Artificial Intelligence (AI) Use Disclosure Statement

In the preparation of this thesis, the following Artificial Intelligence (AI) tools were used: Microsoft Copilot and Chat GPT. These tools were used primarily to generate and edit code for data analysis in SAS. They were also used to improve flow and grammatical errors. The author acknowledges full responsibility for the intellectual content of this work and has ensured that all AI-assisted sections have been reviewed and revised for accuracy and appropriate academic style. All AI-generated content was reviewed and validated for relevance, appropriateness, and accuracy before incorporation into the final document to maintain scholarly integrity of this research.

Digital Accessibility Use Disclosure Statement

In the preparation of this thesis , the following digital accessibility tools were used to ensure this document complies with federal requirements: Microsoft Word Accessibility Checker, and built in formatting tools including structured headings, alternative text for figures, and properly formatted tables. The author acknowledges full responsibility for the intellectual content of this work and has made a good faith effort to comply with digital accessibility requirements in publishing, wherein the nature of the content does not significantly change in order to do so. Furthermore, all content has been reviewed and revised to meet these requirements prior to final publication.

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List of Abbreviations

°C	Degrees Celsius
kg	Kilogram
g	Gram
mL	milliliter
lb.	pound
m	meter
cm	centimeter
WDD	White Drupelet Disorder
TA	Titratable Acidity
SSC	Soluble Solids Content
PAR	Photosynthetically Active Radiation
N	Nitrogen

Chapter 1:

Literature Review

1.1 Caneberry Origin and Significance

Caneberries are a group of deciduous woody shrubs in the *Rosaceae* family *(Genus: Rubus),* characterized by a perennial crown that produces biennial canes. Common caneberries include blackberries and raspberries, which are cultivated for fresh and frozen consumption as well as for use in value-added products and processing (Joh et al., 2017). In addition to their value as a food crop, caneberries have historically been used for medicinal purposes. Various plant parts, including fruit, leaves, and roots, have been utilized in traditional medicine for their antioxidant, anti-inflammatory, and antimicrobial properties, attributed to their high phenolic and anthocyanin content (Hummer, 2010; Lee, 2017). Raspberries were grown by the ancient Greeks and through the spread of civilization are now grown in Great Britain, Europe, North America, New Zealand, and Australia. Blackberries are native to many parts of the world, however domestication of the crop for commercial use began in North America and Europe (Moore and Skirvin, 1990). Previously classified as subgenus *Eubatus*, blackberries range from diploid to dodecaploid (12x) (Foster et al., 2019; Moore and Skirvin, 1990) and can easily hybridize making taxonomic classification difficult (Moore and Skirvin, 1990). Hence, blackberry cultivars are not typically assigned a species (Foster et al., 2019).

Despite the growing interest in caneberry production in the southeastern United States, limited information is available regarding the suitability of raspberry and blackberry cultivars under Central Alabama climatic conditions (Fernandez et al., 2023).

High temperatures, humidity, and variable precipitation present unique challenges to caneberry establishment, productivity, and fruit quality in this region (Maughan et al., 2017; Stafne, 2017). Raspberry and blackberry cultivars differ widely in growth habit, heat tolerance, and productivity, making region-specific cultivar evaluation essential for successful production in nontraditional growing areas such as Central Alabama (Fernandez et al., 2023). Shade structures may mitigate heat and light stress by moderating the canopy microclimate, potentially improving vegetative growth, yield stability, and overall plant performance under stressful environmental conditions (Stafne 2017; Shahid 2021; Xu et al., 2025). Therefore, in Alabama there is a need to evaluate both cultivar performance and to investigate the potential benefits of shade.

1.2 Botanical Description

Blackberries and raspberries both have flowers with five petals, five sepals and many stamens and pistils. Flowers are typically self-fertile and can be pollinated by flying insects and wind (Crandall, 1995). Fruits are aggregated and composed of numerous individual drupelets attached to a fleshy receptacle. Aggregated drupelets remain attached to receptacle tissue for blackberry and separate from receptacle at maturity on raspberry (Crandall, 1995). Individual drupelets are similar physiologically to peaches. There should be at least eighty drupelets per fruit to be commercially viable (Crandall, 1995). After pollination, fruit development takes approximately 30-35 days and 35-45 days for red raspberry and blackberry, respectively (Crandall, 1995), although more recent literature estimates that blackberries need 45-60 days to fully ripen from green to black after pollination (Fernandez et al., 2023).

Several factors influence the overall quality of fruit, particularly fruit size and internal composition. Fruit size is especially important when considering market destination. In Arkansas consumers evaluated physical attributes of blackberries including size and the majority preferred larger berries (Threlfall et al., 2021). Many U-pick growers favor larger berries because they are perceived as more attractive to consumers and fill harvest containers more quickly (Clark, 2021). Fruit of blackberry cultivars typically range from 5g up to 14g on average. Ideally blackberry breeders aim to produce berries with 7 g to 9 g size to ship in clamshells while still being the ideal bite size for consumers (Finn et al., 2014). When presented in clamshells to consumers, the majority preferred larger sized berries in clamshells (Threlfall et al., 2021)

Beyond external characteristics, blackberry internal fruit composition is commonly evaluated to determine overall flavor and fruit quality. Fruit sugar content is represented as percent soluble solids content (SSC), while acidity is measured as titratable acidity (TA) These measurements can be collected using handheld Brix and acidity meters, allowing for efficient field-level assessment. In addition, fruit pH is recorded to estimate the strength and type of acids present, providing further insight into flavor balance (Godwin et al., 2025; Jaywant et al., 2022). Because sweetness and acidity interact to influence perceived flavor, the sugar-to-acid ratio is often a more informative indicator of “sweetness”. A comprehensive evaluation of fifty-two blackberry cultivars reported SSC values ranging from approximately 6 to 16 %SSC and TA values from 0.5 to 2.2% citric acid (Fan-Chiang and Wrolstad, 2010). Acceptable compositional ranges for commercial blackberry production are 8–11 %SSC, 0.7–1.5% TA, and a pH of 3.0–3.6 (Trandel-Hayse et al., 2025).

Blackberries are desirable to consumers for their potential health benefits, flavor, and use in value added products. Important nutritional components of blackberries include dietary fiber, vitamin C, vitamin A, vitamin E, potassium, and calcium (Xu et al., 2024). Blackberry's deep purple color comes from its anthocyanin continents, which can help regulate blood pressure, reduce inflammation, and protect brain health (Xu et al., 2024). In addition, blackberries generally contain high anthocyanin concentrations, contributing to their strong antioxidant capacity and overall nutritional value (Lee, 2017; Kao 2006).

While internal fruit quality strongly influences consumer acceptance, plant architectural traits also play a critical role in production efficiency and cultivar adoption (Strik et al., 2012). Caneberries are typically thorny, and some suggest that thorniness may contribute to plant vigor and high yields (Nesbitt et al., 2015). However, breeding efforts have shifted to develop high yielding thornless varieties that can be competitive against traditional thorny types. Thornless blackberries are easier to prune, train, and harvest and are becoming more popular as new cultivars become available (Nesbitt et al., 2015).

1.3 Economic Significance and Potential

Because of their quick turnaround on fruit production and sales compared to fruit crops that take longer to establish, blackberries are desirable for farmers looking for a quick return on investment and typically reach full production levels in the third year. With proper management blackberry plantings in Alabama should yield between 6,000 to 8,000 pounds per acre (Vinson et al., 2023). Due to an increase in consumer interest, caneberry production is expanding within the United States. In 2017, blackberry production within the US was valued at $31.1 million, with $5.4 million from fresh-market blackberries and $25.7 million from processed blackberries (USDA NASS, 2017).

While caneberry production in the US is concentrated in the Pacific Northwest in Oregon, Washington, and California, blackberries have strong potential in the Southeast (USDA NASS, 2017). Within the Southeast, Georgia, Arkansas, and North Carolina lead in acres bearing (USDA NASS, 2025). Though commercial production within the state is limited, blackberry is the state fruit of Alabama and has great potential for commercial production and growth in the state due to its adaptation to the warm temperate climate (Crandall, 1995). Data from 2017 indicated that there were 208 blackberry farms with around 122 acres dedicated to blackberry production (USDA NASS, 2017). As of 2022, the number of farms has increased to 254 with 186 acres dedicated to blackberry production (USDA NASS, 2022). Alabama growers typically market blackberry locally via on-farm sales or U-Pick operations, with the average operation size of blackberry farms being 0.59 acres (USDA; National IPM Database, 2021). There are three counties in Alabama that have greater than 10 acres of production, including Chilton County in central Alabama. Chilton County is also the primary county for fruit production in Alabama. Neighboring state, Georgia, has 818 acres (USDA, NASS 2022).

Blackberry breeding efforts, led by the University of Arkansas breeding program, have increased viable cultivars for growers in Alabama. The University of Arkansas breeding program has released many blackberry cultivars, including primocane-fruiting and improved thornless cultivars. The program has also focused on improving flavor and obtaining high soluble solids content in new cultivars included in their Sweet Ark line. The USDA and University of Oregon have collaborated to release many new cultivars of western trailing type blackberries and semi trailing hybrids that have not been studied for performance in the Southeast (USDA ARS, 2020; Strik and Finn, 2018).

1.4 Cultivation and Production

Flower initiation of blackberry is believed to be initiated by shortening day length and lowering temperature in late summer or fall, and time of bud initiation is dependent on cultivar and growing environment (Moore and Skirvin, 1990). Blackberries and raspberries perform best with a soil pH between 5.5-6.5 and organic matter over 3% (Crandall 1995). It is also recommended to use a cover crop the year before establishment and then plow the fall before planting and add any needed soil amendments (Crandall 1995).

One important factor when selecting a cultivar is the chill requirement. Blackberries require proper chilling hours to develop flower buds (Yazzetti and Clark, 2001). A chilling hour is typically referencing one hour below 45℉ and above 32℉ (Fernandez, 2023). Blackberry chill requirements can range from 100 to over 1,000 chill units. Cultivars should be able to tolerate the summer temperatures and be productive with good fruit quality. Blackberry chill requirements depend on cultivar and climate adaptation (Moore and Skirvin, 1990)

Caneberries have a unique production system because of their biennial growth habit. The initial canes are called primocanes (vegetative). These canes will undergo a period of dormancy, and the following season (now called floricanes) will produce fruit in the second growing season. During the fruiting period of floricanes, new primocanes will emerge that will produce the following season's crop (Moore and Skirvin, 1990). *Rubus* breeders have discovered mutations that cause primocane fruiting. In raspberries, these are often called fall-bearing or everbearing varieties. There has been recent interest in newly released primocane-fruiting blackberries from University of Arkansas's breeding program.

Caneberries will have either a trailing, erect, or semi-erect growth habit (Strik, 1992) and can be thorny or thornless. Erect, thornless canes are most desirable for many growers to ease labor conditions (Graham and Woodhead, 2009), and with the release of new cultivars of thornless, erect or semi-erect blackberries, there is a need for investigating their production in Alabama. Trailing blackberry production is concentrated in the Pacific Northwest and are primarily grown for processing (Davis et al., 2025). In the southeastern United States, growers have traditionally relied on erect blackberry cultivars, and breeding and grower interest have increasingly focused on thornless types that combine high yield, good fruit quality, and suitability for commercial production (Clark, 2005; Clark and Moore, 2005).

Trellises are typically used to train canes and control the canopy and density of the plants. The T-trellis is frequently used in commercial production and contains two sides of 2-3 wires held up by metal rebar or wooden posts, creating an open V-shaped canopy. V- trellis, which is among the most commonly used trellis systems, uses steel posts at 20 to 30 degree angle from vertical to form a V shaped canopy. There are also shifting trellises or rotating cross arm trellises which are more expensive, but allow for better control of canopy and fruit placement (Fernandez at al., 2023).

The most prevalent diseases found in blackberries in Alabama include rosette, orange rust, and anthracnose. Insect pests include stink bug, spotted wing drosophila, mites, and Japanese beetles (Vinson et al., 2023). Spotted wing drosophila is an especially persistent insect pest that lays eggs into fruit, which can cause leakage and maggots especially post-harvest (Walsh et al., 2011). Alabama cultivars should be selected for resistance to these pests and diseases that are prevalent in the Southeast.

As previously described, the fruit of blackberries are made up of individual drupelets that each contain a seed. Drupelet size and seediness are both important for fruit quality and desirability to consumers. There are physiological disorders associated with discolored drupelets including red drupelet reversion and white drupelet disorder (WDD). Red drupelet reversion is a common postharvest problem that occurs once fruit is removed from the vine causing ripe black drupelets to revert to a red color. This reversion in color is also less desirable to consumers (Threlfall et al., 2021). WDD is a preharvest disorder causing a white, discolored drupelet. Prevalence of WDD is linked to genotype and environmental stressors like humidity and heat stress (Stafne, 2017).

Raspberries are typically not recommended for production in Alabama (Fernandez et al., 2023) and prefer a cool temperate climate. It is important to note that raspberries are not recommended for most southern growers as they typically have higher chilling requirements (Crandall, 1995). They typically prefer cooler climates with consistently cold winters and mild summers. Hence, it is typically recommended to grow raspberries at elevations over 2,000 ft. and raspberries have been successfully grown in some cooler microclimates in the southeast, particularly in North Carolina (Fernandez et al, 2023). Alabama's highest elevation is 2,407 ft above sea level at Mt. Cheaha.

Raspberries experience heat stress and reduced photosynthesis and growth at temperatures over 77 °F which is common for Alabama's hot summers. Shade structures could be a potential solution to allow Alabama growers to mitigate heat stress in raspberry production, however the need for cooler winters may offset this potential.

1.4.1 Use of Shade Cloth in Caneberry Production

Shade cloth is used to reduce temperatures and solar irradiation, and to modify the light quality and quantity to reduce symptoms of heat stress or sunburn in a variety of crops (Shahid, 2021). In horticultural production photosynthetically active radiation PAR ($\mu mol \cdot m^{-2} \cdot s^{-1}$) is typically measured as it is the spectrum usable to the plant. Shade cloth allows growers to control the radiation exposure to plants (Stamps, 2009). Interception of too much PAR can cause oxidative and physical stress to plants. This point is called the light saturation point. In blackberries, reported light saturation occurs at 750-900 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (Caillouet et al., 2016), however one study testing photosynthetic light response observed that some cultivars had a light saturation point of up to 1000 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and that different cultivars had differing responses (Lykins et al. 2021). Shade cloth comes in a variety of colors and coverages (percentage) that can cause varying effects on plant growth and development (Stamps 2009). Aluminet is a color of reflective shade cloth that reflects light. One study found aluminet to reduce temperatures compared to other colors, and additionally aluminet increased yield of roses compared to black shade cloth (Singh et al., 2023).

Raspberries and blackberries can experience sun damage on fruit at fruit surface temperatures of 105 °F, which could occur from ambient temperatures of 85 °F (Maughan et al., 2017). Shade structures have been used on many crops to successfully prevent sun damage (Maughan et al., 2017; Shahid, 2017; Vinson and Spiers, 2023) and preliminary results from a study in Florida resulted in an increased fruit quality in blackberries grown under shade structures (Shahid, 2017). Shade structures have reduced WDD incidence in trials (Vinson and Spiers, 2023) and have potential to increase yields and fruit size (Shahid, 2021). In Alabama, shade had no impact on yield or berry size, but lowered WDD count over both years (Spiers et al., 2014). An additional shade study in Alabama determined that ‘Kiowa’ had greater incidence of WDD than ‘Prime-Ark® 45’, which supports that WDD is also dependent on genotype (Vinson and Spiers, 2024). Adding 40% shade after the 3rd harvest reportedly increased yield by 34% and reduced fruit temperatures for ‘Kiowa’ (Makus, 2010). Cooler and rainier weather resulted in lower overall WDD incidence among multiple cultivars in Mississippi and a shade cloth treatment was found to reduce WDD by 63% (Stafne 2017). In Virginia, shade did not affect yields but decreased WDD and soluble solids content (Xu et al., 2025). Environmental factors had greater significance than shading and because of unexpected environmental changes, growers should be cautious when investing in shade cloth (Xu et al., 2025)

Canopy management also influences shading of fruit, and additional work in MS determined that additional nitrogen to increase cane and leaf growth improved WDD in ‘Sweetie Pie’ (Stafne, 2021). There has also been recent interest in a rotating cross arm trellis (RCA) that allows growers to control the position of the fruit. This research determined that WDD was improved when fruit was grown out of direct sunlight (Takeda et al., 2013) which supports the claim that shade has the potential to improve WDD and fruit quality. Using a RCA trellis improved yield, fruit quality and lowered spotted wing drosophila populations (McWhirt et al., 2020). When comparing an RCA trellis to a traditional T-trellis, RCA had better fruit quality and less post-harvest loss, and yield per plant and berry weight were greater (McWhirt et al., 2020)

1.4.2 Blackberry Cultivar Selection

'Prime-Ark® 45' is a thorny, erect, primocane-fruiting cultivar developed by the University of Arkansas breeding program; It was selected for its firm fruit compared to other primocane-fruiting cultivars and released as a cultivar in 2011 (Clark, 2011). Fruit has good shipping potential, comparable to 'Ouachita', and fruit size ranged from 5 - 6 g in Arkansas, and 7-9 g in California and Oregon (7 and 8.9 g/berry respectively) (Clark and Perkins-Veazie, 2011). SSC of floricane fruits averaged ~ 10% (Clark & Perkins-Veazie, 2011) and reported SSC ranges up to 12% with TA of ~ 0.81 (Threlfall et al., 2016; Trandel-Hayse et al., 2025). Additional trials found yields to be comparable to 'Natchez' and higher yielding in comparison to other primocane varieties grown (APF-12 and APF-8) (Clark and Perkins-Veazie, 2011). Average yields are typically 3-4 kg/plant for floricanes and primocane yields varied based on location (Clark, 2012). 'Prime-Ark® 45' yields were greater than 'Prime-Ark® Traveler' in a study conducted in California from 2017-19 (Daugovish et al., 2021). In a cultivar evaluation conducted in central Alabama from 2017-2019, 'Prime-Ark® 45' had less incident of WDD than 'Kiowa', 'Natchez', 'Ouachita' and 'Sweetie Pie'(Spiers and Vinson 2024). In this same study, mean berry weight was ~5 g and yield was ~2.3kg/plant. Performance and yields were better in California and Oregon when compared to production in Arkansas (Clark, 2012)

'Prime-Ark® Freedom' is a thornless, erect, primocane-fruiting blackberry cultivar released by the University of Arkansas breeding program (Clark, 2014). It was the first thornless primocane-fruiting blackberry to become available commercially and is recommended for home gardens or local sales. ‘Prime-Ark® Freedom’ was evaluated in California and Arkansas and yields in California were much higher and suitable for commercial production. Yields were statistically comparable to ‘Prime-Ark® 45’, ‘Osage’ and ‘Ouachita’, however lower numerically, and lower yields than ‘Natchez’ (Clark, 2014). Clark (2021) hypothesized that the Deep South may show higher yields than West Arkansas due to its early blooming with lower risk of cold damage in the spring. Additionally, Alabama growers reported benefits associated with its large fruit size and early ripening season (Clark, 2021). It is 9-11 days earlier than ‘Natchez’ in Arkansas (Clark 2014). Berries average ~ 10-11g/berry weight when evaluated in Arkansas (Clark, 2014;Clark, 2021) but berries up to 16g were observed when evaluated in California (Clark, 2014). Aromatic compounds were identified to have fruity and floral notes (Xu et al., 2025). SSC averaged around 10%, slightly less than ‘Prime-Ark® 45’ (Clark, 2021). Flavor ratings were also comparable to ‘Prime-Ark® 45’ (Clark, 2021).

‘Prime-Ark® Horizon’ is a primocane-fruiting blackberry cultivar developed by the University of Arkansas breeding program. Plants have vigorous erect growth and are less thorny than other thorny cultivars like ‘Prime-Ark® 45’ (Clark, 2021). It is a midseason variety that ripens a few days later than ‘Prime-Ark® 45’ (Clark, 2021). While data on ‘Prime-Ark® Horizon’ is limited, yields are comparable to ‘Prime-Ark® 45’, and fruit quality is good. Fruit is large and oblong in shape averaging 7.8 g for floricane fruit and 7.2 g for primocane fruit. Floricane fruit can exceed 10 g (Karp & Gasic, 2022). Primocane fruit is larger compared to other primocane-fruiting cultivars, but crop could be negatively impacted by high summer temperatures (Clark, 2021). Fruit has average of 9.6% SSC and 0.99% TA with consistent flavor (Karp & Gasic, 2022).

‘Prime-Ark® Traveler’ is an erect, thornless, primocane-fruiting cultivar released from the University of Arkansas. Floricane fruit ripens earlier than ‘Natchez’ in early June and primocane crop first ripe date ranged from late July to early August in Arkansas (Clark and Salgado, 2016). ‘Prime-Ark® Traveler’ has excellent shipping potential (Clark and Salgado, 2016). Berry size ranges from 6-8 g with floricanes having heavier fruit. Soluble solids content is comparable to ‘Prime-Ark® 45’and range from ~ 9-12%. Titratable acidity was lower than comparison varieties ranging from 0.8% to 0.9% for floricanes and primocanes ranged from 0.6% to 1.0% (Clark and Salgado, 2016). An evaluation of the aromatic compounds noted that ‘Prime-Ark® Traveler’ had more green and fresh notes compared to other cultivars (Xu et al., 2025)

‘Big Daddy’ (previously A-2454T) is a thornless, erect blackberry cultivar released by the University of Arkansas breeding program (Karp and Gasic, 2022). It produces consistently sweet fruit with an average soluble solids content of 11.1% and a low titratable acidity of approximately 0.6%. The cultivar exhibits low red drupelet reversion and has midsized berries averaging 5.8 g, making it appealing to consumers (Karp and Gasic, 2022). Released in 2021, ‘Big Daddy’ has limited published information regarding its performance in Alabama; however, preliminary observations suggest strong potential for home gardens and local markets, with encouraging fruit size and yields noted under Alabama growing conditions (Spiers and Neal, 2024).

‘Caddo’ is a thornless cultivar from the University of Arkansas breeding program, bred especially for flavor (Clark, Worthington, and Ernst, 2019), with high likeability to consumers (Threlfall et al., 2020). It shares parentage with ‘Osage’ and is a seedling of ‘Prime-Ark® 45’ which both have good flavor (Clark et al., 2019). The size and shape of ‘Caddo’ were preferred by consumers in a consumer preference evaluation (Threlfall et al., 2021). Post-harvest quality is considered excellent, making it a good choice for a shipping cultivar (Clark et al., 2019). Soluble solids content averages 10.5% and titratable acidity 1.01%. Average fruit size is 8.0 g, about 2 g larger than ‘Osage’. Caddo has competitive yields comparable to ‘Osage’ and ‘Ouachita’ and averaged 21,535 $kg{\cdot}ha^{-1}$ over 5 years in Arkansas. First harvest is typically June 8th and the harvest period is similar to that of ‘Osage’ in Arkansas (Clark et al., 2019).

‘Columbia Star’ is a thornless cultivar released in 2014 from USDA-ARS breeding program in Corvallis, Oregon. It is an early midseason trailing type cultivar (Finn et al., 2014) and has become a major blackberry cultivar in Oregon and the Pacific Northwest. There is limited information on cultivation of this cultivar in the southern United States due to its acclimation to cooler climates (in comparison to central Alabama). ‘Columbia Star’ appears to be well adapted to areas where trailing blackberry types are grown successfully (Finn et al., 2014). ‘Columbia Star’ had higher yields than ‘Black Diamond’ and ‘Marion’, and higher fruit firmness. In Oregon berries had a mean size of 7.6 g and SSC of 12.74% (Finn et al., 2014).

‘Eclipse’ is a semierect, thornless blackberry cultivar released from the USDA-ARS breeding program in Corvallis, Oregon, and is adapted to the Pacific Northwest. ‘Eclipse’ has good shipping qualities, including favorable fruit size and skin toughness, and exhibits good flavor compared to ‘Triple Crown’ and ‘Chester Thornless’ (Finn et al., 2020). In trials conducted in Aurora, Oregon ‘Eclipse’ was about 3 weeks later than ‘Columbia Star’, with a harvest window from July 15 through August 7. Yield was moderate and lower than comparison cultivars, and plants were slow to establish. It had high quality fruit fit for shipping in clamshells. It had an average berry size of 6.4 g and average SSC of 13.5% (Finn et al., 2020).

‘Galaxy’, another USDA-ARS release from the University of Oregon in 2020, performed similarly to ‘Eclipse’ but produced softer fruit, which may limit its suitability for shipping markets (Finn et al., 2020). ‘Galaxy’ is a semierect, thornless variety. In Aurora, Oregon, ‘Galaxy’ had an average weight of 8.1 g from 2007-2009. Additionally, over three years ‘Galaxy’ had an average yield of 7.7 kg/plant (Finn et al., 2020). From 2011-2017, ‘Galaxy’ had an average of 12.26%, lower than ‘Eclipse’, but higher than ‘Black Diamond’ (Finn et al., 2020). ‘Galaxy’ is an early season cultivar for semierect blackberries, ripening about 3 days earlier than ‘Eclipse’. Additionally, fruit appeared to be tolerable to heat stress with minimal damage (Finn et al., 2020).

‘Kiowa’ is a University of Arkansas cultivar released in 1996. It is a thorny erect, floricane-fruiting cultivar (Moore and Clark, 1996). It is a commonly used cultivar in Alabama that has large yields and large fruit, but low soluble solid content. In Alabama, yields for Kiowa were higher than comparison cultivars from 2016-2021 (Spiers and Vinson, 2024). In Virginia, ‘Kiowa’ had higher yields than ‘Ouachita’ and ‘Natchez’ (Manchester and Samtani, 2022). ‘Kiowa’ is recommended for planting in central Alabama due to its high productivity of large berries. ‘Kiowa’ has large fruit size, typically between 9-14 g per berry, and is not recommended for shipping (Vinson et al., 2023). ‘Kiowa’ has lesser post-harvest quality than ‘Navaho’ (Clark and Moore 1996). SSC are typically ~ 10%. ‘Kiowa’ has a long harvest season, and the average ripe date is mid-

June in Arkansas (Clark and Moore, 1996, 1995). ‘Kiowa’ has a low chilling requirement of 200 hours (Yazzetti and Clark, 2001).

‘Natchez’ is another University of Arkansas thornless cultivar with favorable size and shape (Threlfall et al., 2020). Natchez was released in 2007 and is recommended for Alabama (Vinson et.al, 2023). When evaluated in North Florida, ‘Natchez’ had the highest yield amongst several other cultivars (Agehara et al., 2020). ‘Natchez’ is an early ripening cultivar about 7 days earlier than ‘Ouachita’ (Clark and Moore, 2008). In Arkansas ‘Natchez’ was productive with yields ranging from 8,400 to over 17,000 kg/ha (Clark and Moore, 2008). Similarly, ‘Natchez’ was the highest yielding cultivar when compared to other thornless varieties when evaluated in South Carolina (Lawrence et al., 2020). Fruit size ranged from 4.4 to 8.7 g and was rated higher for size by consumers than other comparison cultivars (Threlfall et al., 2021). Average SSC was 8.7% in a 4-year evaluation in Arkansas (Clark and Moore, 2008). ‘Natchez’ had a longer shelf life than comparison cultivars and is expected to perform well for commercial shipping (Clark and Moore, 2008).

‘Navaho’ is one of the first erect thornless blackberry cultivars released by the University of Arkansas in 1989 (Moore and Clark, 1989). ‘Navaho’ was found to have low yields in North Florida (Anderson, 2015), however in Clemson, ‘Navaho’ had yields over 7 kg/plant in the first year of production (Lawrence, 2020). ‘Navaho’ has a firm fruit (Perkins-Veazie et al.,1998) with excellent postharvest qualities that have led to further advances in cultivars for shipping (Clark, 2016). In Arkansas, ‘Navaho’ is a late-ripening cultivar and ripened on average 15 days after ‘Cheyene’ and 7 days after ‘Shawnee’ (Moore and Clark, 1989). ‘Navaho’ is reported to have an average fruit size of 5 g and soluble solids content of 11% (Moore, 1989). ‘Navaho’ has an estimated chilling requirement of 800 hours (Drake and Clark, 2000)

‘Osage’ is a 2015 patented plant from the University of Arkansas’s breeding program with excellent flavor, excellent post-harvest potential, and little to no white drupelet occurrence (Clark 2015; Clark 2013). The plant also shares parentage with ‘Caddo’ (Clark et al., 2019). ‘Osage’ produces medium sized berries comparable to ‘Ouachita’ (Clark, 2013). Typical berry size is ~5 g. Soluble solids content ranges from 9-11.2% (Trandel-Hayse et al., 2025; Clark, 2013). In Arkansas, ‘Osage’ had a SSC:TA ratio of 15.39, which was comparable to ‘Ponca’ and ‘Prime-Ark® Traveler’. In Arkansas, yield of ‘Osage’ was comparable to ‘Natchez’ and ‘Prime-Ark ® 45’ and greater than ‘Ouachita’ (Clark, 2013). In South Carolina ‘Osage’ had lower yields than ‘Natchez’ and higher yields than ‘Ouachita’ (Lawrence, 2020). Harvest dates lasted from June 10 to July 24, slightly later than ‘Natchez’ and earlier than ‘Ouachita’ in Arkansas (Clark, 2013). In South Carolina harvest lasted late May to July over 3 years (Lawrence, 2020). In Alabama, ‘Osage’ had high yields of small (~4.7 g) sized berries (Spiers and Vinson, 2024)

‘Ouachita’ was released from University of Arkansas breeding program in 2005 (Clark and Moore, 2005). ‘Ouachita’ is a thornless erect cultivar that has competitive yields and strong plant hardiness. ‘Navaho’ is one of its parents (Clark and Moore, 2005). Since its release, ‘Ouachita’ has become a top seller and received The Outstanding Fruit Cultivar Award by ASHS in 2020 for its production and excellent shipping quality (Miller, 2020). ‘Ouachita’ was found to be highly productive in Arkansas and Florida (Anderson, 2015). Fruit of ‘Ouachita’ is reported to have a typical size of

5.5 g and soluble solids content of 9-10% (Trandel-Hayse et al., 2025). In Alabama 'Ouachita' had higher yields than 'Natchez', but lower than 'Kiowa' (Spiers and Vinson, 2024). However in South Carolina, 'Ouachita had high yields that were lower than 'Natchez' (Lawrence, 2020).

'Ponca' is an especially promising thornless cultivar for excellent flavor patented in 2021 (Clark, 2021). When compared to other highly ranked cultivars for flavor, it was ranked highest for sweetness (Clark et al., 2019). 'Ponca' blackberries had SSC of up to 15% and low acid (Threlfall et al., 2021) and was determined to have the best compositional traits (Threlfall et al., 2021; Clark et al., 2019). Not only is 'Ponca' a top competitor for flavor, but a prolific and easily established cultivar (Clark, 2021). Berries of 'Ponca' are medium-sized, typically about 6.2 g. Fruit reaches ripeness around June 3rd with a fruiting period of 55 days yielding an average of 5.8 kg/plant in replicated trials in Arkansas (Clark, 2021).

'Sweetie Pie' is a cultivar released from the USDA-ARS in Poplarville, MS (Stringer et al., 2017), which has a comparable climate to Alabama (Fernandez et al., 2023). The cultivar was released in 2017 and recommended for the Gulf Coast region. Due to softer berries, 'Sweetie Pie' may only be suitable for U-Pick operations and home gardeners (Stringer et al., 2017). 'Sweetie Pie' has excellent flavor and high SSC. In Alabama 'Sweetie Pie' had high SSC but had higher numbers of fruits with WDD than comparison cultivars (Spiers and Vinson, 2024). In Mississippi, 'Sweetie Pie' is especially prone to WDD compared to 'Kiowa' (Stafne et al., 2017)

'Twilight' was released by USDA-ARS in Corvallis, Oregon, and is a semi-erect thornless variety. Fresh fruit has good flavor and appearance and can be shipped well due to its size and texture (Finn, 2020). When trialed in Oregon, ‘Twilight’ yield was moderate (9.98 kg/plant over 3-year average) and comparable to other cultivars, but lower yielding than ‘Triple Crown’ and ‘Chester Thornless’. Fruit size was 8.7 g averaged from 2015-1017. Soluble solids content was high, averaging 13.08% (Finn et al., 2020)

‘Von’ is a thornless floricane fruiting cultivar released by North Carolina State University, named after Mr. Von Harvey Underwood. It has shown promise for North Carolina, having comparable yields to ‘Ouachita’ in one study (Fernandez, 2013). It can require up to 800 chilling hours, making it one of the higher chilling requirements in our study (Fernandez, 2013). In South Carolina, ‘Von’ had high yields comparable to ‘Osage’ and ‘Navaho’ and an average berry weight ranged from ~5 to 6 g (Lawrence, 2020). There is a need for more data on this cultivar in warmer climates and Alabama (Fernandez et al., 2023).

1.5 Objectives

The objectives of this study are to 1) determine the impact of cultivar selection on yields and fruit quality of eighteen blackberry cultivars (Table 1.1) and 2) determine the impact of 30% shade cloth in comparison to full sun on time of harvest, yield, and quality of eighteen blackberry cultivars.

Table 1.1 Blackberry cultivar selections used in this study under full sun and 30% shade cloth at Chilton County Research and Extension Center in Chilton County, Alabama

Cultivar	**Thorns?**	**Growth habit**	**Chilling Units**	**Breeder/Origin**	**Release year**	**Fruiting canes**
Big Daddy	No	Erect	-	University of Arkansas	2021	Floricane
Caddo	No	Erect	400	University of Arkansas	2019	Floricane
Columbia Star	No	Trailing	-	USDA, Oregon	2014	Floricane
Eclipse	No	Semi-erect	-	USDA, Oregon	2020	Floricane
Galaxy	No	Semi-erect	-	USDA, Oregon	2020	Floricane
Kiowa	Yes	Erect	300	University of Arkansas	1996	Floricane
Natchez	No	Erect	400	University of Arkansas	2007	Floricane
Navaho	No	Erect	800	University of Arkansas	1989	floricane
Osage	No	Erect	350-400	University of Arkansas	2012	Floricane
Ouachita	No	Erect	400-500	University of Arkansas	1993	floricane
Ponca	No	Erect	400	University of Arkansas	2019	Floricane
Prime-Ark® 45	Yes	Erect	300	University of Arkansas	2009	Primocane, floricane
Prime-Ark® Freedom	No	Erect	100	University of Arkansas	2014	Primocane, floricane
Prime-Ark® Horizon	Yes	Erect	300	University of Arkansas	2021	Primocane, floricane
Prime-Ark® Traveler	No	Erect	300-400	University of Arkansas	2016	Floricane, primocane
Sweetie Pie	No	Semi-erect	400	USDA, Mississippi	2016	Floricane
Twilight	No	Semi-erect	-	USDA, Oregon	2020	Floricane
Von	No	Erect	800	NC state	1998	floricane

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Chapter 2:

Evaluation of Blackberry Cultivar Performance Under 30% Shade and Full Sun in Central Alabama

2.1 Introduction

Historically, caneberries (*Rubus)* plants, most notably blackberries and raspberries, have been used by people for both food and medicine (Lee, 2017; Hummer 2010). Caneberries are used for value added products like jam, syrup, or baked goods. Due to increasing consumer interest, caneberry production is growing within the U.S. Caneberry production in the United States is primarily concentrated in the Pacific Northwest, however blackberries especially have strong potential in the Southeast. Georgia, Arkansas, and North Carolina lead the southeast bearing blackberry acreage. Blackberry is the state fruit of Alabama and has good potential for commercial production in Alabama because it is adapted to the warm temperate climate. Acreage for blackberry production has grown with a 136% increase in number of operations growing blackberries from 2012-2017 (USDA NASS 2025). In the southeast, new cultivars coming out of the University of Arkansas breeding program have provided new cultivars for growers in the region.

In addition to improved cultivars, cultural practices such as shading that mitigate heat stress may further enhance caneberry production in warm climates. High temperatures and intense solar radiation common in the southeastern United States can negatively affect fruit quality, contributing to sun damage and physiological disorders such as white drupelet disorder (Maughan et al., 2017). Previous studies have demonstrated that shade structures can reduce fruit exposure to excessive heat and radiation, lowering white drupelet incidence and, in some cases, improving fruit quality and yield, although responses vary by cultivar and environment (Spiers et al., 2014; Shahid, 2021; Stafne, 2017). These findings suggest that integrating shade management with cultivar selection may help address key production challenges in the Southeast.

Together, increasing consumer demand, regional suitability, and recent advances in breeding highlight the strong potential for expanding blackberry production in Alabama and the southeastern United States. However, high temperatures and intense solar radiation remain key limitations to fruit quality and marketability in warm climates, particularly through the development of heat-related disorders such as white drupelet disorder. While improved cultivars from regional breeding programs have expanded production opportunities, cultural practices such as shade management may further mitigate environmental stress and improve fruit quality. Because cultivar responses to shade vary, evaluating the interaction between cultivar selection and shade management is critical for developing effective production strategies for southeastern growers. Therefore, this research focuses on assessing the effects of shade and cultivar choice on yield and fruit quality to support sustainable blackberry production in Alabama. The specific objectives were to 1) evaluate eighteen blackberry cultivars to observe performance in Central Alabama and provide cultivar recommendations for Alabama growers and 2) determine effects of shade and whether utilizing 30% shade is a viable way to mitigate heat stress in Central Alabama conditions.

2.2 Materials and Methods

Experimental design and vineyard establishment

A blackberry cultivar trial was initiated at the Chilton Research and Extension Center (CREC) in Clanton, AL, USA (Central Alabama, 32.9200124° N, -86.67042879999997° W). Eighteen blackberry cultivars, received as tissue culture liners, were planted on 5 Apr. 2023 and yield and fruit quality performance were evaluated in 2024 and 2025. The following cultivars were evaluated: ‘Big Daddy’, ‘Caddo’, ‘Columbia Star’, ‘Eclipse’, ‘Galaxy’, Kiowa’, ‘Natchez’, ‘Navaho’, ‘Osage’, ‘Ouachita’, ‘Ponca’, ‘Prime-Ark® 45’, ‘Prime-Ark® Freedom’, ‘Prime-Ark® Horizon’, ‘Prime-Ark® Traveler’, ‘Sweetie Pie’, ‘Twilight’, and ‘Von’ (Table 1.1). ‘Von’ plants were received as “weak” plants and underperformed for duration of study, and were removed from further analysis.

Cultivar performance was evaluated under two different environmental conditions. One plot was established in open field conditions (full sun) and one plot was established under a 30% aluminet shade cover (30% aluminet, Growers Solutions, Cookville, TN). Shade fabric was secured to a modified hoop-house structure 4.27 m high × 9.14 m wide × 36.58 m long. To fit under shade cover row spacing of plants under shade were ~2.4 m and plants in full sun row spacing was ~3.0 m. Both plots had in row spacing of 3’. Each plot was established as a randomized complete block design with eight single-plant replications. Plants were established on raised beds (~0.8 m wide) covered with black weed fabric. Plants were drip irrigated at 3.4 L/plant per hour for an hour a day. Plants were fertilized based on 27.2 kg (60 lbs.) N/acre/year recommendations according to the Southeast Regional Caneberry Production Guide

(Fernandez et al., 2023). Plants were trained to a T-trellis with three parallel wires on each side of planting: lower wires ≈ 0.2 m from soil surface spaced 0.5 m apart, middle wires ≈ 0.6 m from soil surface spaced 0.7 m apart, and upper wires 1 m from soil surface spaced 1 m apart. Plants were pruned to have three floricanes on each side of the trellis and secured to wires to open the canopy. Each summer after senescence of floricanes, primocanes were tip-pruned to the top trellis and secured to wire.

Environmental Data

Data loggers (Spectrum Technologies, Inc., Aurora, IL) were used to collect environmental data. Three loggers were installed, with one positioned in the center of the open-field plot and two placed at the center of each shade-covered high tunnel. Loggers were mounted on PVC poles approximately 1 m above the soil surface to record ambient temperature, soil temperature, photosynthetically active radiation (PAR), and relative humidity (RH) on an hourly basis. Soil samples collected in 2023 from the full sun and 30% shade plots had pH values of 6.7 and 7.2, respectively. The full sun plot and the shade covered plot contained a mixture of loam and light clay. Soil samples collected in summer 2025 from the full-sun and 30% shade plots had pH values of 6.5 and 6.9, respectively.

Horticultural Performance

Bloom (50% and 90% bloom) dates were recorded yearly by visually assessing when 50% and 90% of buds being open; bloom dates were taken from April to May. Fruit was harvested 1-2 times a week depending on load and ripeness to determine the average yield over time and total yield of each cultivar. Yield was harvested into baskets and weighed in grams with a battery powered scale in the field. Blackberries were harvested beginning at 7:00 am, to minimize effects of heat on harvest, twice a week in 2024 and once a week in 2025.

Fruit Quality

A subsample (25 berries) from each plant was taken from each basket to evaluate individual berry weight and fruit quality. Only subsamples that had at least 25 berries were used for analysis. Individual weight was also taken in grams by dividing the weight of subsample by 25. White drupelet disorder (WDD) incidence was recorded as number of berries per subsample with WDD.

Fruit composition (SSC, TA, and pH) measurements were taken from the first four reps of each treatment and for three times per cultivar (one early-, mid-, and late-season sample per cultivar). Composition samples were collected in 50mL centrifuge tubes, placed in cooler with ice for transport, and stored in -20 °F freezer prior to data collection. Once all samples were collected, they were ground with Geno grinder by adding steel balls to homogenize the contents of tubes (2010 Geno/Grinder, SPEX SamplePrep LLC, Metuchen, NJ). Once homogenized, 0.5ml of juice was diluted with 24.5 mL of deionized water to make samples for titratable acidity. SSC was measured from homogenized fruit juice. SSC and TA were both measured using a Brix-Acidity meter (PAL-BX/ACID Meter, ATAGO, U.S.A., Inc., Bellevue, WA). The pH of homogenized mixture was taken with a pH meter (Orion Star A214 pH/ISE meter, Thermo Fisher Scientific, Auburn, AL).

Data analysis

Analysis of variance was conducted in SAS version 9.4 (SAS Institute, Carey, NC) using PROC GLIMMIX. Dependent variables included total yield per plant, individual berry weight, WDD incidence, SSC, TA, pH and SSC:TA ratio. Independent variables were cultivar and shade treatment. Cultivar, shade treatment, and cultivar x shade interaction were treated as fixed effects and replication was treated as a random effect in a randomized complete block design. Mixed model ANOVA was conducted and least square means were estimated and separated using Tukey-Kramer adjusted pairwise comparisons at $\alpha = 0.05$.

2.3 Results

Environmental Data

Air temperatures were similar under full sun and shade treatments (Fig. 2.1). Over both years maximum and mean temperatures averaged 0.1 °C higher under full sun, and minimum temperatures averaged 0.2 °C higher under full sun, compared to shade. While air temperatures were minimally affected by shade treatment, soil temperature was consistently higher under full sun (Fig. 2.2). On average, soil temperatures were 1.6 °C higher under full sun for 2024. Max PAR levels were reduced ~23% to 38% under the 30% shade cloth in 2024 (Fig. 2.3). Peak PAR values occurred in July 2024 at ~2,135 μmol/m²/s in July 2024, while shade peaked at ~1,584 μmol/m²/s in the same month. Data was not collected for soil temperature and PAR in full sun in 2025 due to logger malfunction.

Bloom and Harvest Timing

Bloom dates were similar when comparing shade to full sun in 2024 and 2025. Bloom development from 50% to 90% open bloom ranged from 3-10 days (Table 2.1). ‘Prime-Ark® Freedom’ was the earliest blooming cultivar in both years by approximately 10 d (90% full bloom in mid-Apr). ‘Columbia Star’, ‘Natchez’, and ‘Prime-Ark® Traveler’ reached 90% full bloom earlier than remaining cultivars in both years (late Apr.). ‘Eclipse’, ‘Galaxy’, and ‘Navaho’ were the latest blooming cultivars.

Dates for first harvest were similar between shade and full sun, and between the two years. Though ‘Columbia Star’ reached 90% full bloom 10 d after ‘Prime-Ark® Freedom’, these cultivars were harvested first each year with the same first harvest dates (Table 2.2). The later blooming cultivars ‘Eclipse’, ‘Galaxy’ and ‘Navaho’ were also the later cultivars to begin harvest (mid-June), with most other cultivars beginning harvest in late May – early June. There was more variability for the dates for last harvest (and harvest duration) between the cultivars, years, and shade treatments. The “earliest” cultivars, ‘Prime-Ark® Freedom’ and ‘Columbia Star’, typically had the shortest harvest duration. However, ‘Prime-Ark® Freedom’ had a long harvest period in 2025 due to primocane harvest. Overall, the harvest duration was longer in 2025 compared to 2024 and often extended under shade compared to full sun. This effect is more evident in the primocane-fruiting cultivars, with the exception of ‘Prime-Ark® Freedom’ in 2024.

Yield

In 2024, yield was greater under 30% shade (2.98 kg/plant) compared to full sun (1.7 kg/plant) (Table 2.3). There were significant main effects of cultivar and shade, but no significant interaction of cultivar*shade. In 2025, the interaction of cultivar*shade and cultivar influenced yield. Shade did not influence yield in 2025 as the mean yield/plant was 4.72 kg in full sun and 4.6 kg under 30% shade (data not included). The cumulative yield/plant over both years were 7.53 kg under shade and 6.16 kg in full sun. While overall means were greater under shade, all cultivars had similar cumulative yields in full sun compared to shade except ‘Big Daddy’. ‘Osage’, ‘Big Daddy’, and ‘Prime-Ark® 45’ had greater yields under 30% shade compared to full sun in 2024, with similar yields regarding shade in 2025. ‘Kiowa’ produced among the greatest yields in both years at 3.1 kg in 2024 and 9.1 kg in 2025, respectively. ‘Ponca’ (9.9 kg), ‘Prime-Ark® Horizon’ (8.5 kg), ‘Big Daddy’ under shade (10.1 kg), ‘Navaho’ under shade (10.5 kg), ‘Osage’ under shade (9.7 kg), and ‘Prime-Ark® 45’ under shade (9.83 kg) had similar cumulative 2-year yields to ‘Kiowa’ (12.21 kg). ‘Columbia Star’ (0.8 kg), ‘Eclipse’ (2.3 kg), ‘Galaxy’ (3.8 kg), and ‘Prime-Ark® Freedom’ (3.25 kg) in normal field conditions were among the least productive cumulatively for both years.

White Drupelet Disorder

In 2024 and 2025, cultivar*shade, shade, and cultivar influenced white drupelet disorder (WDD) (Table 2.4). The number of berries with white drupelets (out of 25-berry samples for each harvest date) was 0.65 in 30% shade compared to 0.85 in full sun in 2024, and 0.47 under 30% shade compared to 0.98 in full sun in 2025 (data not included). Cultivars that tended to have the greatest incidence of WDD without shade in 2024 included 'Eclipse' (2.12), 'Twilight' (2.31), 'Prime-Ark® Freedom' (2.65), ‘Kiowa’ (1.78) and ‘Big Daddy’(1.52), and to a lesser extent: ‘Sweetie Pie’(1.14). However, 'Prime-Ark® Freedom' was the only cultivar to have less WDD under 30% shade (0.31) when compared to full sun in 2024. ‘Columbia Star’, ‘Ponca’, ‘Osage’, ‘Prime-Ark® Traveler’, ‘Prime-Ark® Horizon’, and ‘Prime-Ark® 45’ had among the lowest incidence of

WDD, though WDD was not a prevalent issue for many cultivars. Though WDD was less overall under 30% shade in 2025, ‘Kiowa’ was the only cultivar with significantly reduced WDD under 30% shade (1.21) compared to full sun (2.83). In 2025, ‘Big Daddy’ in full sun (4.27) had the greatest incidence of WDD, followed by ‘Kiowa’ (2.83) in full sun and ‘Big Daddy’ (2.88) under 30% shade. All other cultivars had similarly low incidences of WDD in full sun or shade in 2025.

Berry Weight

Berry weight was influenced by the cultivar, shade, and the interaction of cultivar*shade (Table 2.5). In both years, mean berry weight was greater under shade treatment. In 2024, berry weight was 8.04 g under 30% shade and 6.7 g in full sun. In 2025, berry weight was 9.07 g under shade and 7.56 g in full sun. Mean berry weight in the shade was 8.7g compared to 7.2g in full sun when averaged over both years. Cultivar impacted berry size as mean berry weight ranged from 4.0-15.3g over the two years. ‘Kiowa’ and ‘Prime-Ark® Freedom’ tended to have the greatest berry weight. ‘Kiowa’ had a mean berry weight of 11.07 g in full sun and 13.98 g in 30% shade. ‘Prime-Ark® Freedom’ also showed a highly significant impact on berry size under shade treatment with a mean berry weight of 10.34 in full sun compared to 13.19 g under 30% shade. Among the smaller sized berries in a typical field environment were ‘Columbia Star’, ‘Eclipse’, ‘Galaxy’, ‘Navaho’, ‘Osage’, ‘Ponca’, and, and ‘Prime-Ark® Traveler’.

Soluble Solids Content (SSC)

Cultivar and shade influenced soluble solids content (SSC) in both years of this study (Tables 2.6, 2.7). In both 2024 and 2025, shade had a negative effect on SSC, resulting in lower average values across all cultivars compared with full sun conditions. In 2024, mean SSC was 12.24% under full sun and 10.39% under shade. Overall SSC values were lower in 2025, averaging 9.79% in full sun and 9.1% under shade. In 2024, all cultivars met or exceeded the acceptable soluble solids range for commercial production (Trandel-Hayse et al., 2025). In 2024, 'Eclipse' had the highest numerical value for SSC (13.39%), followed by 'Twilight' (13.28%), but SSC values were statistically similar to all other cultivars except for 'Natchez' (Table 2.6). 'Eclipse' was not evaluated in 2025 due to insufficient data; however, 'Twilight' had the highest SSC that year, with an average of 10.94% (Table 2.7). 'Twilight' in full sun had similar SSC to all other cultivars except for 'Big Daddy', 'Kiowa', 'Natchez', and 'Prime-Ark® Horizon' in 2025.

TA

Cultivar was the primary variable that influenced titratable acidity (TA) in both years, however shade likely had some influence in 2024 (P = 0.0595) (Tables 2.6, 2.7). There were no interactions of cultivar*shade on TA in either year. In 2024, 'Navaho' in full sun had the greatest numerical value for TA (1.41%) which was statistically similar to all cultivars in shade and all cultivars in full sun except for 'Big Daddy' (0.7 %), 'Caddo' (0.75 %), 'Eclipse' (0.75 %), 'Osage' (0.74 %), 'Ponca' (0.74 %), 'Prime-Ark® 45' (0.64 %), 'Prime-Ark® Horizon' (0.76 %), and 'Prime-Ark® Traveler' (0.58 %), respectively. In 2025, 'Kiowa' under shade had the greatest numerical value for TA (1.23%), which was statistically similar to all other cultivars except for 'Osage' (full sun 0.65 % and shade 0.67 %), 'Prime-Ark® 45' (0.65 %), under shade, and 'Prime-Ark® Traveler' (0.52 %), in full sun.

Soluble Solids Content to Titratable Acidity Ratio

There were significant effects of the interaction of cultivar*shade, cultivar, and shade on SSC:TA in 2024 (Table 2.6). In 2024, SSC:TA ranged from 11.06 – 22.39 for all cultivars in full sun, and 8.11 – 15.43 for cultivars under shade. 'Prime-Ark® Traveler' in full sun had the highest SSC:TA value (22.4) in 2024, but was statistically similar to all other cultivars in full sun except for 'Galaxy' (14.4), 'Kiowa' (14.1), 'Natchez' (11.1), and 'Sweetie Pie' (13.9). 'Ponca' had similarly high SSC:TA values when grown in full sun or shade in 2024. In 2025, cultivar and shade were the only significant main effects on SSC:TA 'Prime-Ark® Traveler' grown in full sun had the greatest SSC:TA (19.2) again in 2025, and 'Ponca' had consistently high SSC:TA in both treatments over both years. When grown in full sun, 'Big Daddy' (10.6), 'Kiowa' (8.4), 'Natchez' (10.2), 'Prime-Ark® Horizon' (9.4) and 'Sweetie Pie' (10.3) had lower SSC:TA compared to 'Prime-Ark® Traveler' in 2025. 'Kiowa' had the lowest numerical values for SSC:TA compared to other cultivars under similar shade or full sun treatment in 2025.

2.5 Discussion and conclusion

Shade cloth is used to reduce temperatures, solar irradiation and to modify the light quality and quantity to reduce symptoms of heat stress or sunburn in a variety of crops (Makus, 2010; Maughan et al., 2017; Shahid, 2021; Spiers and Vinson, 2023). In our study, air temperatures were similar under 30% shade compared to full sun. The 30% aluminet shade treatment was placed on a converted hoop house structure that was ~4.3 m at maximum height, which could have negated some benefits of reducing air temperatures. Previous research indicates that shade can reduce ambient temperatures (Guan, 2016; Laur et al., 2021; Mditshwa et al., 2019). Maximum air temperature in a high tunnel covered with 30% black shade cloth was about ~5.6 °C lower than in an unshaded tunnel, while night temperatures were similar in a study conducted in Indiana (Guan, 2016). Likewise, 30% shade cloth in Georgia high tunnels resulted in lower average daytime air temperature and lower soil temperature compared with the non-shaded treatment (Laur et al., 2021). Mditshwa et al. (2019) also noted that the effects of shade netting on orchard microclimate depend strongly on shade level, net color, and structural design. In our study, shade did reduce soil temperatures and PAR. Likely due to the minimal effects of shade treatment on air temperatures, bloom and harvest dates were similar for shade and full sun treatments, though harvest was extended for several cultivars under shade treatment in year 2.

In Mar. to Aug. 2024, 58.2 cm (22.9 in.) of rainfall was recorded at the research site, and for the same duration in 2025, 94.7 cm (37.3 in.) of rainfall occurred. Though yields were greater under shade in 2024, shade did not influence yield in 2025. Shade can also affect soil moisture (Laur et al., 2021; Mditshwa et al., 2019), and the soil did appear to be more saturated under the shade structure, as surface water was prevalent between raised beds for longer durations compared to the full-sun plot. However, due to the raised beds, plants were asymptomatic for stress/disease. Greater rainfall in 2025 resulted in increased berry weight and lower SSC, which indicated that water availability affected fruit quality due to water accumulation in the fruit (Dixon et al., 2015; Ehret et al., 2012).

In 2024, fruit quality was substantially reduced by insect damage, primarily from spotted wing drosophila (*Drosophila suzukii*) and green June beetle (*Cotinis nitida*), which resulted in a shortened harvest season and termination of data collection in early

July. Drosophila larvae were observed as well as soft fruit and visible adults. Despite these challenges, visual observations indicated improved fruit quality and yield under shade compared with full sun. In contrast, the 2025 harvest season was longer, and shade extended late season production of most primocane fruiting cultivars into August. This seasonal extension did not occur for the early-ripening cultivar 'Prime-Ark® Freedom' in 2024, as primocane fruit was largely unmarketable due to elevated insect pressure.

Shade reduced the incidence of white drupelet disorder (WDD) in both years of this study, consistent with previous research demonstrating that reduced light intensity can mitigate WDD in blackberry (Stafne et al., 2017; Stafne et al., 2021; Vinson and Spiers, 2023). Similar reductions in WDD have also been reported with canopy-modifying systems such as cross-arm trellis training (Takeda et al., 2013). Excessive radiation above the light-saturation point can increase fruit surface temperatures and contribute to heat-related fruit disorders (Maughan et al., 2017); although fruit temperature was not measured in this study, it was likely higher under full-sun conditions, which may explain the greater WDD incidence observed. Cultivar differences were also evident, as 'Big Daddy', 'Kiowa', 'Eclipse', 'Prime-Ark® Freedom', and 'Sweetie Pie' tended to exhibit higher WDD incidence, supporting previous reports that WDD susceptibility is cultivar dependent (Stafne et al., 2017; Stafne et al., 2021; Spiers and Vinson, 2019). While 'Sweetie Pie' is known to be particularly prone to WDD, severity in this study was lower than that reported in South Mississippi trials (Stafne 2017)..

In addition to reducing WDD, shade consistently increased berry size across cultivars, corroborating findings from Florida and other warm-climate studies (Shahid, 2021). However, shade also reduced SSC and increased TA relative to full sun, indicating potential trade-offs between improved external fruit quality and flavor attributes. These results support the conclusion that WDD expression and fruit quality responses to shade are governed by both environmental conditions and genotype (Stafne et al., 2017; Stafne et al., 2021).

All cultivars but 'Columbia Star' were viable for production in the second year of production based on yields alone. Alabama extension claims that healthy mature plants should yield 2,722 to 3,629 kg/acre (6000-8000 lbs/acre) (Vinson et al., 2023) while Texas A&M Extension estimates 2,268 to 4,536 kg/acre (5,000 to 10,000 lbs/acre) (Nesbitt et al., 2015). To meet this level of production, plants would need to yield approximately 1.50 kg plant^{-1} under shade at 0.91 m in-row × 2.4 m row spacing and 1.87 kg plant^{-1} in full sun at 0.91 m in-row × 3.0 m row spacing. In the first year of production (when yields are typically lower) 'Natchez', 'Prime-Ark® 45', 'Kiowa', 'Osage', 'Ponca', 'Prime-Ark® Horizon', 'Sweetie Pie', and 'Big Daddy' had sufficient yields in full sun. All cultivars under shade except for 'Columbia Star', 'Twilight', and 'Galaxy' had sufficient yields in 2024. In 2025 all cultivars under both treatments achieved sufficient yields except for 'Columbia Star'. After the first year of production, Ponca', and 'Navaho' were also among higher yielding varieties. In the first and second year 'Prime-Ark® Horizon' and 'Osage' had high yields. 'Kiowa' had the highest yields over both years. In addition, 'Kiowa' had the largest berry weight over both years. While berry weight alone doesn't determine yield some studies indicate that berry size can be a factor in yield in addition to cane number (Dixon et al., 2015). ‘Kiowa’ is a thorny cultivar but is a reliable, high yielding variety for Alabama growers. Dr. Arlie Powell has had ‘Kiowa’ plants that have lasted 25 years using the TPUPS production method (Polozola, 2025). Additionally, previous trials at the CREC in Alabama have shown ‘Kiowa’ to be the highest yielding compared to other plants in both studies, which our data supports (Spiers and Vinson 2024).

Yield trends in the present study differed from several reports across the southeastern United States. In north Florida, ‘Kiowa’ was not the top-producing cultivar, as ‘Natchez’ and ‘Ouachita’ consistently outperformed it, with ‘Kiowa’ producing smaller berries with lower soluble solids content and reduced yields (Andersen, 2015). Similarly, trials in New Mexico identified ‘Natchez’ and ‘Ouachita’ as the highest-yielding cultivars (Yao et al., 2018). In South Carolina, ‘Natchez’ was also a top performer, with higher first-year yields than those observed in the present study, and ‘Prime-Ark® Freedom’ produced greater yields than reported here (Lawrence, 2020). Comparable to the present study, ‘Prime-Ark® Freedom’ produced large berries in South Carolina, although berry size was greater in this trial, particularly under shade (Lawrence, 2020). ‘Osage’ produced larger berries in Alabama than reported in previous trials conducted in Alabama and Arkansas (Clark, 2013; Spiers and Vinson, 2024); however, both ‘Osage’ and ‘Ponca’ exhibited relatively small berries with good fruit quality and high yields, consistent with prior evaluations in Arkansas (Threlfall et al., 2021). ‘Prime-Ark® 45’ was among the higher-yielding cultivars in this study, which aligns with previously reported performance in Arkansas (Clark, 2012), and yields exceeded those observed in earlier Alabama trials (Spiers and Vinson, 2024).

In summary, the shade structure resulted in some potential benefits, especially in the first year of production. Yield was improved in the first year and in both years, shade resulted in increased berry size and less WDD. Increased berry size is preferred by consumers (Threlfall et al., 2021), but 7-8 g fruit is preferred for postharvest longevity (Clark and Finn, 2008). In contrast to potential benefits, shading resulted in lower SSC and SSC:TA, and higher TA, which would result in less sweet berries. Additionally in 2025 shade only improved yield for some cultivars, thus cultivar selection may be more important for growers to consider than investing in shade. Additionally, shade structures are prone to damage from high winds and hailstorms (Mditshwa et al., 2019). In December 2024, high winds and storms resulted in damage to the shade structure and had to be replaced completely. Risk of damage to shade structures is another reason why growers should be cautious when investing in shade cloth. Because of the variability in environmental factors, effectiveness of shade cloth varied from year to year which supports Xu et al.'s caution to growers that want to invest in shade cloth (Xu et al., 2025). There is a need for more research into the efficiency of shade cloth structures (Mditshwa et al., 2019). In the present study, storm damage to the shade structure resulted in an additional replacement cost of $2,947.83, excluding labor for a 9.14 m wide × 36.58 m long structure. This cost is equivalent to approximately $35,700 per acre of shaded production. These expenses highlight the financial risk associated with shade structures in regions prone to severe weather events. Fruit quality and heat damage like WDD can be mitigated by cultivar selection. Hence, caution is warranted when recommending shade cloth installation for commercial growers, as additional years of harvest data are needed to fully evaluate the long-term cost–benefit relationship of shade use. Future research should focus on identifying more durable and cost-effective shade structure designs that maximize fruit quality benefits while minimizing vulnerability to wind damage in production systems experiencing consistent heat stress.

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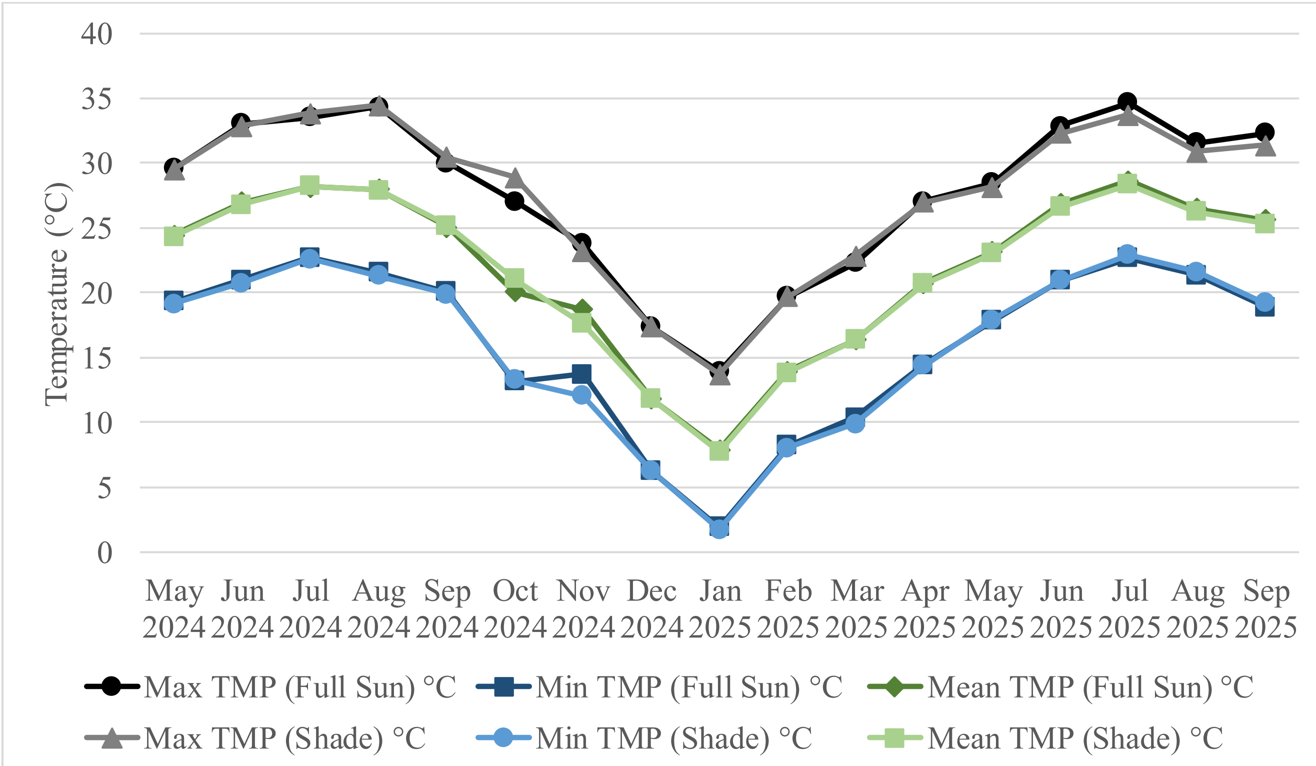

Figure 2.1. Monthly maximum, mean, and minimum air temperature from May 2024 through September 2025 under full-sun and 30% shade treatments at the Chilton County Research and Extension Center in Chilton County, Alabama. darker colors represent full-sun conditions, while lighter symbols represent shaded conditions. Values shown are monthly means of daily maximum, mean, and minimum air temperatures.

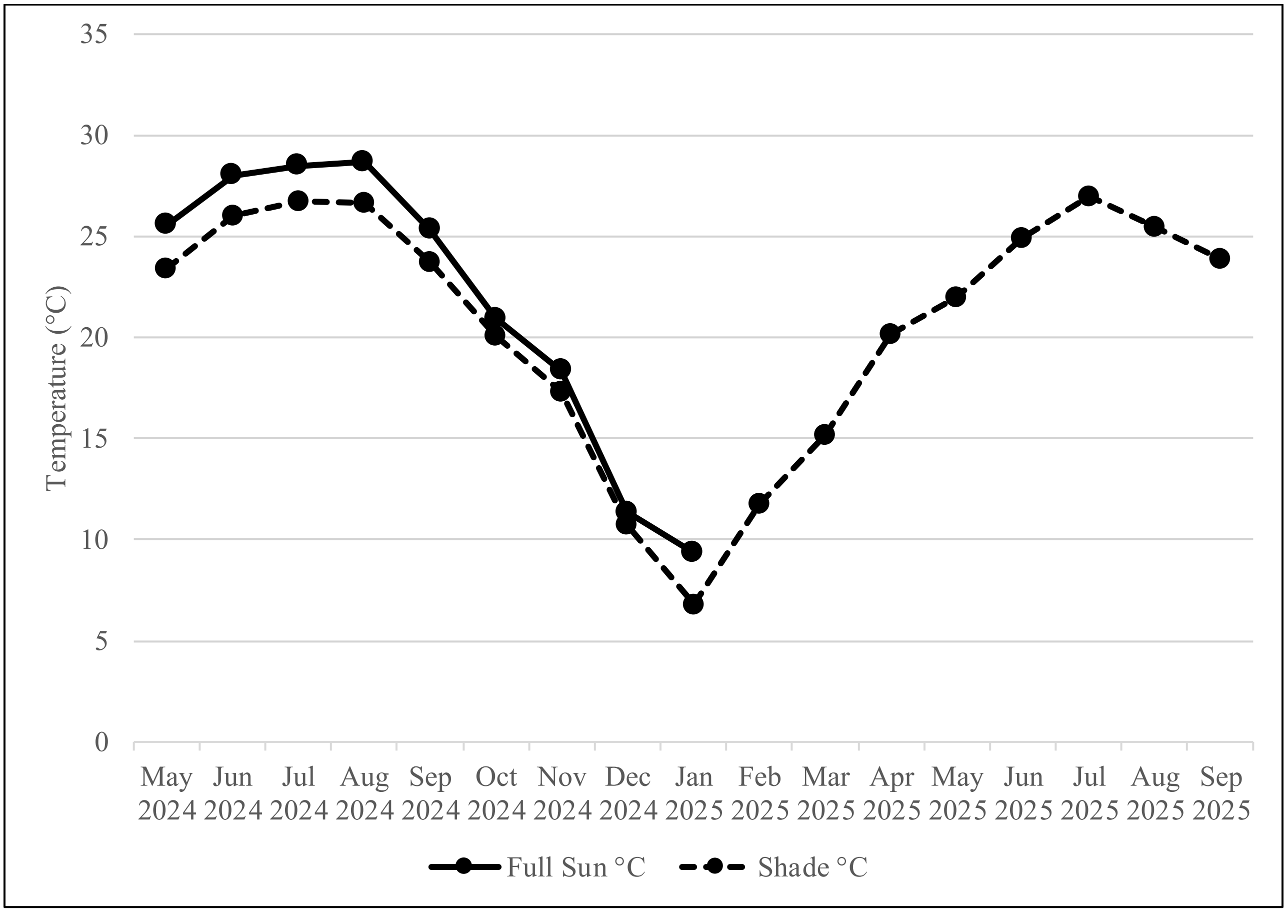

Figure 2.2. Soil temperature from May 2024 to September 2025 under full sun and 30% shade at Chilton County Research and Extension Center in Chilton County, Alabama. Values shown are monthly means of mean soil temperature. Dotted lines represent shaded conditions while the solid line represents full sun soil temperatures.

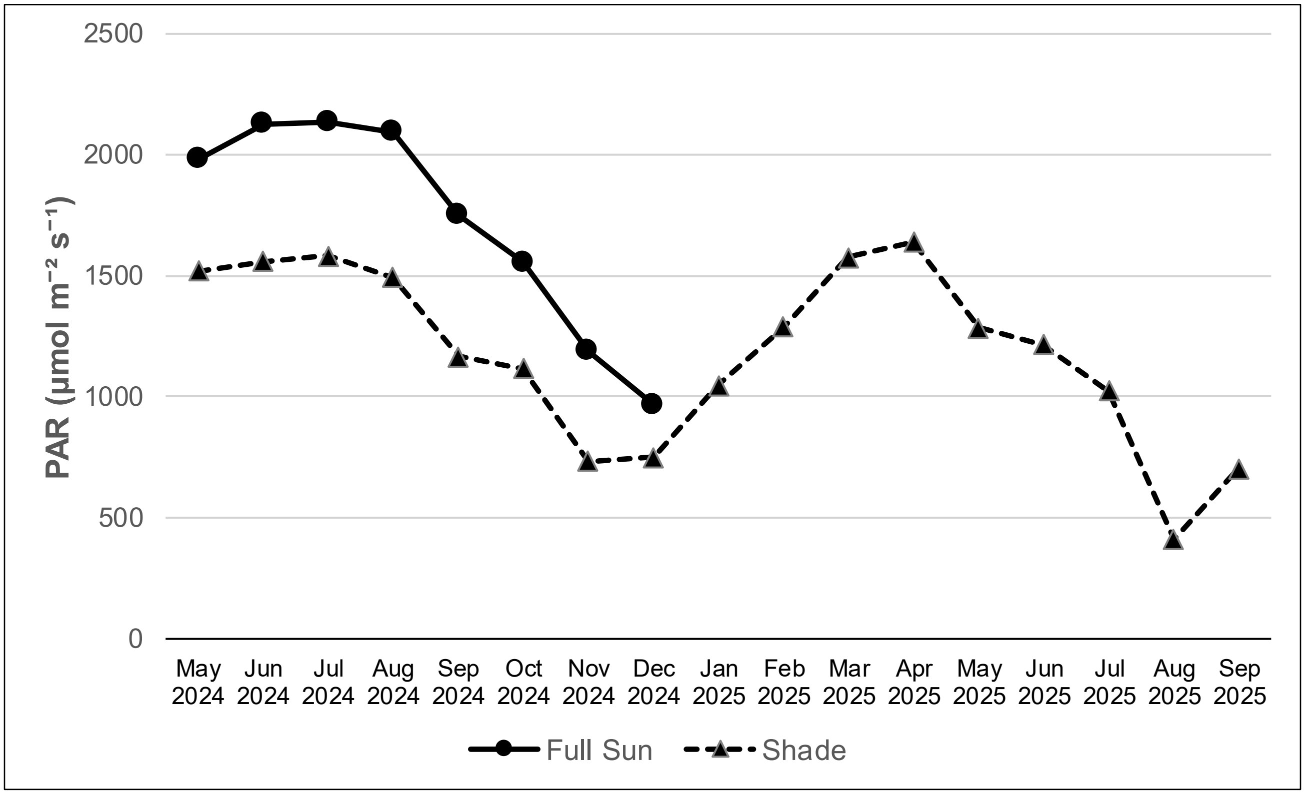

Figure 2.3 Average monthly maximum PAR values from March 2024 to September 2025 under full sun and 30% shade at Chilton County Research and Extension Center in Chilton County, Alabama. Dotted lines represent mean monthly maximum PAR values under shaded conditions while the solid line represents PAR under full sun conditions.

Table 2.1. Flowering dates of blackberry cultivars at 50% and 90% open bloom under full sun and 30% shade cloth at CREC in Chilton County, Alabama in 2024 and 2025.

	2024		2025	
Cultivar	50%	90%	50%	90%
Big Daddy	2-May	10-May	28-Apr	6-May
Caddo	30-Apr	10-May	28-Apr	2-May
Columbia Star	17-Apr	22-Apr	25-Apr	28-Apr
Eclipse	10-May	16-May	8-May	13-May
Galaxy	16-May	24-May	13-May	19-May
Kiowa	22-Apr	2-May	25-Apr	2-May
Natchez	17-Apr	22-Apr	21-Apr	25-Apr
Navaho	5-May	12-May	8-May	13-May
Osage	22-Apr	2-May	21-Apr	28-Apr
Ouachita	26-Apr	2-May	25-Apr	2-May
Ponca	22-Apr	2-May	25-Apr	2-May
Prime-Ark® 45	22-Apr	2-May	21-Apr	25-Apr
Prime-Ark® Freedom	-	12-Apr	4-Apr	15-Apr
Prime-Ark® Horizon	22-Apr	2-May	25-Apr	28-Apr
Prime-Ark® Traveler	22-Apr	26-Apr	21-Apr	25-Apr
Sweetie Pie	26-Apr	2-May	25-Apr	2-May
Twilight	2-May	10-May	2-May	6-May

Table 2.2. Harvest dates, first to last harvest days and peak harvest days of blackberry cultivars under full sun and 30% shade cloth at CREC in Chilton County, Alabama in 2024 and 2025.

	2024				2025			
	First- Last Harvest		Peak Harvest		First- Last Harvest		Peak Harvest	
Cultivar	Full Sun	30% Shade	Full Sun	30% shade	Full Sun	30% shade	Full Sun	30% shade
Big Daddy	5/28- 7/8	6/3- 7/8	6/17	6/18	6/5- 7/8	6/3- 7/29	6/12	6/10
Caddo	5/28- 7/1	5/28- 7/8	6/11	6/3	5/27- 7/29	6/3- 7/29	6/26	7/1
Columbia Star	5/15- 6/4	5/15- 6/14	5/22	5/22	5/23- 6/5	5/23- 6/10	6/5	6/3
Eclipse	6/17- 7/1	6/10- 7/8	6/17	6/18	6/18- 7/15	6/17- 7/22	7/1	7/15
Galaxy	6/25- 7/8	6/18- 7/8	7/1	7/1	6/18- 7/15	6/17- 7/29	7/8	7/1
Kiowa	5/28- 7/1	5/28- 7/8	6/17	6/3	5/27- 7/22	6/3- 7/22	6/12	6/17
Natchez	5/28- 6/25	5/28- 6/25	6/11	6/3	6/5- 7/8	6/17- 7/15	6/12	6/24
Navaho	6/4- 7/8	6/3- 7/8	7/1	7/8	6/12- 7/29	6/17- 7/29	7/15	7/1
Osage	5/22- 7/8	5/28- 7/8	6/4	6/7	5/27- 7/8	6/3- 7/22	6/12	6/10
Ouachita	5/28- 7/8	5/28- 7/8	6/11	6/18	6/5- 7/22	6/10- 7/22	6/26	6/17
Ponca	5/28- 7/8	5/22- 7/8	5/28	6/3	5/27- 7/15	6/3- 7/22	6/5	6/10
Prime-Ark® 45	5/28- 7/8	5/28- 7/8	6/4	6/3	5/27- 7/8	6/3- 8/29	6/5	6/10
Prime-Ark® Freedom	5/15- 5/22	5/15- 5/28	5/15	5/15	5/23- 7/29	5/23- 7/29	5/27	6/3
Prime-Ark® Horizon	5/28- 7/8	5/28- 7/8	6/11	6/3	6/5- 7/8	6/3- 8/29	6/12	6/17
Prime-Ark® Traveler	5/28- 6/17	5/28- 7/8	5/28	6/3	5/27- 7/8	6/3- 7/29	6/5	6/10
Sweetie Pie	5/28- 7/8	6/3- 7/8	6/4	6/18	6/5- 7/8	6/3- 7/29	6/26	7/1
Twilight	5/28- 7/8	6/3- 7/8	6/25	6/10	6/5- 7/22	6/10- 7/29	6/26	7/1

Table 2.3 Cultivar and shade effect on total yield per plant (kg) under full sun and 30% shade in 2024 and 2025 and cumulative yield per plant grown at CREC in Chilton County, Alabama

	2024[z]		2025[z]		Total[z]	
Cultivar	Full sun	30% shade	Full sun	30% shade	Full sun	30% shade
Big Daddy	2.55 c-h	4.39 ab	3.27 d-i	5.68 a-e	5.82 e-k	10.07 a-d
Caddo	1.21 f-j	1.99 d-j	4.95 b-g	5.77 a-e	6.17 d-k	7.76 c-i
Columbia Star	0.42 j	0.52 ij	0.35 i	0.63 hi	0.77 m	1.15 lm
Eclipse	0.22 j	1.52 e-j	2.05 ghi	4.10 d-h	2.28 klm	5.62 f-k
Galaxy	0.50 ij	1.13 g-j	3.27 d-i	3.02 h-i	3.77 i-m	4.15 i-m
Kiowa	3.10 a-e	4.71 a	9.11 a	8.10 ab	12.21 ab	12.82 a
Natchez	3.00 a-e	4.46 ab	4.60 b-g	2.68 e-i	7.60 c-i	7.14 c-j
Navaho	1.78 d-j	2.72 c-g	5.96 a-e	7.82 abc	7.74 c-i	10.54 abc
Osage	2.13 d-i	4.15 abc	5.44 b-e	5.50 b-g	7.57 c-i	9.65 a-f
Ouachita	1.77 d-j	3.31 a-d	3.98 e-i	3.05 g-i	5.74 e-k	6.36 d-k
Ponca	2.21 d-i	2.97 b-f	7.73 abc	6.29 a-d	9.94 a-d	9.26 a-f
Prime-Ark® 45	2.55 c-h	4.64 ab	4.30 c-g	5.19 b-g	6.85 c-j	9.83 a-e
Prime-Ark® Freedom	0.52 ij	2.32 d-i	2.58 e-i	2.58 e-i	3.25 j-m	4.90 g-l
Prime-Ark® Horizon	2.85 b-g	4.16 abc	5.64 a-f	4.96 b-g	8.50 b-h	9.12 a-g
Prime-Ark® Traveler	1.26 f-j	2.62 c-h	3.78 d-i	4.78 b-g	5.03 g-l	7.39 c-i
Sweetie Pie	1.96 d-j	3.44 a-d	4.52 c-g	5.08 b-g	6.47 c-j	8.51 b-h
Twilight	1.60 e-j	0.87 hij	4.07 d-h	2.16 f-i	4.94 h-l	3.75 j-m
[y]p-value (cultivar*shade)	0.0618		0.0089		0.0126	
[y]p-value (cultivar)	<.0001		<.0001		<.0001	

[y]p-value (shade)	<.0001	0.718	<.0001

[z] Different lower-case letters within columns which do not share a similar letter are significantly different ($\alpha < 0.05$) by Tukey's HSD test.
[y] p-values > 0.05 are not significant

Table 2.4. Average white drupelet incidence per 25 berry subsamples under full sun and 30% shade at CREC in Chilton County, Alabama from 2024 and 2025.

	2024[z]		2025[z]	
Cultivar	Full sun	30% shade	Full sun	30% shade
Big Daddy	1.52 a-f	1.81 a-d	4.27 a	2.88 ab
Caddo	0.44 fgh	0.59 fgh	1.06 c	0.55 c
Columbia Star	0.06 h	0.06 h	0.0 c	0.0 c
Eclipse	2.12 ab	1.43 a-g	1.34 c	0.66 c
Galaxy	0.40 fgh	0.32 gh	0.88 c	0.24 c
Kiowa	1.78 a-e	2.00 abc	2.83 b	1.21 c
Natchez	0.54 fgh	0.34 fgh	0.95 c	0.28 c
Navaho	0.65 d-h	0.24 h	0.42 c	0.36 c
Osage	0.08 h	0.27 gh	0.33 c	0.11 c
Ouachita	0.58 fgh	0.81 c-h	0.55 c	0.69 c
Ponca	0.16 h	0.10 h	0.08 c	0.10 c
Prime-Ark® 45	0.22 h	0.17 h	0.19 c	0.02 c
Prime-Ark® Freedom	2.65 a	0.31 gh	0.91 c	0.36 c
Prime-Ark® Horizon	0.26 gh	0.16 h	0.28 c	0.04 c
Prime-Ark® Traveler	0.39 fgh	0.03 h	0.25 c	0.20 c
Sweetie Pie	1.14 b-h	0.64 d-h	1.06 c	0.22 c
Twilight	2.31 ab	2.33 a	1.30 c	0.37 c
[y]p-value (cultivar*shade)	<.0001		0.0007	
[y]p-value (cultivar)	<.0001		<.0001	
[y]p-value (shade)	0.0061		<.0001	

[z] Different lower-case letters within columns which do not share a similar letter are significantly different (α < 0.05) by Tukey's HSD test.
[y] p-values > 0.05 are not significant

Table 2.5 Average berry weight (g) for 2024 and 2025 and mean berry weight of both years of blackberries grown under full sun and 30% shade at CREC in Chilton County, Alabama

Cultivar	2024[z]		2025[z]		Mean[z]	
	Full sun	30% shade	Full sun	30% shade	Full sun	30% shade
Big Daddy	8.32 cde	9.43 bc	6.58 i-m	9.09 cde	7.52 g-m	9.08 c-g
Caddo	7.97 d-g	9.00 cd	9.46 cd	11.18 b	8.90 c-h	10.07 bcd
Columbia Star	4.16 k	5.25 jk	4.71 m	5.15 lm	4.24 q	5.28 opq
Eclipse	3.99 k	5.95 ijk	6.13 klm	7.34 f-k	5.15 pq	6.64 j-p
Galaxy	5.59 ijk	7.49 d-h	6.53 j-m	8.91 c-f	6.33 l-p	8.08 e-j
Kiowa	10.29 b	12.76 a	12.15 b	15.26 a	11.07 b	13.98 a
Natchez	7.82 d-g	9.43 bc	7.02 g-m	7.69 e-k	7.37 h-m	8.64 d-h
Navaho	5.07 k	6.35 hij	6.04 klm	6.95 h-m	5.60 n-q	6.82 i-o
Osage	6.64 g-j	7.48 d-h	6.42 klm	8.03 d-j	6.48 k-p	7.78 e-l
Ouachita	6.86 f-j	8.24 de	7.47 f-j	8.27 d-i	7.01 i-n	8.21 e-j
Ponca	5.49 jk	6.50 hij	6.35 klm	7.42 f-k	5.99 m-p	6.97 i-n
Prime-Ark® 45	8.02 def	8.36 cd	7.21 f-l	8.39 d-g	7.42 h-m	8.38 e-i
Prime-Ark® Freedom	9.42 bcd	12.29 a	10.62 bc	14.01 a	10.34 bc	13.19 a
Prime-Ark® Horizon	7.75 d-g	8.79 cd	8.23 d-i	9.24 cd	8.05 e-j	9.22 cde
Prime-Ark® Traveler	5.76 ijk	7.17 e-i	5.93 klm	7.56 f-k	6.19 m-p	7.54 f-m
Sweetie Pie	7.93 d-g	8.08 def	7.98 d-j	8.67 def	7.99 e-k	8.36 e-i
Twilight	7.23 e-k	8.84 cd	8.32 d-h	9.56 cd	7.88 e-l	9.12 c-f
[y]p-value (cultivar*shade)	<.0001		<.0001		0.0034	
[y]p-value (cultivar)	<.0001		<.0001		<.0001	
[y]p-value (shade)	<.0001		<.0001		<.0001	

[z] Different lower-case letters within columns which do not share a similar letter are significantly different ($\alpha < 0.05$) by Tukey's HSD test.
[y] p-values > 0.05 are not significant

Table 2.6. General composition, soluble solids content (SSC), titratable acidity (TA), pH, and SSS:TA of blackberry cultivars grown under full sun and 30% shade at CREC in Chilton County, Alabama in 2024 and 2025.

2024								
	SSC[z]		TA [z]		pH[z]		SSC:TA[z]	
Cultivar	Full sun	30% shade	Full sun	30% shade	Full sun	30% shade	Full sun	30% shade
Big Daddy	11.4 a-h	9.2 i	0.70 cd	1.05 a-d	3.46 a-e	3.06 e-h	17.8 a-d	10.2 efg
Caddo	12.0 a-f	10.6 d-i	0.75 cd	0.95 a-d	3.37 b-g	3.11 d-h	16.2 a-f	12.3 c-g
Eclipse	13.4 a	11.1 b-i	0.75 bcd	1.19 a-d	3.40 a-f	2.95 gh	18.8 abc	10.3 c-g
Galaxy	11.8 a-g	10.6 e-i	0.86 a-d	0.87 a-d	3.30 c-g	3.02 fgh	14.4 b-g	12.8 c-g
Kiowa	12.4 a-e	9.5 hi	0.91 a-d	1.25 abc	3.18 d-h	2.95 gh	14.1 c-g	8.3 g
Natchez	10.2 f-i	9.0 i	1.01 a-d	1.18 a-d	3.21 c-h	3.04 e-h	11.1 c-g	8.8 fg
Navaho	12.7 abc	10.6 d-i	1.41 a	1.08 a-d	3.39 b-f	2.86 h	14.8 a-g	12.6 c-g
Osage	12.1 a-f	10.4 e-i	0.74 cd	0.91 a-d	3.49 a-d	3.35 b-g	17.3 a-e	12.7 c-g
Ouachita	12.2 a-e	10.5 d-i	0.94 a-d	1.40 ab	3.37 b-f	3.04 e-h	14.7 a-g	8.1 g
Ponca	12.8 abc	11.4 a-h	0.74 cd	0.86 a-d	3.74 ab	3.29 c-g	18.3 abc	15.4 a-g
Prime-Ark® 45	13.2 ab	9.9 ghi	0.64 cd	0.96 a-d	3.60 abc	3.24 c-h	22.0 ab	10.9 c-g
Prime-Ark® Horizon	11.7 a-g	10.0 ghi	0.76 bcd	0.84 a-d	3.27 c-g	3.21 c-h	16.1 a-e	13.6 c-g
Primeark Traveler®	12.0 a-f	10.5 e-i	0.58 d	1.11 a-d	3.80 a	3.26 c-h	22.4 a	11.3 c-g
Sweetie Pie	12.4 a-d	10.7 c-i	1.04 a-d	1.29 abc	3.27 c-g	3.03 e-h	13.9 c-g	8.9 efg
Twilight	13.3 ab	11.7 a-g	0.95 a-d	1.1 a-d	3.37 b-g	3.24 c-h	16.6 a-e	13.3 c-g
[y]p-value (cultivar*shade)	0.194		0.0595		0.0048		0.0039	
[y]p-value (cultivar)	<.0001		<.0001		<.0001		<.0001	

[y]p-value (shade)		<.0001		<.0001		<.0001		<.0001
				2025				
	SSC[z]		TA [z]		pH[z]		SSC:TA[z]	
Cultivar	Full sun	30% shade	Full sun	30% shade	Full sun	30% shade	Full sun	30% shade
Big Daddy	8.1 fg	8.0 fg	0.90 abc	0.77 abc	3.23 cde	3.18 cde	10.6 bcd	11.0 a-d
Caddo	10.6 abc	10.3 a-e	0.74 abc	0.76 abc	3.32 b-e	3.29 b-e	17.4 ab	13.8 a-d
Galaxy	10.7 abc	9.7 a-g	0.85 abc	0.94 abc	3.29 b-e	3.14 cde	12.6 a-d	10.6 a-d
Kiowa	8.3 efg	8.3 efg	1.08 ab	1.23 a	3.11 de	3.06 e	8.4 cd	6.9 d
Natchez	8.6 d-g	7.5 g	0.88 abc	1.10 ab	3.18 cde	3.14 cde	10.3 bcd	7.3 d
Navaho	9.8 a-f	9.5 a-g	0.84 abc	1.03 abc	3.17 cde	3.24 cde	13.3 a-d	10.2 bcd
Osage	9.8 a-f	9.1 a-g	0.65 bc	0.67 bc	3.56 abc	3.56 abc	15.7 a-d	14.8 a-d
Ouachita	9.9 a-f	9.4 a-g	0.92 abc	1.11 ab	3.26 b-e	3.15 cde	11.2 a-d	9.6 bcd
Ponca	10.6 abc	9.9 a-f	0.73 abc	0.83 abc	3.59 ab	3.55 abc	16.6 abc	13.9 a-d
Prime-Ark® 45	10.3 a-d	9.9 a-f	1.09 ab	0.65 bc	3.36 b-e	3.29 b-e	13.6 a-d	19.1 a
Prime-Ark® Freedom	10.9 ab	9.8 a-f	0.80 abc	0.68 abc	3.49 abc	3.58 abc	16.1 a-d	15.5 a-d
Prime-Ark® Horizon	8.7 b-g	8.2 fg	0.99 abc	0.91 abc	3.10 de	3.15 cde	9.4 bcd	9.2 bcd
Prime-Ark® Traveler	9.3 a-g	8.3 fg	0.52 c	0.73 abc	3.85 a	3.50 abc	19.3 a	12.8 a-d
Sweetie Pie	10.5 abc	8.4 d-g	1.11 ab	1.19 ab	3.18 cde	3.13 de	10.3 bcd	8.0 d
Twilight	10.9 a	10.0 a-f	0.91 abc	0.95 abc	3.24 cde	3.48 a-d	13.4 a-d	14.3 a-d
[y]p-value (cultivar*shade)		0.498		0.1117		0.0482		0.1576
[y]p-value (cultivar)		<.0001		<.0001		<.0001		<0.0001

[y]p-value (shade)	<.0001	0.3412	0.1872	0.0219

[z] Different lower-case letters within columns which do not share a similar letter are significantly different (α < 0.05) by Tukey’s HSD test.
[y] p-values > 0.05 are not significant.

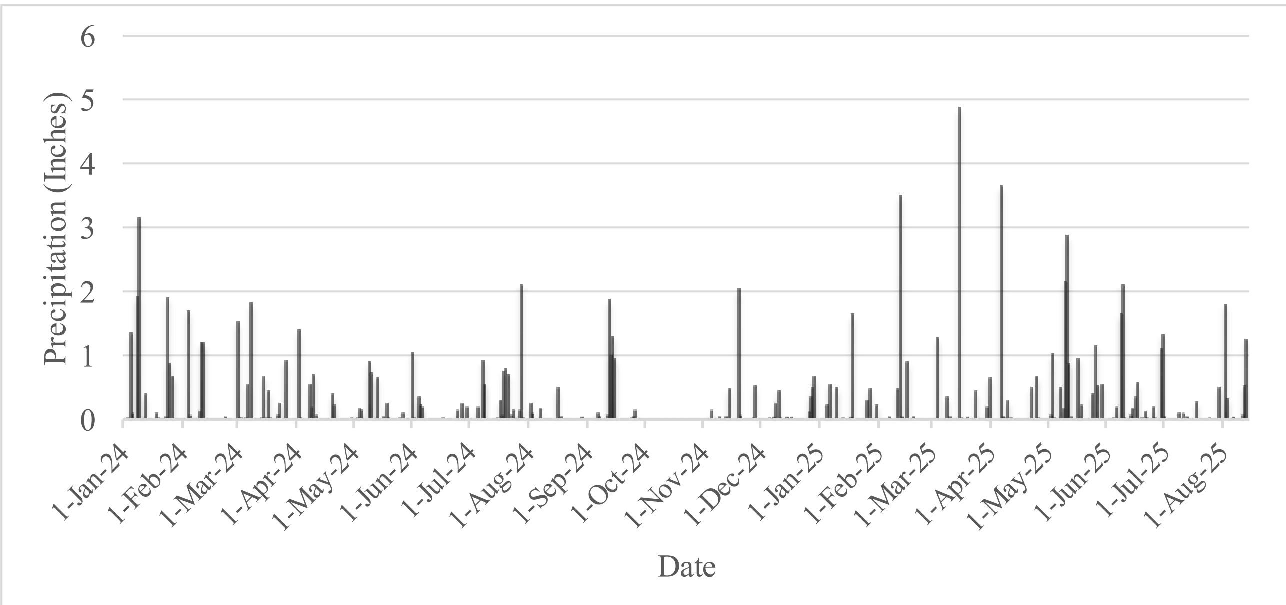

Figure 2.4 Total precipitation (Inches) from January 2024 to August 2025 at Chilton County Research and Extension Center in Chilton County, Alabama