Performance of Newly Released and Well-Established Rabbiteye Blueberry (*Vaccinium ashei*) Cultivars in North Alabama

by

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Abstract

Rabbiteye blueberries (*Vaccinium ashei* Reade) are the primary blueberry species produced in Alabama. Many cultivars of rabbiteye blueberry have been recently developed with diverse vegetative and cropping characteristics, but scientific data on their performance in Alabama is limited. An experiment was established at the North Alabama Horticulture Research Center, Cullman, AL (lat. 34° 11' N, long. -86° 47' E), USDA Hardiness Zone 7B, to evaluate the performance and horticultural value of the following rabbiteye blueberry cultivars: 'Alapaha', 'Baldwin', 'Brightwell', 'Climax', 'Ira', 'Montgomery', 'Onslow', 'Powderblue', ' Premier', 'Tifblue', and 'Yadkin'. Cultivar flowering and ripening season, yield potential, fruit quality characteristics, plant ornamental qualities, and vegetative growth were investigated during 2009 and 2010. 'Alapaha', 'Climax', and 'Premier' were found to have early ripening in north Alabama. 'Alapaha' flowered later than the earliest flowering cultivars, but ripened consistently early, and this later flowering can serve to protect 'Alapaha' from late frosts. Cultivars were not found to differ with respect to their cumulative yield in their fifth and sixth leaf. 'Brightwell' and 'Climax' had the firmest berries, while 'Climax' and 'Premier' had the sweetest berries. Additionally, studies focused on cultivar ornamental qualities were conducted to evaluate and compare their ornamental qualities for use as functional landscape plants by analyzing berry fall foliage color, surface color, summer foliage color, and bush form. 'Alapaha' and 'Yadkin' had long lasting red fall foliage, with 'Alapaha' having duller and darker fall color and 'Yadkin' displaying a lighter, more intense fall color. 'Ira' and 'Premier' were found to have intense, long lasting fall color that was more yellow. 'Powderblue' had the most waxy and attractive summer foliage and berry. 'Alapaha' and 'Onslow' cultivars were found to have the most upright growing habit. 'Austin' and 'Climax' rabbiteye blueberries grown on two soil types in Columbia, AL (lat. 31° 15' N, long. -85° 9' E; Plant Hardiness Zone 8A), were compared with respect to vegetative growth, yield, and fruit quality in order to evaluate the effect of the soil quality based on land's prior use. The soil previously used for crop production was found to have above 2% soil organic matter, and the soil previously left to pasture was found to have approximately twice as much organic matter. Foliar analysis revealed little difference in the elemental content of the leaves from plants grown on old crop land and pasture land. Fruit set was higher on pasture land, and yields were found to be as much as three times higher for plants grown on pasture land than those grown on old crop land. Plants grown on pasture land were also found to be noticeably more vigorous on the pasture land as well. Higher plant vigor and yields may be a result of the alleviation of establishment stress provided by the higher organic content found on the pasture land site.

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CHAPTER ONE

Biological and Horticultural Characteristics of Newly Released and Well-Established Rabbiteye Blueberry (*Vaccinium spp.*) Cultivars:

Literature Review

The blueberry is a member of the Ericaceae family (Austin, 1994), and is a member of the genus *Vaccinium*, which also include roughly 400 species that can be found on every continent except Antarctica and Australia (Ballington, 1990). It is thought that the *Vaccinium* species originated in South America, but the true cluster fruited blueberry species are largely confined to the acidic soils of the eastern United States (Ballington, 1990). All blueberries grown for fruit production in the tropical and subtropical regions originate from species or interspecific hybrids in the *Vaccinium* section *Cyanococcus*, and 10 subgenera are found in North America and Mexico (Ballington, 1990).

Presently, the most prominent species used for commercial production are *Vaccinium corymbosum* L. (northern highbush), *Vaccinium angustifolium* Aiton (lowbush), *Vaccinium ashei* Reade (rabbiteye blueberry), and southern highbush, which was developed from an interspecific hybridization of native southern species *Vaccinium darrowi* with rabbiteye and northern highbush species (Austin and Bondari, 1993; Draper, 2007). The southern highbush blueberry has the advantage of early ripening of the highbush combined with the low chilling requirements of *V. darrowi*, allowing the fruit to be sold at a premium price early in the season (Marshall, 2008; Pattern, 1991). Additionally, a halfhigh blueberry bush (*Vaccinium corymbosum x V. angustifolium*), originating from a cross between the northern highbush and the lowbush, is grown commercially, and was developed for a short stature that would survive low temperatures when covered by snow (Draper, 2007).

Northern highbush blueberries are commonly grown in Michigan, New Jersey, and North Carolina, and lowbush blueberries, which are a largely wild species, are cultivated in Maine and Quebec (Darnell and Davies, 1990). Rabbiteye are the primary blueberry species grown in the Southeast United States (Darnell and Davies, 1990). Southern highbush blueberries are becoming an important part of Southern blueberry production particularly in Florida and Georgia (Draper, 2007; Pattern, 1991). Rabbiteye blueberries are native to the North American subtropical zone, and are being used increasingly for production as more commercially viable cultivars are released (Darnell and Davies, 1990).

Rabbiteye blueberries are the most prominent and the best adapted of the blueberry species for cultivation in the southeastern United States, and particularly to Alabama (Dozier, 1991). Southeastern states, including Alabama, Georgia, Louisiana, Mississippi, South Carolina, and Texas, grow primarily rabbiteye blueberry and account for more than 80% of the total rabbiteye acreage in the United States (Spiers, 1990). Rabbiteyes are native to the Southeast, are heat and drought tolerant, grow on a wide range of soils, and provide abundant yields (Miller-Butler et al., 2009; Esendugue et al., 2008). Rabbiteye blueberries have traditionally been grown in areas with naturally acidic soil, but the use of mulch, acids, sulfur, and organic matter soil amendments have expanded rabbiteye production to land previously unsuited for blueberry cultivation (Draper, 2007). Commercial rabbiteye yields typically range from 2,268 to 3,629 kg/acre on well-maintained fields, sometimes reaching as high as 4,536 kg/acre. A field can continue to be productive for 30 years or more (Esendugue et al., 2008). Rabbiteye blueberry cultivars are more resistant to diseases and insects and have sweet fruit with excellent firmness, and a longer shelf life than other blueberry species (Esendugue et al., 2008). Rabbiteye blueberry bushes can grow to a height of 3.1meters or more, have high vigor, and produce small to medium-large berries ranging in color from black to light blue (Austin and Bondari, 1993).

According to the United Nations' Food and Agriculture Organization (FAO), in 2000, 240,412 metric tons of blueberries were produced by 15 countries in the world. Worldwide production increased to 331,347 metric tons, or by 73%, in 2008 (FAO, 2010). North America accounts for the majority of world blueberry production, and according to the New Jersey Agricultural Statistics Service (2007), in 2005, the United States of America accounted for 51% of the world blueberry production. In 2005, the United States gross production was valued at 250 million (FAO, 2010), and blueberries are the second most important berry crop in the United States (Saftner et al., 2008). According to Strik (2006), a 2003 survey found that the use of improved southern highbush and rabbiteye selections has led to an increase in production and plantings in the southern United States. Both the total area harvested and crop yields in the United States have continued to grow. In the years between 1998 and 2008, United States production area increased by 58% and production levels increased by 76% (FAO, 2010).

Rabbiteye blueberries are historically an important commercial crop for Alabama, and many farms produce rabbiteye blueberries for sale in the fresh market either exclusively, or as a supplemental crop (Kezis et al., 1998). The New Jersey Agricultural Statistics Service (2007) reports that in 2006 Alabama ranked 13th in the nation for harvested acres, yield per acre, utilized production, as well as value of utilized production. As illustrated by Table 1, essentially 100% of the blueberries currently produced in Alabama are sold in the fresh market (USDA, 2010). In 1998, 310 acres were harvested in Alabama, yielding 730 kg/acre. According to the same source, over the next decade, there was only a 3% increase in harvested acreage but a 71%

increase in yield per acre. Blueberry acreage almost doubled by 2009, when an additional 275 acres were established in the Dothan area (Clint Smith, president of the Wiregrass Blueberry Growers Association, personal communication). Alabama farm gate value has increased in the same time period by approximately 13%.

Blueberry Plant Development

Blueberries require a certain number of chilling hours, or hours below 7˚C, for floral and vegetative buds to break (Darnell and Davies, 1990; Spiers, 1978; Spiers et al., 2006). Rabbiteyes are native to the Gulf South, and generally have inherently low chilling requirements (Spiers, 1990). They usually require from 400 to 700 hours chilling hours at 6-7˚C for bud break (Spiers et al., 2006). Typically, rabbiteye blueberries are grown in areas where the temperatures drop below 7˚C for 400 to 700 hours per year (Spiers, 1978), and cultivar chilling requirements must be considered in cultivar selection based on the climate in which the rabbiteye blueberries will be grown (Spiers et al., 2006).

Once the required chilling hours are met for a particular plant, floral buds and vegetative buds break dormancy (Spiers, 1978). Spiers (1978) found that as flower development continues, the bud's susceptibility to cold damage increases, but rabbiteye blueberry floral buds tend to be very cold hardy. Only slight damage to dormant rabbiteye blueberry flower buds have been reported at temperatures as low as -28˚C, but Spiers (1978) found that at later stages of development flowers were damaged by temperatures of -1˚C. Ehlenfeldt (2006) found that under New Jersey conditions, 50% of flower buds were damaged in temperatures ranging from -24.9˚C to -13.7 ˚C among 25 rabbiteye blueberry cultivars.

Low chilling requirements in rabbiteye blueberry causes it to be to be susceptible to late spring frosts, which can cause crop loss. Early flowering cultivars are particularly susceptible (Spiers, 1978). Studies by Patten et al. (1991) showed 'Climax', the standard early flowering rabbiteye cultivar, to be very susceptible to spring frost damage. Susceptibility to late spring frost and the lack of winter hardiness have been identified as important problems in current rabbiteye blueberries (Ehlenfeldt et al., 2006). It is estimated that between 60% and 80% of rabbiteye blueberry flowers must set fruit to achieve commercial production levels, thus freeze damage can be devastating on blueberry crops (NeSmith et al., 1999).

Spiers (1978) documented 7 distinct stages of floral bud development. Stages of development are as follows: Stage one, no visible swelling; stage two, visible swelling of bud, scales separating, flowers still completely enclosed; stage three, budscales separated, apices of flower visible; stage four, individual flowers distinguishable, bud scales abscised; stage five, individual flowers distinctly separated, corollas unexpanded and closed; stage six, corollas completely expanded and open; stage seven, corollas dropped (Spiers, 1978). Spiers (1978) found an inverse relationship exists between the stage of development and the flower bud's susceptibility to cold damage. Spiers (1978) found that swollen flower buds were not damaged by temperatures of -4˚ C, but some were killed at -6˚ C. At stage four, or when individual flowers become distinguishable, flower buds were killed by -4˚ C, and during the transition to the distinctly separated individual flowers stage, temperatures of -2˚ C were lethal (Spiers, 1978). Temperatures of 0˚ C were not found to damage any of the flower buds in developmental stages one through five, but temperatures of -1˚ C were damaging to flowers with open corollas approaching stage six of flower bud development.

Rabbiteye blueberries tend to be more vigorous and disease resistant than highbush blueberries, but also tend to have lower fruit set (Darnell and Davies, 1990). After mild winters, it has been documented that rabbiteye blueberries can be seen to bloom normally, but then fruit sets insufficiently, leading to low yields (Darnell and Davies, 1990). According to Davies (1986), any decrease in rabbiteye blueberry fruit set, or fruit drop, tends to occur in the first 3 to 4 weeks of full bloom and gradually decreases for the next 2 to 3 weeks. A number of factors can contribute to the level of fruit set on rabbiteye blueberry, such as cultivar cross-compatibility, presence and activity of effective pollinators, water stress, plant nutrition, growth regulators, and the accumulation of chill hours (Davies, 1986).

Field observations suggest that the mild winters lead to a reduction in the number of floral buds that break, leading to less concentrated blooming and pollination, and subsequently low fruit set (Darnell and Davies, 1990). Darnell and Davies (1990) attempted to quantify the effect of insufficient chilling accumulation on fruit set and budbreak in rabbiteye blueberry. Their findings indicate that suboptimal chilling is not a major contributing factor in decreased fruit set. Conversely, in some cases, increased chilling was found to increase flower production, which may serve to increase competition, thus reducing fruit set. This phenomenon has been observed in apples (Darnell and Davies, 1990).

Ritzinger and Lyrene (1999) suggest that the fruit set in blueberries is likely tied to the flower structure and its attractiveness to pollinators. Rabbiteye flowers have angled sides, similar to an inverted funnel, which serves to reduce within-flower self-pollination and promote pollination by insects, particularly bees (Ritzinger and Lyrene, 1999). Blueberries are largely self-unfruitful and set very little fruit when not cross-pollinated (Davies, 1986). Bee pollinators and interplanting with cross-compatible cultivars have been used to increase fruit set levels

(Davies, 1986). Studies have indicated that the floral morphology of blueberry flowers may affect pollination and subsequently fruit set. Eck and Mainland (1971) found that the distance between stigma and anther pore had a negative correlation with fruit set. Blueberry flowers with shorter corollas that are wider in the middle and are narrower at the base were found to have higher incidents of fruit set (Eck and Maineland, 1971; Ritzinger and Lyrene, 1999). Rabbiteye blueberries typically have long corolla tubes with rather narrow apertures, which may lead to reduced pollination by making pollination more difficult for honey bees (Ritzinger and Lyrene, 1999). Morphology of the rabbiteye blueberry better lends itself to pollination by sonicating bees, which cause the flower to release its pollen through a response to vibrations from the bee's flight, rather than by penetrating the flowers, as honey bees do (Ritzinger and Lyrene, 1999).

Harvest season for rabbiteye blueberries begins in late May in Florida, continuing to August in North Carolina (Spiers, 1990). Harvest typically spans 6 to 8 weeks depending on the cultivars planted, and lasts about 3 weeks per cultivar (Spiers, 1990). The use of cultivars with a range of maturing periods allows for an extended growing season and market availability (NeSmith, 2006).

Fruit Development and Nutritional/Quality Characteristics

Blueberry fruit are epigynous or "false" berries, because they originate from inferior ovaries as opposed to berries derived from superior ovaries (Vicente et al., 2007). Following fertilization, the ovary rapidly swells, and over the next month the berry remains green with little change in volume (Eck, 1988). Later, the calyx end begins to purple and the berry continues to become more purple over the next few days (Eck, 1988). The berry volume increases during this color changing phase, and the diameter often enlarges by 50% (Eck, 1988). After the berry achieves final color, the diameter can still increase as much as 20% as the flavor and sweetness improve (Eck, 1988). Current rabbiteye varieties typically have berry size between 1.0 and 1.5 g (NeSmith, 2009). In a study comparing sensory and instrumental qualities of blueberries, Saftner et al. (2008) found that sensory scores for appearance were best correlated with berry size. In other words, consumers prefer larger berries.

Blueberry fruit contain vitamins A, C, and E, as well as carbohydrates, protein, fiber, and fat. They also contain organic acids and polyphenolic substances including chlorogenic, citric, malic, quinic, acetic, caffeic, p-coumaric, and shikimic acids (Druice and Percival, 2003). According to Druice and Percival (2003), the combinations of these organic compounds give blueberries the highest oxygen radical absorbency capacity of over forty commercially available fruits and vegetables. The nutraceutical compounds in blueberries have been linked to a number of health benefits, such as their capability to reduce blood sugar, serum cholesterol, and triglyceride levels. Blueberries also have antiallergenic, anti-viral and antiproliferative activities (Druice and Percival, 2003). Blueberries have been found to have a protective effect against numerous diseases, such as diabetes, stroke, lung and stomach cancers. Additional health benefits of blueberries are their effect on reducing the loss of age-related motor skills and memory, and improving urinary tract and visual health (Druice and Percival 2003). Increased reports of the fruit’s health benefits has likely contributed to national as well as worldwide increase in demand and production (Druice and Percival, 2003).

Berry color is affected by both the total anthocyanin content coupled with the quantity and structure of the waxy coating and is a highly complicated attribute (Silva et al., 2005). Blueberries are deep purple to black, but the berries are covered by a glaucous covering, giving the berries their bluish color (Austin and Bondari., 1993). Furthermore, the color is highly influenced by the state of the epicuticular wax found on the berries and the presence of rodlet wax structures, which are responsible for the light blue color found on some blueberries (Sousa et al, 2006). Cultivars with deep-blue berries and a waxy coat, producing a light-blue berry, tend to be the most desirable berries to the consumer (Austin and Bondari, 1993; Sousa et al., 2006). Generally, the lack of a waxy bloom is an indicator of post-harvest mishandling or overripe berries (Sousa et al., 2006).

Rabbiteye blueberries tend to be susceptible to rain induced splitting, but the level of susceptibility is cultivar dependent (Marshall et al., 2008). Typically, splitting is brought on by heavy rains, which saturate the soil near harvest time. Conversely, drought stricken plants have a tendency toward splitting as well (Marshall et al., 2008). In heavy rains, water is not only absorbed through the skin of the berry, but it is also absorbed through the roots, leading to splitting (Marshall et al., 2008). Firm fruits are generally a desirable trait, as they are good indicators of a cultivar's suitability for mechanical harvesting as well as long-distance shipping, but firmer fruits have a higher tendency toward splitting (Marshall et al., 2008).

Blueberry Culture

Cultural practices for rabbiteye blueberry are less challenging than they are for the northern highbush, as rabbiteyes grow on a wide range of soils, including sandy clay loam, loam, loamy sand, and sand soil series (Esendugue et al., 2008). Well-drained upland soils with low nutrient and water holding capacity, as well as low organic matter are optimal (Esendugue et al., 2008; Spiers, 1983). If the organic matter is found to be below 2%, it is recommended that pine bark mulch or peat moss is added at planting (Esendugue et al., 2008; Spiers, 1983). Growth is not as good on previously farmed land when compared to virgin land, unless organic matter is worked into the soil to at least 2% (Esendugue et al., 2008).

On sandy soils, the optimal pH for blueberry production should be adjusted to 4.0 to 5.3 and optimal pH on clay soils is 4.5 to 5.3 (Esendugue et al., 2008). In soils with pH levels above 5.2 iron chlorosis can occur (Spiers and Braswell, 1992). Spiers and Braswell (1992) stated that excessive calcium (Ca) and sodium (Na) absorption, common at higher soil pH levels, may impede growth. Ca fertilizer-induced Fe deficiency, or lime-induced chlorosis, has been documented in soils that have been raised to a pH above 5.5, and growth and yields have also been documented to be negatively affected by a high soil pH (Spiers and Braswell, 1992). The level of Ca in the soil does not appear to play as large a role in Ca absorption as the pH level in rabbiteye blueberry production. Additionally plant growth is also retarded by higher Na absorption rates found at higher pH levels (Spiers, 1984; Spiers and Braswell, 1992). Sulfur (S) is used in commercial blueberry production to lower pH to the optimal level and lime is used to raise pH levels in the soil (Spiers, 1984; Spiers and Braswell, 1992).

Moisture stress is considered the determining factor in rabbiteye establishment, and irrigation, organic matter incorporation, and mulching all serve to alleviate this stress (Spiers, 1983). Spiers (1983) found that irrigation and mulching combined led to better vigor, less chlorosis, greater plant vigor, and yields five times that of non-irrigated and non-mulched bushes. Drip irrigation is typically used for rabbiteye blueberry production, delivering a maximum of 2,500 to 3,000 gal/acre per day (Esendugue, 2008). Mulching and irrigation are large expenses, but irrigation is considered essential for commercial production, while mulching is recommended when organic matter is below 2% and it is economically feasible (Spiers, 1983).

Spiers and Braswell (1992) found water quality to be an extremely important factor with regards to the effects on plant growth and vigor from Ca and Na uptake. Rabbiteye blueberries, irrigated with water containing moderate amounts of Na and Ca, were treated with various levels of S to lower the soil pH (Spiers and Braswell, 1992). Even with high rates, S applications were not sufficient to counteract the effects of Ca and Na in the irrigation water, and when higher levels did lower the pH to more acceptable levels, plant growth and vigor were not affected (Spiers and Braswell, 1992). The cations of importance for water quality are the levels of Ca, Mg, and Na. The important anions include Cl, SO_4, and CO_3, and the combinations of Na with Cl and HCO_3 that form salts that are harmful to plant growth (Haby et al., 1986). Studies by Spiers (1990) have shown that blueberries are very sensitive to excess salinity, and irrigation water with more than 50 ppm should be avoided.

Blueberries are salt-sensitive plants, but they respond well to fertilization (Esendugue et al., 2008). Four applications per year are recommended for younger plants, and bearing bushes are typically fertilized two or three times a year (Esendugue et al., 2008). Typically, a 1:1:1 ratio (oxide base) is recommended at rates to give N at 33.6-55.0 $kg \cdot ha^{-1} \cdot yr^{-1}$, but recommendations vary with soil type (Austin and Bondari, 1993). A complete fertilizer is typically used with an ammonium N source, such as $(NH_4)_2SO_4$ to lower the pH, and urea as a natural N source (Spiers, 1990). The plant age, precipitation levels, and soil conditions should all be taken into account when formulating fertilizer applications (Austin and Bondari, 1993).

Rabbiteye blueberries are sufficiently vigorous to produce a heavy crop and still produce adequate fruiting shoots, so only a small amount of pruning is needed annually to keep bushes at a manageable size and to make harvesting easier (Spiers, 1990). Additionally, rabbiteyes can benefit from pruning immediately after harvest, as the pruning can stimulate the production of new fruiting wood for the following season (Spiers, 1990).

Pests and Disease

Rabbiteyes are more resistant to fungal pathogens than highbush blueberries, and in the past, most southern states did not even have a disease spray program (Spiers, 1990). Currently, some of the diseases of concern to rabbiteye production are mummy berry (*Monilinia vaccinii-corymbosi*), Botrytis and Botrytis blight (*Botrytis cinerea*), Alternaria leaf spot (*Alternaria tenuissima*), bacterial leaf scorch (*Xylella fastidiosa*), double spot (*Dothichiza caroliniana)*, Gloeocercospora leaf spot (*Gloeocercospora inconspicua*), leaf rust of blueberry (*Pucciniastrum vaccinii*), powdery mildew (*Microsphaera alni*), Septoria leaf spot (*Septoria albopunctata*), Botryosphaeria stem canker (*Botryosphaeria cortices*), stem blight of blueberry (*Botryosphaeria dothidea*), Phomopsis twig blight (*Phomopsis spp.*), and Amarillaria root rot (*Armillaria mellea, A. ostoyae*) (www.extension.org/blueberries).

Cline (2000) reports that stem blight is the most common disease causing the death of young blueberry plantings in the southeastern United States, and can be managed through site selection and cultural practices, as fungicides are likely only beneficial after pruning or similar wounding.

Late summer to early fall defoliation of rabbiteye blueberry, commonly caused by fungal pathogens, can cause the reduction of flower bud production (Lyrene, 2002). Long, hot, humid days during the growing season, accompanied by rain, promote fungal foliar diseases such as septoria leaf spot (*Septoria albopunctata*), phyllositica leaf spot (*Phyllositica vaccinii*), and blueberry leaf rust (*Pucciniastrum vaccinii*) (Williamson and Miller, 2002). It is suggested that the leaf abscission causes the plant to lose its ability to detect the shortened photoperiods, which stimulates flowering (Lyrene, 2002). Additionally, the loss of a nearby source of carbohydrates may limit an axillary bud's potential to be transformed into a flower bud (Lyrene, 2002). This early defoliation has been documented to reduce yields, and cultivars vary in the level of susceptibility to early defoliation (Lyrene, 2002). Cultivars which are disease resistant, as well as those which differentiate flower buds earlier, before the premature defoliation occurs, are shown to be less susceptible to this phenomenon (Lyrene, 2002).

Some of the insect pests of economic concern to rabbiteyes are blueberry gall midge (*Dasineura oxycoccana*), blueberry maggot (*Rhagoletis mendax*), spotted wing Drosophila (*Drosophila suzukii*), green stink bugs (*Acrosternum hilare*), and brown stink bugs (*Euschistus servus*) (www.extension.org/blueberries).

Weed control is crucial for successful rabbiteye blueberry establishment, and young plants can easily be overgrown by weeds (Austin, 1994). Weed control should be implemented one year prior to planting rabbiteye blueberries, and bermudagrass, nutsedge, briars, johnsongrass, and honeysuckle are persistent weeds that should be eradicated, as weed control is limited until the plants are established (Austin, 1994). Weed growth interferes with new canes emerging from the ground, which is where much of the rapid growth takes place (Esendugue et al., 2008). Typically, a pre-emergent herbicide is used in early spring and midsummer, as the young new canes are sensitive to herbicides (Esendugue et al., 2008). Shielded sprayers or hand wand applications are generally required four to eight times per year (Esendugue et al., 2008).

Cultivation and Cultivar Development

Historically, northern highbush was the first blueberry to be cultivated, followed by rabbiteye (Draper, 2007). Wild rabbiteye blueberries, transplanted from western Florida in 1893, were the first known commercial rabbiteye plantings (Spiers, 1990). Wild rabbiteyes were also similarly planted in Alabama, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina, with total acreage reaching more than 3,500 acres across the South (Spiers, 1990). These plants were unselected bushes, which produced dark, gritty berries with poor taste (Spiers, 1990).

Cultivation of rabbiteye blueberries began in 1940 with a cooperative effort between the U.S. Department of Agriculture, the University of Georgia, and North Carolina State University (Draper, 2007; Spiers, 1990). Superior selections from the wild were intercrossed, and thorough seedling screening was performed (Draper, 2007). The first cultivars were released in 1950 (Draper, 2007), but the planting of cultivated blueberries was initially slow in North America (Strik, 2006). Early cultivars tended to have fruit that were nearly black with a poor taste and large seeds, but have since been replaced by improved varieties (Austin and Bondari, 1993).

In 1910, the USDA blueberry breeders attempted to cross rabbiteye blueberry with the highbush with little to no success (Lyrene, 2002). This was because of differences in the species ploidy level (Lyrene, 2002). All cultivated blueberries are polyploids; rabbiteye blueberries are hexaploid, while standard highbush, lowbush, and all half-high bushes are tetraploid (Ballington, 1990; Lyrene, 2002). It has never been determined how the hexaploid *Vaccinium* arose from the tetraploid and diploid *Vaccinium* (Lyrene, 2002). Rabbiteye blueberries have a narrow germplasm source, which has caused some difficulties in breeding (Ballington, 1990; Lyrene, 2002).

Since nearly all of the nuclear genes in rabbiteye blueberry come from four selections ‘Myers,’ ‘Black Giant,’ ‘Ethel,’ and ‘Clara’, inbreeding has been used to promote desirable traits, but has resulted in the loss of vigor and fruit weight (Ballington, 1990). Additionally, a narrower germplasm increases the risk of reduced pest/disease resistance. Efforts are currently being made in breeding programs to widen the germplasm of *Vaccinium* species (Ballington, 1990). According to Ballington (1990), inbreeding between current gene pool is severe enough to impede successful rabbiteye cultivar development. Additionally, the rabbiteye blueberry’s narrow gene pool leaves rabbiteye blueberries exposed to a possible pathogen attack if cytoplasmic resistance became important (Ballington, 1990). Efforts are being made in breeding programs to widen the germplasm base, but increased efforts are needed (Ballington, 1990). It has been suggested that 50 to 100 wild blueberry selections be used to essentially redomesticate the species in order to widen the gene pool, but the resources are simply not available for such an undertaking (Lyrene, 2002).

Currently, most of the blueberry breeding programs are taking place in Arkansas, Florida, Georgia, Idaho, North Carolina, New Jersey, Michigan, Minnesota, Mississippi, and California (Strik, 2006). Florida, Georgia, Texas, North Carolina, and Mississippi all have active rabbiteye blueberry breeding programs aimed largely at producing early ripening, low-chilling, high yielding cultivars (Spiers, 1990). Some of the other qualities that are desired in new rabbiteye blueberry cultivars are the development of increased cold hardiness, better adaptation to particular climates, adaptation to mineral soils or soils with high pH, the extension of the fruit season, high vigor, reduced plant stature, high quality fruit, suitability for mechanical harvest, disease or insect resistance, tolerance to environmental stress, and higher nutraceutical properties (Ballington 1990; Draper, 2007; Strik, 2006).

Yield is the most important trait from the grower's perspective, and cultivars that are not only high yielding, but are consistently high yielding across years are desirable (NeSmith, 2006). Yield is a function of many factors including flower clusters per plant, flower number per cluster, flowering twigs per bush, fruit set and drop, and fruit size (Davies, 1986). The commercial crop yields are typically considerably less than that documented in experimental plots, primarily due to inconsistencies in plant health and pollination as well as seasonal influences (Patel and George, 1997).

Late-flowering, early ripening cultivars and/or tolerance to low temperatures during and following bloom are also desirable traits that breeders are striving for in rabbiteye due to the risk of late spring frost damage (Ballington, 1990; Ehlenfeldt et al., 2006; Spiers, 1978). In much of Alabama, blueberries with low chilling requirements are used, but once the chilling requirements are met, there is still a risk of late spring frost (Spiers, 1978). 'Alapaha' is a rabbiteye cultivar which flowers after 'Climax', the standard for early cultivars, but the fruit ripens at approximately the same time (NeSmith and Draper, 2004). Thus, 'Alapaha' is additionally protected against a late freeze event, while still maintaining the benefits of an early crop. In areas in which rabbiteyes are used for production, chilling requirements are often met in December or January, and once these chilling requirements are met, warm temperatures stimulate vegetative and flower bud growth and swelling (Spiers, 1978). The further along the bud is in its development stage, the more susceptible to cold damage it is (Spiers, 1978). With the availability of cultivars with a range of flowering times, a grower can select cultivars that match their risk of late spring frosts and consequent crop loss (NeSmith, 2006).

In addition to the flowering period, the ripening period is also important in blueberry production. The ability to target an early market for premium prices is one reason a grower would risk a late freeze by planting an early flowering and fruiting cultivar such as 'Climax' (NeSmith, 2006). In New Zealand, breeding efforts have targeted fruiting periods that coincide with offseason times in the northern hemisphere to attain premium prices (Patel and George, 1997). Additionally, cultivars can be combined with early, mid, and late season ripening to extend the harvest season over 6 to 8 weeks (NeSmith, 2006).

Time of flowering and ripening is crucial to determining a cultivar's potential to be adapted to particular regions and to target certain markets (NeSmith et al., 2006). Monitoring these periods is useful, but the actual number of days can vary quite widely, and different regions, microclimates, and weather can all affect the number of days from flowering to ripening (NeSmith et al., 2006). NeSmith et al. (2006) illustrated that the use of this period as a unit of thermal time, or heat units, rather than days is likely a better method for recording these periods. NeSmith (2006) used temperature readings from nearby weather stations to calculate chilling hours and heat units each year. This allowed calculation of fruit development for various cultivars in days as well as heat units. It was found that the variations in development time could be better predicted using heat units. Knowing the thermal time or heat units for a cultivar's fruit development time allows that information to be transferable and comparable, as it can be relative to certain regions or environments (NeSmith et al., 2006).

Ballington (1990) states that due to increasing restrictions on pesticides, breeding for resistance to major diseases, pests, and mites are an important direction for cultivar development. Due to the fact that rabbiteye blueberries are hexaploid and have a narrow gene pool, breeding resistance to all common diseases and insects is very challenging (Ballington, 1990).

Another goal of the blueberry breeding programs is to develop plants that are adapted to mechanical harvesting and pruning, as labor becomes in increasingly short supply (Ballington, 1990). For mechanical harvesting, plants should exhibit concentrated ripening periods, moderate vigor, a moderate number of narrowly upright canes (which could be trained into a narrow hedge row to fit a mechanical harvester), a large number of flower buds, a high resistance to wound pathogens, small to moderate fruit size, a light blue color, small scars, loose fruit clusters, moderate ease of fruit removal, crisp flesh texture, a firm berry, tough/elastic skin, and desirable sugar/acid ratio to assure extended shelf life (Ballington 1990). According to NeSmith et al. (2004), 'Climax' is considered the standard in Georgia for mechanically harvested blueberries for the fresh market. It has an upright form, narrow crown, and a concentrated harvest (Austin, 1994; Eck, 1988). Silva et al. (2005) found rabbiteye blueberries to have a tougher skin than highbush blueberries, which is desirable for mechanical harvesting.

On the other hand, large berries with a small dry scar are desired for hand picking, and the berry should be attached well enough to hold the berry when fully ripe, but also detach easily to avoid tearing the skin of the berry (Austin and Bondari, 1993).

Firmness is one of the key factors analyzed for cultivar selection (Austin and Bondari, 1993), and rabbiteye blueberries are more firm than those of northern highbush (*V. corymbosum*) or *V. darrowi* (Sousa, 2006). Cultivars with softer berries will often bruise if they are harvested mechanically and do not withstand shipping well (Silva et al., 2005). Firm varieties are well-suited for mechanical harvesting and long-distance shipping (Marshall et al., 2008; Saftner et al., 2008; Austin and Bondari, 1993). Machine harvested berries have been found to be softer and show a higher incidence of postharvest decay than hand harvested berries (Silva et al., 2005). As farms and farm cooperatives grow in size and shipping distances increase, firmer rabbiteye fruits will be needed for mechanical harvesting and shipping (Silva et al., 2005). According to NeSmith (2009), berries that have firmness exceeding 175 g/mm are likely a good threshold for berries that are suitable for mechanical harvesting. Marshall et al. (2008) showed that when breeding efforts are aimed at producing firmer fruits, cultivars may be selected that are susceptible to rain induced cracking, as firmer varieties tend to have more susceptibility to cracking. Thus, cultivars should be screened for both firmness and susceptibility to cracking (Marshall et al., 2008).

Saftmer et al. (2008) found that compression firmness was best correlated to panelist scores for juiciness, and also was correlated to bursting energy and texture during chewing in a study rating sensory qualities of rabbiteye blueberry fruit among cultivars. This indicates a firmer berry is more desirable to consumers. However, berry firmness is affected by maturity more than cultivar differences, and slight differences in maturity between cultivars may have reduced the relationship between instrumental firmness and the sensory scores (Saftner et al., 2008).

Over the past two decades fresh blueberry consumption has increased, which has led to an increase in cultivars bred for fresh consumption (Saftner et al., 2008). Fresh blueberries are being shipped longer distances as blueberry gains popularity, causing an increase in demand for fruit that are of high quality, reduced softening, and increased shelf life (Vicinte, 2007). Marketing of rabbiteyes in the southern states ranges from 90% local sales in South Carolina to 95% shipping in Georgia (Spiers, 1990). Berry size and quality are extremely important for fresh market blueberries (NeSmith 2006; Saftner et al., 2008), and the quality of fresh fruit is usually indicated by four major aspects: visual quality (color, and the lack of skin disorders); organoleptic quality (taste, texture, flavor); nutritional quality and hygienic quality (microbiological safety and residues) (Sousa et al., 2004). Fruit size is among the most important traits for the fresh blueberry market, and current rabbiteye varieties typically have berries between 1.0 and 1.5 g (NeSmith, 2009). NeSmith (2009) reported the University of Georgia breeding program has selections that are being tested that produce berries that are more than 2 g and even as much as 3 g, and it is thought that these larger fruit should serve to improve customer appeal. Additionally, cultivars that consistently produce large berries over multiple harvests are needed (NeSmith, 2006).

A study of farmers' market patrons in 2006 indicated that farmers' market customers tend to be concerned largely with the quality of the food at these markets, rather than price (Lyon et al., 2009), as was the case in a study on farmers' market customers in Maine in 1995, where the quality of produce was consistently mentioned as the key attraction (Kezis et al., 1998). Large, light colored berries with excellent flavor are desirable characteristics for berries sold in the farmers' market (Saftner et al, 2008). Customers of farmers' markets expect higher quality produce, but are also willing to pay premium prices (Kezis et al., 1998). The sensory qualities, such as size, appearance, taste, and chewing texture are likely the most influential factor on blueberry preference in farmers' markets (Lyon et al., 2009).

As more improved rabbiteye blueberry cultivars are released, it becomes increasingly more important to test and monitor fruit quality (Austin and Bondari, 1993). Instrumental measurements such as such as the fruit color, fruit weight, firmness, soluble solids content (SSC), total acids (TA), the SSC/TA ratio, and pH have been widely studied in rabbiteyes, but the sensory data is lacking (Saftner et al., 2008). These sensory qualities include appearance acceptability, fruit sized appropriately, bursting intensity, skin toughness, chewing texture, juiciness, sweetness, tartness, flavor intensity, flavor acceptability, and overall eating quality (Saftner et al., 2008).

A blueberry's taste is a component of several factors, particularly the aromatic volatiles, SSC, TA, and the ratio of SSC/TA (Saftner, 2008). It is difficult to accurately rate flavor, but blueberries should have a good balance of sugar to acid with a good aftertaste (Austin and Bondari, 1993). The tangy taste in blueberry is due partially to the tartness which counterbalances the sweetness (Austin et al., 2005). Austin and Bondari (1993) determined that high soluble solids content with low acid tended to be a pleasant tasting berry, and that low total acid negatively affects storage capacity. Soluble solids, pH, and SSC/TA ratio have been shown to be correlated with berry deterioration, but a high SSC/TA ratio is the best indicator (Austin et al., 2005). Rabbiteye blueberries are tart when they first turn blue, and often get a negative image in the marketplace because fruit are often picked at this stage (Draper, 2007). Berry maturity at harvest is one of the main factors affecting storage life and berry quality, and there is ultimately a compromise between ensuring the optimum eating quality and providing the flexibility needed for marketing as well as transportation (Sousa et al., 2004).

Rabbiteye blueberries tend to be more resistant than highbush to postharvest decay, and they also typically have a smaller, dry picking scar (Silva et al., 2005). This scar is considered to be the primary path of entry for postharvest decay organisms, thus a small, dry picking scar is a desirable fruit characteristic (Parra et al., 2007; Silva et al., 2005). Large berries with small, dry picking scars are the most desirable, but cultivars that produce larger berries often produce larger picking scars (Parra et al., 2007).

Cultivar selection is crucial in matching the cultivar's biological and horticultural traits with the area and market. Blueberry cultivars can differ in many ways, and proper cultivar selection will drastically influence whether the crop production is successful and profitable. It is important to test new and old cultivars on each growing location, as they will perform differently in different climates and growing environments. A study conducted nearly two decades ago (Dozier, 1991) provides useful information on cultivar performance, but the cropping potential of newly released cultivars have not been studied in our state. This study was designed with the objective of evaluating vegetative characteristics, fruiting and flowering habits, fruit quality, and ornamental qualities of new and old cultivars for their performance in Northern Alabama.

Selected Cultivar Descriptions

‘Tifblue’, a mid to late season blueberry produced by the University of Georgia’s breeding program in 1955, was created from a cross of ‘Ethel’ x ‘Clara’ and is considered a mid to late season variety (Austin, 1994; Eck, 1966; Trehane, 2004). ‘Tifblue’ is the most widely planted rabbiteye blueberry cultivar in the world and is used as the standard to which other cultivars are compared (Austin, 1994; Trehane, 2004). It requires 550 to 650 chilling hours, is a vigorous, erect bush, with good cane production, and the fruit of ‘Tifblue’ are medium to large light blue berries which are firm and tend to have an excellent picking scar (Trehane, 2004; Austin, 1994; Eck, 1966). The fruit have been known to take several days after appearing ripe to develop full flavor, additionally, the ripe fruit holds well to the bush (Austin, 1994; Trehane, 2004). Sub-optimal chilling or frost damage can lead to problems with ultimate fruit size, and wet soils or heavy rain can lead to a problem with fruit cracking in ‘Tifblue’ (Austin, 1994).

‘Climax’ was introduced in 1974 by the Georgia Coastal Plains Experiment Station and the USDA as an early flowering and ripening cultivar (Austin, 1994; Eck, 1988; Trehane, 2004). ‘Climax’ flowers early, requires 450-500 hours of chilling, and has a concentrated harvest, but due to the early flowering it is at risk to being damaged by late spring frosts (Austin, 1994; Eck, 1988). It is a moderately upright bush with spreading canes and relatively narrow crowns, and produces medium sized, dark blue berries, with good flavor (Eck, 1988; Austin, 1994). According to NeSmith et al. (2004), 'Climax' is considered the standard in Georgia for mechanically harvested blueberries for the fresh market.

'Powderblue' is a mid to late season rabbiteye blueberry resulting from a cross of 'Tifblue' x 'Menditoo', released by the University of North Carolina in 1978 (Austin, 1994). 'Powderblue' berries are particularly light blue in color, smaller than 'Tifblue', with a small, dry scar, good firmness, and a sweet, but not aromatic flavor (Austin, 1994). 'Powderblue' bushes are vigorous with an upright to semi-upright growth habit and small to medium crowns (Austin, 1994). The time of flowering to fruit maturity are similar to that of 'Tifblue', and it has a chilling requirement of 550 to 650 hours (Austin, 1994).

'Premier' is a 1978 introduction from the North Carolina Agricultural Experiment Station and the USDA, from a cross of 'Tifblue' x 'Homebell' (Austin, 1994; Eck, 1988). It requires 450 to 500 chilling hours and is somewhat self-fertile (Trehane, 2004). 'Premier' is considered an early to mid-season ripening variety, ripening 2 to 3 weeks before 'Tifblue' (Eck, 1988), and is vigorous and productive, producing large, light blue berries (Eck, 1988; Trehane, 2004). For sturdiness, 'Premier' benefits from summer pruning (Austin, 1994). It is known to be highly adaptable, with the ability to withstand some higher pH soils (Austin, 1994; Trehane, 2004). Additionally, 'Premier' is fully self-fertile, but will not set a full crop without cross-pollinators (Austin, 1994). 'Premier' is known to have misshapen or deformed flowers, but this has not been shown to significantly impact fruit set (Austin 1994).

'Brightwell', a cross of 'Tifblue' x 'Menditoo', was released in 1981 by the University of Georgia Coastal Plain Experiment Station and the USDA as an early yielding cultivar with medium large, firm, light blue berries with a good picking scar and a vigorous, upright growth habit (Austin, 1994; Eck, 1988; Lyrene, 2002; Trehane, 2004). It is a low-chilling variety, requiring only 300 to 400 hours, but flowering is often delayed until after late freezes, granting it protection against late freeze damage (Austin, 1994). Compared with 'Tifblue', 'Brightwell' has been shown to have more consistent fruit set and has been shown to be more resistant to cracking in rainy weather (Lyrene, 2002), and it is a good candidate for mechanical harvesting, as the fruit separates easily from the bush (Eck, 1988). It has been found to have insufficiently strong branches to hold the fruit in years with excessively heavy crop loads, but this can be alleviated with summer pruning (Trehane, 2004). 'Brightwell' has replaced 'Tifblue' as the most widely planted rabbiteye in the southeastern United States (Lyrene, 2002).

'Baldwin', a 1985 release from the Georgia Agricultural Experiment Station and the USDA, was created from a cross of 'Tifblue' x Ga. 6-40 ('Meyers' x 'Black Giant') and is a late ripening variety (Eck, 1988; Austin, 1994). It has an extended 6 to 7 week ripening period and requires approximately 450 to 500 chilling hours (Austin, 1994; Trehane, 2004). It is a vigorous, upright, and productive bush, with large, dark blue, firm berries with good flavor and a small dry picking scar (Austin, 1994; Eck, 1998). 'Baldwin' requires hand picking for high yields, and consequently is recommended for the pick-your-own market and home plantings (Austin, 1994; Eck, 1998).

'Austin' is an early ripening selection of a cross of 'Brightwell' x T-110 released by the University of Georgia and the USDA released in 1996 (Hall and Draper, 1997). It ripens along with 'Climax', requiring 450 to 500 chilling hours, and produces large to medium-sized fruit of high quality. 'Austin' also is a good candidate for mechanical harvesting (Hall and Draper, 1997). When compared to 'Climax', 'Austin' has comparable yield with larger berries, and fewer seeds (Hall and Draper, 1997). ‘Austin’ is moderately vigorous with an upright habit, and has good cane production to renew the plant (Hall and Draper, 1997).

‘Ira’ is an early to mid-season ripening cultivar released from North Carolina State University in 1997, and was produced from a cross of ‘Centurion’ x NC911 (Okie, 1999). It is known for its consistent cropping across a wide array of environments, and produces a larger berry than ‘Tifblue’ with flavor, picking scar, firmness, and soluble solids : acid ratio equal to that of ‘Tifblue’. ‘Ira’ is a vigorous plant, although slightly less vigorous than ‘Tifblue’ or ‘Premier’, with an upright growth habit and flowers slightly after ‘Tifblue’. Although ‘Ira’ is reported to be self-fertile it benefits from a cross-pollinator (Okie, 1999).

‘Montgomery’ is an early rabbiteye blueberry cultivar originating from the cross of NC763 x ‘Premier’, introduced in 1997 by the University of North Carolina (Okie, 1999). ‘Montgomery’ produces berries that are larger than ‘Tifblue’ berries but smaller than ‘Premier’ berries, and the fruit have a good color, picking scar, and flavor with average firmness (Okie, 1999). It produces berries that are resistant to cracking, stemming, and tearing with superior shelf life to ‘Premier’. ‘Montgomery’ is a semi-erect, moderately vigorous bush, and is easily trained. While moderately self-fertile, a pollinator is recommended for ‘Montgomery’ (Okie, 1999).

‘Yadkin’ is a mid to late season ripening cultivar released from North Carolina State University in 1997 derived from a cross of ‘Premier’ x ‘Centurion’, and is a full sibling to ‘Onslow’ (Okie, 1999). The fruit on ‘Yadkin’ are particularly flavorful and aromatic, and are slightly larger than ‘Tifblue’, medium-blue colored, and have excellent firmness and picking scar. Additionally, the shelf-life has been shown to be better than ‘Premier’, and ‘Yadkin’ fruit show resistance to cracking, tearing, and stemming (Okie, 1999). ‘Yadkin’ has medium vigor and a semi-upright growth habit with fruits tending to be concentrated toward the tips of the shoots. ‘Yadkin’ has been reported to be particularly self-fertile, but should still be planted with cross-pollinators where earliness is a concern (Okie, 1999).

‘Alapaha’ was selected in 1972 at the Coastal Plains Experiment Station, Tifton, GA, and it was released in 2000 as a high yielding, early ripening cultivar which is semi-self-fertile resulting from a cross of T-65 x ‘Brightwell’ (NeSmith and Draper, 2004; Okie, 2002). ‘Alapaha’ requires 450 to 500 chilling hours and flowers approximately one week after ‘Climax’, but ripens at approximately the same time, giving added protection against late frost without a delay in fruiting (NeSmith and Draper, 2004). It has a vigorous, upright growth habit with narrow crowns, and it produces medium sized berries with good color, flavor, firmness, and a small, dry picking scar and has been indicated as a good candidate for mechanical harvesting (NeSmith and Draper, 2004; Okie, 2002).

‘Onslow’ is a late-ripening cultivar released by North Carolina State University in 2001, originating from the cross of ‘Premier’ x ‘Centurion’, and is a full sibling to ‘Yadkin’ (Okie, 2002). The fruit are large and medium blue, and when allowed to fully ripen are particularly aromatic (Okie, 2002). ‘Onslow’ is a very upright and vigorous growth habit, ripening mid to late season, and it produces large fruit with excellent picking scar and firmness. ‘Onslow’ is a good pollinator for ‘Tifblue’ or ‘Powderblue’. Additionally, ‘Onslow’ appears to tolerate higher pH and is more cold tolerant than most other rabbiteyes (Okie, 2002).

Ornamental Qualities

The ornamental blueberry market, although small by comparison, is becoming more important and should be considered when evaluating new cultivars (Scalzo et al., 2009b).

Merhaut (2003) states that some of the outstanding characteristics that will accelerate the desire for blueberries in the ornamental market are as follows: diversity, as there are many cultivars available with a range of growth habits, canopy, shapes, and leaf color; the bush size, as there are larger varieties as well as dwarfed varieties; growth habit, as rabbiteyes can be easily maintained at 5-6 ft; leaf characteristics, as there are varying colors of leaves from green to glaucous blue; fruiting characteristics, as the fruit are good for both eating and as a landscape accent; and disease and drought resistance, as they will tend require less input.

Internationally, there is increased interest in retail sales of blueberries for home use. Scalzo et al. (2009b) reported that in New Zealand, retail sales of blueberry plants has increased significantly in recent years, and this unprecedented demand is likely due to the healthful properties of blueberries. Additionally, current trends in New Zealand public gardens are toward decorative plants which are also functional (Scalzo et al., 2009b), which has likely fueled the interest in functional landscape plants. In Germany, 50% of blueberry plants are currently sold to home gardeners (Scalzo et al. 2009a*)*. Some of the characteristics which tend to be most important to home gardeners are ease of management, attractive foliage and flowers, attractive growth habit, and good fruit production (Scalzo et al. 2009a).

Ornamental use of blueberries is not new. *V. ashei* was reported to have been hybridized with *V. darrowi* to produce evergreen blueberry bushes with noted ornamental value as early as the 1950's (Lyrene and Sherman, 1977). More recently, some southern highbush blueberries have been produced with desirable landscape characteristics. For instance, 'Desoto' is a dwarf cultivar which only grows to a maximum of 2 meters (Stringer et al, 2006). Pink fruited selections have also been produced. 'Florida Rose' is a rabbiteye blueberry selection that has berries that are pink on top, where the sun hits, and white on the bottom, where shaded (Lyrene, 2004). G-435 and ARS 96-138, also pink fruited selections, were created by crossing *V. ashei* and half synthetically derived, hexaploid, high-bush germplasm (Ehlenfeldt and Finn, 2007). In New Zealand, 'Hortblue Onyx', a compact bush that has the ability to bloom multiple times per year, was created from open pollinated *V. simulatum* (Scalzo et al., 2009b). Another cultivar produced in New Zealand originated from open pollinated *V. corymbosum*, 'Hortblue Petite' is a bushy plant with multiple blooms annually (Scalzo et al., 2009b). 'Hortblue Poppins' is a tetraploid *V. corymbosum* which was selected for home garden use, and has been an extremely successful cultivar release in Europe (Scalzo et al., 2009a). Scalzo et al. (2009a) states that it has an upright habit, attractive architecture and foliage, and has high quality fruit, and its foliage is unique in that it is similar in shape to an upturned umbrella.

When evaluating the ornamental qualities of the blueberry bushes, Scalzo et al. (2009a, b) reported on ornamental characteristics such as leafing density, bush structure, cluster density and size, structure, fruit color, bloom, berry size, and overall appearance.

By identifying cultivars with desirable ornamental qualities and documenting those characteristics, homeowners could identify blueberries that could be used in various landscape applications, thus creating a functional and appealing landscape. By assessing both new and old rabbiteye cultivars, novel new traits can be identified as well as determining the ornamental value of some of the more established and researched cultivars.

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Table 1. National Agricultural Statistics Service report on blueberry production and utilization in Alabama 1998-2008.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total utilized production (lbs)[z]	500	650	450	530	430	450	610	560	350	410	360
Fresh use (lbs)[z]	480	560	450	530	430	450	610	560	350	410	360
Processed (lbs)[z]	20	90	450	530	430	450	610	560	350	410	360

[z]1,000 lbs

CHAPTER TWO

Investigations on the Performance of Newly Released and Well-Established Rabbiteye Blueberry Cultivars in North Alabama

Abstract

Many cultivars of rabbiteye blueberry (*Vaccinium ashei* Reade) have been recently developed with diverse vegetative and cropping characteristics, but scientific data on their performance in Alabama is limited. An experiment was established at the North Alabama Horticulture Research Center, Cullman, AL (lat. 34° 11' N, long. -86° 47' E), USDA Hardiness Zone 7B, to evaluate the performance and horticultural value of the following rabbiteye blueberry cultivars: ‘Alapaha', 'Baldwin', 'Brightwell', 'Climax', 'Ira', 'Montgomery', 'Onslow', 'Powderblue', ' Premier', 'Tifblue', and 'Yadkin'. Cultivar flowering and ripening season, yield potential, fruit quality characteristics, and vegetative growth were investigated during 2009 and 2010. ‘Alapaha’, ‘Climax’, and ‘Premier’ were found to have early ripening in north Alabama. ‘Alapaha’ flowered later than the earliest flowering cultivars, but ripened consistently early, and this later flowering can serve to protect ‘Alapaha’ crop from late frosts damage. Cultivars were not found to differ with respect to their cumulative yield in their fifth and sixth leaf. ‘Brightwell’ and ‘Climax’ had the firmest berries, while ‘Climax’ and ‘Premier’ had the sweetest berries.

Introduction

Rabbiteye blueberries (*Vaccinium ashei* Reade) are the most prominent and the best adapted of the blueberry varieties for cultivation in the southeastern United States. Alabama, Louisiana, Mississippi, South Carolina, and Texas grow rabbiteye blueberry almost exclusively (Spiers, 1990, Draper, 2007). Rabbiteye blueberries are native to the Southeast, tolerant to heat and droughts, more resistant to diseases and insects, grow on a wide range of soils, provide abundant yields, sweet fruit with excellent firmness, and a longer shelf life than other blueberry species (Miller-Butler et al., 2009; Esendugue et al., 2008). Rabbiteye blueberry bushes can grow to a height of 10 feet or more, have high vigor, and produce small to medium-large berries ranging from black to light blue (Austin and Bondari, 1993). Commercial rabbiteye yields typically range from 2,270 to 3,630 kg/acre on well-maintained fields, sometimes reaching as high as 4535 kg/acre, and a blueberry orchard can continue to be productive for 30 years or more (Esendugue et al., 2008).

Rabbiteye blueberries are historically an important commercial crop for Alabama, and many farms produce rabbiteye blueberries for sale in the fresh market either exclusively, or as a supplemental crop (Kezis et al., 1998). The New Jersey Agricultural Statistics Service (2007) reports that in 2006 Alabama ranked 13th in the nation for harvested acres, yield per acre, utilized production, as well as value of utilized production. Essentially 100% of the blueberries currently produced in Alabama are sold in the fresh market (USDA National Agricultural Statistics Service, 2010). In Alabama, 310 acres were harvested in 1998, yielding 730 kg/acre. According to the National Agricultural Statistics Service (2010), over the next decade, there was only a 3% increase in harvested acreage, but a 71% increase in yield per acre in Alabama. The blueberry acreage almost doubled by 2009, when an additional 275 acres were established in the Dothan area alone (Clint Smith, president of the Wiregrass Blueberry Growers Association, personal communication). Alabama farm gate value for blueberries has increased in the same time period by approximately 13% (USDA National Agricultural Statistics Service, 2010).

Public interest has likely aided this increase in demand and production due to the increased reports of the fruit's health benefits (Druice and Percival, 2003). Blueberries contain vitamins A, C, and E, as well as carbohydrates, protein, fiber, and fat, and also contain organic acids and polyphenolic substances including chlorogenic, citric, malic, quinic, acetic, caffeic, p-coumaric, and shikimic acids (Druice and Percival, 2003). According to Druice and Percival (2003), the combinations of these organic compounds give blueberries the highest oxygen radical absorbency capacity of over forty commercially available fruits and vegetables. The nutraceutical compounds in blueberries have been linked to a number of health benefits, such their capability to reduce blood sugar, serum cholesterol, and triglyceride levels. Blueberries also have antiallergenic, anti-viral and antiproliferative activities (Druice and Percival, 2003), and they have been found to have a protective effect against diabetes, stroke, lung and stomach cancers. Additional health benefits of blueberries are their effect on reducing the loss of age-related motor skills and memory, and improving urinary tract and visual health (Druice and Percival, 2003).

Cultivation of rabbiteye blueberries began in 1940 with a cooperative effort between the U.S. Department of Agriculture, the University of Georgia, and North Carolina State University (Draper, 2007; Spiers, 1990). Superior selections from the wild were intercrossed, and thorough seedling screening was performed (Draper, 2007). The first cultivars were released in 1950 (Draper, 2007), but the planting of cultivated blueberries was initially slow in North America (Strik, 2006). Early cultivars tended to have fruit that were nearly black, with a poor taste, and large seeds, but have since been replaced by improved varieties (Austin and Bondari, 1993).

A narrow gene pool plagues rabbiteye breeding, as nearly all of the nuclear genes originate from four selections: 'Myers,' 'Black Giant,' 'Ethel,' and 'Clara' (Ballington, 1990).

Inbreeding has been used to promote desirable traits, but has resulted in the loss of vigor and fruit weight (Ballington, 1990). In addition, narrower germplasms increase the risk of reduced pest/disease resistance, and efforts are currently being made in breeding programs to widen the germplasm of *Vaccinium* species but increased efforts are needed (Ballington, 1990).

Currently, Florida, Georgia, Texas, North Carolina, and Mississippi all have active rabbiteye blueberry breeding programs aimed largely at producing early ripening, low-chilling, high yielding cultivars (Spiers, 1990). Some of the other qualities that are desired in new rabbiteye blueberry cultivars are the development of increased cold hardiness, better adaptation to particular climates, adaptation to mineral soils or soils with high pH, the extension of the fruiting season, high vigor, reduced plant stature, high quality fruit, suitability for mechanical harvest, disease and insect resistance, tolerance to environmental stress, and higher nutraceutical properties (Strik, 2006; Ballington 1990; Draper, 2007).

Yield is the most important trait from the grower's perspective, and cultivars that are not only high yielding, but are consistently high yielding across years are desirable (NeSmith, 2006). Yield is a function of many factors including the amount of flower clusters per plant, flower number per cluster, flowering twigs per bush, fruit set and drop, and fruit size (Davies, 1986). The commercial crop yields are typically considerably less than that documented in experimental plots, primarily due to inconsistencies in plant health and pollination as well as seasonal influences (Patel and George, 1997).

Flowering and fruiting seasons are important traits that vary from cultivar to cultivar. Late-flowering, early ripening cultivars and/or tolerance to low temperatures during and following bloom are also desirable traits that breeders are striving for in rabbiteye due to the risk of late spring frost damage (Ehlenfeldt et al., 2006; Ballington, 1990; Spiers, 1978). In much of

Alabama, blueberries with low chilling requirements are used, but once the chilling requirements are met, there is still a risk of a damaging late spring frost (Spiers, 1978). With the availability of cultivars with a range of flowering times, a grower can select cultivars that match their risk of late spring frosts and consequent crop loss (NeSmith, 2006). Rabbiteye blueberry floral buds tend to be rather cold hardy, but as flower development continues, the bud's susceptibility to cold damage increases (Spiers, 1978).

Spiers (1978) documented 7 distinct stages of floral bud development. An inverse relationship was observed between the stage of development and the flower bud's susceptibility to cold damage (Spiers, 1978). Spiers (1978) found that swollen flower buds were not damaged by temperatures of -4˚ C, but some were killed at -6˚ C. At stage four, or when individual flowers become distinguishable, flower buds were killed by -4˚ C, and during the transition to the distinctly separated individual flowers stage, temperatures of -2˚ C were lethal (Spiers, 1978). Temperatures of 0˚ C were not found to damage any of the flower buds in developmental stages one through five, but temperatures of -1˚ C were damaging to flowers with open corollas approaching stage six of flower bud development.

In addition to the flowering period, the ripening period is also important in blueberry production. The ability to target an early market for premium prices is one reason a grower would risk a late freeze by planting an early flowering and fruiting cultivar such as 'Climax' (NeSmith, 2006). Cultivars can be combined with early, mid, and late season ripening to extend the harvest season over 6 to 8 weeks (NeSmith, 2006).

The intended method of harvest also affects cultivar selection, such as mechanical harvesting or hand harvesting (Ballington, 1990). For mechanical harvesting, plants should exhibit concentrated ripening periods, moderate vigor, a moderate number of narrowly upright canes (which could be trained into a narrow hedge row to fit a mechanical harvester), a large number of flower buds and canes, a high resistance to wound pathogens, small to moderate fruit size, a light blue color, small scars, loose fruit clusters, moderate ease of fruit removal, crisp flesh texture, a firm berry, tough/elastic skin, and desirable sugar/acid ratio to assure extended shelf life (Ballington 1990). According to NeSmith et al. (2004), 'Climax' is considered the standard in Georgia for mechanically harvested blueberries for the fresh market. It has an upright form, narrow crown, and a concentrated harvest (Eck, 1988; Austin, 1994). When compared to blueberry crops harvested by commercial hand-pickers, Van Dalfsen (1999) found mechanical harvesters had a reduction in yield of 14 to 16%, and roughly ten times as many immature berries.

Historically, high yield and firmness to withstand shipping were the primary characteristics selected for, but over the past two decades fresh blueberry consumption has increased, leading to emphasis on other qualities such as berry size, increased shelf-life, and increased berry quality (Saftner et al., 2008). Fresh blueberries are being shipped longer distances as blueberry gains popularity, causing an increase in demand for fruit that are of high quality, reduced softening, and increased shelf life (Vicinte, 2007). Marketing of rabbiteyes in the southern states ranges from 90% local sales in South Carolina to 95% shipping in Georgia (Spiers, 1990). Berry size and quality are extremely important for fresh market blueberries, and firm varieties are well-suited for long-distance shipping (Austin and Bondari, 1993; Saftner et al., 2008; NeSmith 2006). Crops grown for farmers' markets need to be of very high quality, but firmness for shipping is not as much of a concern (Lyon et al., 2009; Marshall et al., 2008; Saftner et al., 2008).

Firmness is one of the key factors analyzed for cultivar selection (Austin and Bondari, 1993), and rabbiteye blueberries are more firm than those of northern highbush (*V. corymbosum*) or the evergreen blueberry (*V. darrowii)* (Sousa, 2006). Cultivars with softer berries will often bruise if they are harvested mechanically and do not withstand shipping well (Silva et al., 2005). Firm berries are well-suited for mechanical harvesting and long-distance shipping (Marshall et al., 2008; Saftner et al., 2008; Austin and Bondari, 1993). Machine harvested berries have been found to be softer and show a higher incidence of postharvest decay than hand harvested berries due to damage from the machine harvester (Silva et al., 2005). As farms and farm cooperatives continue to grow in size with large plantings and shipping distances increase, firmer rabbiteye fruits will be needed for mechanical harvesting and shipping (Silva et al., 2005). Marshall et al. (2008) showed that when breeding efforts are aimed at producing firmer fruits, cultivars may be selected that are susceptible to rain induced cracking, as firmer varieties tend to have more susceptibility to cracking. Cultivars should be screened for both firmness and susceptibility to cracking (Marshall et al., 2008).

The quality of fresh fruit is usually indicated by four major aspects: visual quality (color, and the lack of skin disorders); organoleptic quality (taste, texture, and flavor); nutritional quality and hygienic quality (microbiological safety, residues) (Sousa et al., 2006). Fruit size is among the most important traits for the fresh blueberry market, but cultivars that consistently produce large berries over multiple harvests are needed (NeSmith, 2006). In a study comparing sensory and instrumental qualities of blueberries, Saftner et al. (2008) found that sensory scores for appearance were best correlated with berry size. In other words, consumers prefer larger berries. The sensory qualities, such as berry size, color, size, and taste are likely the most influential factor on blueberry preference in farmers’ markets (Lyon et al., 2009). Customers of farmers' markets expect higher quality produce, but are also willing to pay premium prices (Kezis et al., 1998).

Berry color is an important factor of fruit quality, and deep-blue berries with a waxy coat, producing a light-blue berry tend to be the most desirable (Austin and Bondari, 1993; Sousa et al., 2006). Blueberries are deep purple to black, but the berries are covered by a glaucous covering, giving blueberries their bluish color (Austin and Bondari., 1993). Berry color is affected by both the total anthocyanin content coupled with the quantity and structure of the waxy coating and is a highly complicated attribute (Silva et al., 2005). The color is highly influenced by the state of the epicuticular wax found on the berries and the presence of rodlet wax structures, which are responsible for the light blue color found on some blueberries (Sousa et al. 2006). Generally, the lack of a waxy bloom is an indicator of post-harvest mishandling or overripe berries (Sousa et al., 2006).

A blueberry's taste is a component of several factors, particularly the aromatic volatiles, SSC, TA, and the ratio of SSC/TA (Saftner, 2008). It is difficult to accurately rate flavor, but blueberries should have a good balance of sugar to acid with a good aftertaste (Austin and Bondari, 1993). The tangy taste in blueberry is due partially to the tartness which counterbalances the sweetness (Austin and Bondari, 1993). Austin and Bondari (1993) determined that high soluble solids content with low acid tended to be a pleasant tasting berry, but that low total acid negatively affects storage capacity. Soluble solids, pH, and SSC/TA ratio have been shown to be correlated with berry deterioration, but the SSC/TA ratio is the best indicator (Austin et al., 2005). Rabbiteye blueberries are tart when they first turn blue, and often get a negative image in the marketplace because fruit are often picked at this stage (Draper, 2007). Berry maturity at harvest is one of the main factors affecting storage life and berry quality, as berries do not continue to ripen after harvest. Ultimately there must be a compromise between ensuring the optimum eating quality and providing the flexibility needed for marketing as well as transportation (Sousa et al., 2004).

Rabbiteye blueberries tend to be more resistant than highbush to postharvest decay, and they also typically have a smaller, dry picking scar (Silva et al., 2005). This scar is considered to be the primary path of entry for postharvest decay organisms, thus a small, dry picking scar is a desirable fruit characteristic (Silva et al., 2005; Parra et al., 2007). Large berries with small, dry picking scars are the most desirable, but cultivars that produce larger berries often produce larger picking scars (Parra et al, 2007).

Ballington (1990) states that due to increasing restrictions on pesticides, breeding for resistance to major diseases, pests, and mites are an important direction for cultivar development. Some of the diseases that resistance is desired for are mummy berry (*Monilinia vaccinii-corymbosi*), botrytis, and botrytis blight (*Botrytis cinerea*), Alternaria leaf spot (*Alternaria tenuissima*), bacterial leaf scorch (*Xylella fastidiosa*), double spot (*Dothichiza caroliniana),* Gloeocercospora leaf spot (*Gloeocercospora inconspicua*), leaf rust of blueberry (*Pucciniastrum vaccinii*), powdery mildew (*Microsphaera alni*), Septoria leaf spot (*Septoria albopunctata*), Botryosphaeria stem canker (*Botryosphaeria cortices*), stem blight of blueberry (*Botryosphaeria dothidea*), Phomopsis twig blight (*Phomopsis spp.*), and Amarillaria root rot (*Armillaria mellea, A. ostoyae*) (www.extension.org/blueberries). Some of the insect pests of economic concern to rabbiteyes are blueberry gall midge (*Dasineura oxycoccana*), blueberry maggot (*Rhagoletis mendax*), spotted wing Drosophila (*Drosophila suzukii*), green stink bugs (*Acrosternum hilare*), and brown stink bugs (*Euschistus servus*) (www.extension.org/blueberries). Due to the fact that rabbiteye blueberries are hexaploid and have a narrow gene pool, breeding resistance to all common diseases and insects is very challenging (Ballington, 1990).

This study is aimed to evaluate the performance of 11 new releases and well-established rabbiteye blueberry cultivars in North Alabama. Science-based cultivar evaluation will help growers select the best suited blueberry cultivars for their growing location and targeted market, to sustain blueberry production, and can lead to increased profits. There is limited information available on blueberry cultivar performance in Alabama and particularly in North Alabama. A study by Dozier et al. (1991) conducted nearly two decades ago in southern Alabama evaluated several rabbiteye cultivars, but information is lacking on the performance of newly released rabbiteye cultivars in various locations throughout the state. Our objective in this study is to evaluate the vegetative growth and development, yield potential, and fruit quality of newly released and well-established rabbiteye blueberry cultivars for their performance in Alabama.

Materials and Methods

Eleven rabbiteye blueberry cultivars planted in Cullman, AL (lat. 34° 11' N, long. -86° 47' E), USDA Hardiness Zone 7B, at the North Alabama Experiment Station were utilized in this experiment. The older cultivars studied included ‘Baldwin’, ‘Climax’, ‘Brightwell’, ‘Powderblue’, and ‘Premier’, and the newer releases tested were ‘Alapaha’, ‘Ira’, ‘Montgomery’, ‘Onslow’, and ‘Yadkin’. The experimental design was a randomized controlled block design with 6 replications and 2 plants per replications, with a total of 132 plants in the experimental plot.

The blueberries were planted in the fall of 2007, and the 2009 and 2010 seasons were considered the initial cropping seasons. Three-year rooted cuttings were used and standard commercial practices were implemented for the planting and maintenance of the bushes (Himelrick et al. 1999). At planting, 18.9 L of peat moss were incorporated into the planting holes and 15.2 cm of pine bark mulch were added to amend the soil. Supplemental irrigation was installed to ensure successful plant establishment and production using drip tape. Plants were fertilized 3 times a year in April, May, and June using 0.1 kg of a 14-5-10 custom blueberry blend fertilizer (Southern States Cooperative, Inc.) in 2007 and 2008. Ammonium sulfate ($(NH_4)_2SO_4$) was applied at a rate of 0.2 kg per plant at the start of the growing season, and an additional application was made after fruiting.

Blueberry flowering was recorded by visually rating the percentage of fully open flowers on each bush at 7 day intervals. A flower was considered fully open when the stigma was observed protruding from the bell of the flower, and observations began when all cultivars were estimated to have at least 5% of the flowers fully open and continued until all experimental bushes reached 95% open flowers.

In April of 2009, the crop experienced damage from a late season frost, and damage was estimated based on a 5 point scale representing the percentage of flowers damaged on each bush (0=0-5%, 1=6-20%, 2=21-40%. 3=41-60%, 4=61-80%, and 5=81-100%) .

Flower bud density was determined as a number of flower buds per cane cross sectional area (cm^2) in 2009. The diameters of 2 canes per bush, with a diameter between 1.0 and 3.0 cm, were measured and flagged, and the number of flowers was counted on each cane. Flower bud density was expressed by the number of flower buds per unit cross sectional area. Due to an increase in plant size and crop load, this method was not feasible in the 2010 season, when fruit set was determined by flagging 2 fruiting shoots of a similar size (between 20 and 60 cm length) on each bush. The length of the fruiting shoot was measured and the fruit were counted. The shoot length was divided by the number of fruit set in order to determine the number of fruit per unit fruiting shoot. To obtain the initial fruit set, data was collected in May, and then the same shoots were counted again just before harvest in late June to determine the final fruit set.

Experimental bushes were hand-harvested on a weekly basis, starting when approximately 50% of the berries on the bush were fully colored, and bushes without a significant number of ripe berries were not harvested. Yield data were recorded on each harvest date for each experimental plant. In addition to determining the average yield per bush per harvest, the average total yields per bush were determined across both seasons.

Berry subsamples were collected from each harvested bush to determine cultivar fruit qualities characteristics. Berries were placed in a cooler and kept at 4˚C before analysis. A 20 g subsample from each plant harvested was stored at -80˚C for later determination of soluble solids content (SSC), titratable acidity (TA), and pH.

The fruit quality analysis was performed by measuring berry surface color, average fruit weight, firmness, number of berries with wet scar, berry dry weight, soluble solids content (SSC), titratable acidity (TA), the SSC/TA ratio, and pH. The average berry weight was determined on a 50 berry subsample/bush. Fruit firmness was determined on a 10 berry subsample/bush using a handheld FT 02 penetrometer (McCormick Scientific, Richmond, IL) using a 1.5 mm probe. According to NeSmith (2009) berries that have firmness exceeding 175 g/mm are likely a good threshold for berries that are suitable for mechanical harvesting. Fruit were held stationary between the thumb and index finger on a flat surface, and the probe was pressed against the fruit in a slow and steady motion until the berry was pierced. The percentage of berries with wet picking scar was determined by examining a 50 berry subsample per bush. Berry dry weight (g) was determined by drying 10 berry subsample/bush at 77˚ C in a Grieve model sc-350 oven (Grieve Corporation, Round Lake, IL, USA) for 36 hours, and then the berry weight was recorded.

SSC, TA, and pH were determined using a method described by Vinson et al. (2010). SSC was determined by first pureeing approximately 20 g of frozen fruit and 20 ml of HPLC water, obtained from a Millipore Direct-Q 5 filter system (Millipore Corp., Bedford, MA), using a ceramic mortar and pestle into a homogeneous liquid (Vinson et al., 2010). The resulting liquid was analyzed using a digital refractometer (Pal-1 Atago, Co., Tokyo, Japan) to determine the % SSC at room temperature. To determine TA, the homogeneous liquid was clarified with a centrifuge at 15,000 g_n at 4°C for 20 minutes (Model J2-21; Beckman Centrifuge, San Antonio, TX), and the supernatant was filtered with double-layered cheese cloth. The resulting supernatant was brought to a final volume of 40 mL with HPLC water and thoroughly mixed. Five mL of supernatant were diluted to a final volume of 30 mL with HPLC water, which was used to determine TA with an automated titrimeter (Metrohm Titrino Model 751GDP and Metrohm Sample Changer; Metrohm Corp., Herisau, Switzerland). The titrimeter was maintained at 10°C in a Fisher Scientific refrigerated chromatography chamber (Model Isotemp Laboratory Refrigerators; Fisher Scientific, Raleigh, NC). A 0.1 M solution of NaOH was titrated to an end point of pH 8.1. The results were expressed as citric acid equivalent through the following formula: [(mL NaOH x 0.1 N x 0.064 meq·g^{-1} of juice) x 100]. SSC: TA ratio was determined by dividing SSC by TA. The titrimeter also determines the pH of the sample used to determine the TA (Vinson et al., 2010).

Ten berry subsamples from each harvested bush from each harvest date were analyzed to determine the external fruit color. A Minolta CM-2002 Spectrophotometer (Minolta, Tokyo, Japan), using the CIELAB color space (L*, a*, b*, C, h°) was utilized. The CIELAB color space can be visualized as a three dimensional graph, and equal distances on this graph represent visually equal distances in color differences (McGuire, 1992; Voss and Hale, 1998). L* can be visualized as the z axis, L* indicates an objects lightness on a 0 to 100 scale, with 0 representing black and 100 representing white (McGuire, 1992; Voss and Hale, 1998). Hue is represented by a* and b*, and a* can be visualized as the horizontal coordinate (x axis), and a positive a* indicates purplish-red, a negative a* indicates bluish-green (McGuire, 1992; Voss and Hale, 1998). The b* represents the vertical coordinate (y axis), and a positive b* indicates yellow, while a negative b*indicates blue (McGuire, 1992; Voss and Hale, 1998). A more appropriate way to represent these readings is through the use of Chroma (C*) and hue angle (h°), as these values are less likely to be misinterpreted (McGuire, 1992). Chroma indicates the saturation or intensity of the color, and the C* value represents the distance from the origin to the (a*, b*) coordinates (Voss and Hale, 1998). The hue angle (h°) is easier to visualize than a* and b* values, as on a 360° color wheel red-purple corresponds to an angle of 0°, yellow corresponds to an angle of 90°, bluish-green corresponds to 180°, and blue corresponds to an angle of 270° (Sapers, 1984; McGuire, 1992). The berry wax is evaluated by analyzing the L* values (Sapers, 1984; Austin and Bondari, 1993), and the color of the berries were evaluated by analyzing the C* and h° (Austin and Bondari, 1993).

Cultivar vegetative characteristics were evaluated by determining leaf area, chlorophyll readings, and plant growth index. Average leaf area was based on a 30 leaf sample per bush collected late summer and measured with a Licor LI-3100 area meter (Lincoln, NB, USA). Mature leaves located at least 5 nodes away from the terminal bud were used. Chlorophyll readings were taken on 10 leaves per experimental bush. Mature leaves located at least 5 nodes back from the terminal bud were used. Bush heights, as well as the plant width measured perpendicularly and diagonally to the planting row were measured to determine plant growth index of each experimental plant.

Since the experiment was designed as a completely randomized complete block design, fruit and yield characteristic data were based on all measurements across the harvest season as a whole, regardless of harvest date. All experimental data was analyzed using PROC GLIMMIX (SAS Version 9.2.1, SAS Institute Inc., Cary, NC). Mean separations were carried out using the Bonferroni mean separation test. The significance levels were represented by * (0.05), ** (0.01), and *** (0.001) respectively, and P-values ≤ 0.05 were deemed insignificant. Vegetative, flowering, and fruit set characteristic measurements were analyzed individually.

Results and Discussion

In the 2009 flowering season, 5% flowering stage began on March 23 and on April 7 all of the cultivars under test had over 60% open flowers. A week later, on April 14, all cultivars had more than over 90% open flowers (Figure 1). 'Baldwin', 'Montgomery', and 'Onslow' flowering stage was the most advanced on March 24, when 'Tifblue' had the least open flowers. Flowering began approximately 2 weeks later in the 2010 season, but was condensed into 3 weeks as opposed to 5 weeks in 2009 (Figure 1, 2). In the 2010 season, the 5% flowering stage began on April 7 and all cultivars were found to be at 100% full bloom on April 21st. 'Climax' was found to have the highest percentage of open flowers on April 7, when nearly 25% of its flowers were fully open. 'Premier' and 'Tifblue' also had a high percent of open flowers on April 7. 'Ira', 'Onslow', and 'Yadkin' did not reach the 5% flowering stage until April 14. 'Climax' again had the highest percentage of fully open flowers (80%), and 'Premier' and 'Tifblue' flowering rates were not found to be different from 'Climax'. 'Alapaha' and

‘Brightwell’ were found to have over 50% fully opened flowers on April 14, when ‘Ira’ only had 16% fully open flowers.

No differences were observed across cultivars with respect to the percentage of frost damaged flowers in 2009 (Table 1).

In June, ‘Premier’ was found to have the highest number of flower buds, based on the fruit set density expressed as a number of flower buds per mm^2 cane cross sectional area (CCSA) in 2009 (Table 2). ‘Alapaha’, ‘Baldwin’, ‘Brightwell’, ‘Climax’, ‘Montgomery’, ‘Tifblue’, and ‘Yadkin’ were not found to be different with respect to flower bud density from ‘Premier’ ranging from 0.16 fruit per cm^2 to 0.22 fruit per cm^2. ‘Onslow’ was the cultivar with the lowest flower bud number per cm^2 CCSA. The initial fruit set count was made on May 24, 2010 and the final fruit set was determined on June 19. ‘Baldwin’ was found to have the highest initial number of fruit set with 3.2 fruit per cm fruiting wood (Table 2). ‘Alapaha’ and ‘Brightwell’ also had a high initial fruit set number of 2.8 fruit/cm fruiting wood, while ‘Ira’ and ‘Tifblue’ had the lowest initial fruit set of 1.9 and 2.0 fruit/cm fruiting wood respectively. Fruit loss based on the initial and final fruit set number ranged from 0.1 and 0.2 fruit per cm fruiting wood, which is considered negligible.

The earliest ripening varieties in both years were ‘Alapaha’, ‘Climax’, and ‘Premier’ (Figure 3, 4). ‘Brightwell’, ‘Montgomery’, and ‘Tifblue’ had an intermediate ripening period beginning on June 22, and ending on July 16, in 2009 (Figure 3). ‘Baldwin’, ‘Ira’, ‘Onslow’, ‘Powderblue’, and ‘Yadkin’ matured late in 2009. In 2010, ‘Brightwell’ and ‘Tifblue’ also started their ripening early in the season (Figure 4). ‘Ira’, ‘Montgomery’, ‘Powderblue’, and ‘Yadkin’ had an intermediate ripening period beginning on June 28, and ending on July 16, 2010. ‘Baldwin’ and ‘Onslow’ matured late in the season, between July 5, and August 5 in

2010. Additionally, ‘Baldwin’, ‘Brightwell’, and ‘Powderblue’ also had an extended harvest season, lasting up to 5 weeks, or one additional week more than the other cultivars.

In 2009, all cultivars yielded between 1.0 and 1.2 kg per bush (Table 3), and no difference in yield between cultivars tested was found in 2009. In 2010, ‘Tifblue’ was the highest yielding cultivar, producing 2.4 kg/bush, followed by ‘Alapaha’, ‘Brightwell’, Climax, and ‘Premier’ which yielded between 2.0 and 2.3 kg/bush (Table 3). ‘Montgomery’ was the lowest producer in 2010, 1.6 kg per plant, and the fruit yield of all cultivars, with the exception of ‘Tifblue’ were not different. No differences in cumulative yield across both seasons were observed among cultivars (Table 3).

In both years of this study, differences in mean berry weight were found between tested cultivars. ‘Onslow’ had the largest average berry of 1.5 g in both years, and ‘Alapaha’ had the smallest berry of 0.9 and 1.0 g respectively (Table 3). Berries from ‘Baldwin’, ‘Premier’, and ‘Tifblue’ were not different from those of ‘Onslow’ in 2009, and ‘Montgomery’, ‘Premier’, ‘Brightwell’, and ‘Ira’ were not in 2010. ‘Ira’ and ‘Powderblue’ berries were not different in size from ‘Alapaha’ in 2009, and ‘Baldwin’ and ‘Powderblue’ berry size did not differ from ‘Alapaha’ in 2010. Silva et al. (2005) found that ‘Climax’, ‘Premier’, and ‘Tifblue’ all produced larger berries in a Mississippi cultivar trial than were seen in this study, producing berries ranging from 1.7 to 1.9 g.

‘Climax’ was found to have the highest dry berry weight in 2009, weighing 2.7 grams per 10 berries, and ‘Alapaha’, Onslow’, and ‘Powderblue’ dry berry weight were lower, each averaging 2.4 g per 10 berry sample (Table 3). In 2010, ‘Onslow’ had the greatest dry weight per 10 berries, weighing 3.4 per 10 berries, and ‘Brightwell, ‘Ira’, ‘Premier’, ‘Montgomery’, and ‘Yadkin’ were not lower (Table 3). ‘Alapaha’ had the lowest dry berry weight, 1.9 g.

‘Brightwell’ was found to have the firmest berry in 2009 and 2010, measuring 205 and 201 g/mm (Table 4). ‘Climax’ was not found to be different in either season, measuring 194 g/mm and 202 respectively. ‘Montgomery’ had the softest berry in 2009, measuring 164 g/mm, and ‘Alapaha’ was found to have the softest berry in 2010, measuring 169 g/mm. ‘Alapaha’, ‘Montgomery’, and ‘Premier’ had consistently softer berries across seasons, ranging from 164 to 173 g/mm in 2009 and 169 to 177 g/mm in 2010.

‘Baldwin’ had the highest percentage of berries with wet scar in both 2009 and 2010 - 3.0% and 3.4% respectively, and ‘Tifblue’ berries did not have a high percentage of berries with wet scar in either year (Table 4). In 2009, ‘Powderblue’ had the lowest occurrence of wet scar on its berries, and all berries of cultivars except ‘Baldwin’ did not show differences in wet scar occurrence. In 2010, ‘Yadkin’ was found to have the lowest percentage of berries with wet scar.

Berries with low acidity and high pH have good keeping quality (Austin and Bondari, 1993), and a pH of 2.25 to 4.25 has been reported as acceptable (Saftner et al., 2008). In 2009, ‘Yadkin’ berries had the highest pH, measuring 3.65, but the majority of cultivars produced berries that did not have different pH values (Table 5). ‘Baldwin’ and ‘Onslow’ both had lower pH of 3.34 and 3.35 respectively. In 2010, all cultivars again fell within the acceptable range of 2.25 to 4.25 (Table 5). ‘Yadkin’ berries again had the highest pH, measuring 3.9, while ‘Brightwell’, ‘Premier’, and ‘Tifblue’ berries had a lower pH, measuring 3.80. ‘Baldwin’ had the lowest pH of 3.62, while ‘Montgomery’, ‘Onslow’, and ‘Powderblue’ were not found to differ.

Saftner et al. (2008) states that soluble solids content (SSC) above 10% is acceptable for blueberry fruit. In 2009 and 2010, all cultivars were found to have berries in the acceptable range except ‘Onslow’, which had the lowest sugar content of 9.4% in 2009 (Table 5).

‘Alapaha’, ‘Climax’, ‘Brightwell’, ‘Premier’, ‘Tifblue’, and ‘Yadkin’ all had higher sugar contents in both years, and ‘Baldwin’, ‘Montgomery, ‘Onslow’, and ‘Powderblue’ all were found to have lower sugars in both 2009 and 2010. ‘Premier’ was found to have the highest SSC in 2009 at 15.4%, and ‘Onslow’ had the lowest sugar content, 9.4%. ‘Baldwin’, ‘Ira’, and ‘Powderblue’ were not found to differ in sugar content. In 2010, ‘Yadkin’ had the highest SSC, measuring 15.6%, and ‘Baldwin’ had the lowest sugar content, with an SSC of 14.5% (Table 5). ‘Brightwell’, ‘Premier’, and ‘Tifblue’ all had high sugar levels as well, each with just over 15% SSC, and the sugar content of ‘Montgomery’, ‘Onslow’, and ‘Powderblue’ was not different from ‘Baldwin’.

The acceptable range for total acidity (TA) in blueberry, according to Saftner (2008), should vary between 0.3 and 1.3%, and berries with high SS and low TA tend to have a pleasant taste. In 2009 ‘Alapaha’ and ‘Yadkin’ berries were the least acidic and below the optimal range, with TA measuring 0.2% (Table 5). ‘Baldwin’ was found to have the most acidic berries, with a TA of 0.4%. ‘Baldwin’, ‘Montgomery’, ‘Powderblue’, and ‘Tifblue’ were found to fall into the accepted range in 2010, with TA ranging between 0.3 and 0.5%, and all other cultivars fell slightly below this range (Table 5). However, no differences were observed across cultivars for the 2010 season for berry TA.

A high SSC/TA ratio is an indicator of a good tasting blueberry, and a high correlation has been found between this ratio and storage quality (Austin and Bondari, 1993). A ratio between 10 and 33 has been cited as an acceptable range for the SSC/TA ratio (Saftner et al., 2008). In 2009, ‘Baldwin’, with a SSC/TA ratio of 27; ‘Onslow’, 30; ‘Powderblue’, 33; and ‘Ira’, 33 fell within this range (Table 5). The remaining cultivars had SSC/TA ratios ranging from 37 to 62, and Alapaha had the highest ratio at 62. ‘Yadkin’ had the highest ratio of 86 in

2010, and ‘Premier’ also had a high ratio of 84 (Table 5). ‘Montgomery’ had the lowest ratio of 52. None of the cultivars were found to have ratios within the described optimal range in 2010. The high ratios in 2010 are likely due to the low acid content of the berries.

‘Powderblue’ had the lightest berry skin in both years, with lightness (L*) measurements of 32.45 and 36.74 respectively (Table 6). ‘Baldwin’, ‘Ira’, and ‘Yadkin’ had consistently darker berries across 2009 and 2010 with L* ranging from 25.61 to 30.61 (Table 5). ‘Powderblue’ had the most intensely colored berries, or highest chroma (C*) in both seasons, 4.10 in 2009 and 5.84 in 2010 (Table 6). ‘Premier’ and ‘Tifblue’ had intensely colored berries across seasons. ‘Alapaha’ berries were found to have the lowest C* in both years, 2.22 and 3.63 respectively. In 2009, the h˚ angle of the berries fell between bluish-green (180˚) and blue (270˚) (Table 5). ‘Yadkin’ was found to have the most blue berry skin in 2009, and ‘Alapaha’ berries were found to be greener. All other cultivars tested were not found to be different than ‘Yadkin’ in terms of their skin color hue angle. In 2010, the h˚ angel of the berries of all cultivars in test fell between blue (270˚) and red-purple (360˚). ‘Powderblue’ berries were the most blue in 2010, and ‘Onslow’ berries were the most red-purple. ‘Alapaha’, ‘Baldwin’, and ‘Brightwell’ were not found to be different than ‘Onslow’ in 2010.

No differences were observed among cultivars with regards to plant growth index (PGI) (Table 7). In both 2009 and 2010, ‘Yadkin’ was found to have the greatest leaf area, measuring 17.4 and 13.7 cm^2 (Table 7). ‘Alapaha’, ‘Baldwin’, ‘Brightwell’, ‘Climax’, and ‘Ira’ had smaller leaf area in both seasons. In 2009, ‘Brightwell’ had the highest chlorophyll levels (48.0), while ‘Alapaha’, ‘Montgomery’, ‘Onslow’, ‘Powderblue’, ‘Premier’, and ‘Tifblue’ were not found to differ (Table 7). ‘Yadkin’ was the cultivar with the lowest chlorophyll level in 2009. In 2010, ‘Brightwell’ had the highest chlorophyll content and only ‘Climax’ and ‘Yadkin’ had lower foliar chlorophyll levels.

‘Yadkin’ was found to have the most sprawling growth habit, but all cultivars except ‘Alapaha’ and ‘Onslow’ were not found to be different, with a form index ranging from 2.4 to 3.7 (Table 8). ‘Alapaha’ had the most upright growth habit.

Conclusions

The 2010 results indicated that ‘Climax’ and ‘Premier’ are early flowering cultivars and thus might run the risk of damage due to late spring frost. ‘Alapaha’ appears to bloom later, although it still has an early flowering habit, and thus may not be as prone to damage from late spring frost. Similarly, Dozier et al. (1991) found ‘Climax’ to be the earliest cultivar in their variety trial in central Alabama, as did NeSmith (2006) in a Georgia variety trial. ‘Alapaha’ was found to bloom just after ‘Climax’ in Georgia as well (NeSmith, 2006).

‘Baldwin’ was shown to have a high fruit set in both experimental years, but this did not translate into high yields in either season. Fruit loss didn’t seem to be an issue as indicated by the initial and final fruit set densities. Davies (1996) states that decreases in fruit set, or fruit drop, tend to occur in the first three to four weeks after bloom and gradually decrease for the next few weeks. The initial fruit set was determined in late May in 2010, which might have been too late, since the majority of fruit loss might already have occurred.

‘Alapaha’, ‘Climax’, and ‘Premier’ had early ripening seasons in both years of this study. These results suggest these cultivars are likely good selections for North Alabama for targeting early market production. Our data are in agreement with conclusions by NeSmith (2006), who also found ‘Alapaha’ and ‘Climax’ to be the earliest ripening varieties in Georgia. ‘Baldwin’ and ‘Onslow’ matured late in the season, and would be good candidates for the extension of the blueberry harvest season in North Alabama. ‘Baldwin’, ‘Brightwell’, and ‘Powderblue’ were found to have extended harvest seasons, which suggests they may be well suited for production at pick-your-own operations. Dozier et al. (1991) also found that ‘Powderblue’ had an extended 5 week harvest season in Alabama. Berries sold late in the season receive lower prices than berries sold in the early market, but a late ripening variety with an extended season has the benefit of extending the season as well as likely overlapping with other ripening seasons. ‘Baldwin’ berries are not well suited for shipping, as they likely have a shorter shelf life than other cultivars tested, as indicated by low berry pH and high occurrence of picking scar, and likely should be considered for pick-your-own operations mainly.

Due to greater berry firmness, ‘Brightwell’ and ‘Climax’ may be better suited for shipping and mechanical harvesting as compared to the other cultivars tested. ‘Alapaha’, ‘Montgomery’, and ‘Premier’ each had soft berries over both seasons. These results coincide with the findings of NeSmith (2006), who also found ‘Brightwell’ and ‘Climax’ to have the firmest berries of the rabbiteye blueberry cultivars tested in Georgia. Additionally, Silva et al. (2005) found that ‘Climax’ was the firmest berry of those tested in Mississippi. ‘Alapaha’, ‘Onslow’, and ‘Yadkin’ were indicated to have a more upright growth habit in 2010, which is also desirable for mechanical harvest.

‘Brightwell’ and ‘Yadkin’ berries may be well-suited for the shipped fresh market, as they has a firm berries and the high pH. Firm berries ship well, and a high berry pH indicates a good shelf-life.

While no differences were seen across cultivars in 2009 with respect to yield per bush or in cumulative yield across both seasons, 2010 yield data indicate that ‘Alapaha’, ‘Brightwell’, ‘Premier’, and ‘Tifblue’ were high yielding cultivars. Late spring frost damage experienced in the Cullman region in 2009 may be accountable for the low crop of ‘Baldwin’ and ‘Powderblue’ cultivars. These coincide with findings by Dozier et al. (1991), who concluded that ‘Tifblue’ and ‘Premier’ are highly productive cultivars in Central Alabama. Additionally, ‘Powderblue’ was found to be a low producer in early years, eventually becoming one of the top producers (Dozier, 1991).

‘Premier’ and ‘Climax’ had the highest sugar content among all cultivars in our test. ‘Onslow’ and ‘Baldwin’ were found to have lower SSC in both years. ‘Yadkin’ berries were least acidic and ‘Baldwin’ berries were the most acidic in 2009, but differences were not observed in 2010. The low TA generally led to higher SSC/TA ratios.

In both years, ‘Powderblue’ had the lightest colored berry, which indicates the presence of a waxier surface (Austin and Bondari, 1993; Sousa et al., 2006). Additionally, ‘Powderblue’ had the highest chroma, indicating the most saturated color, and the hue angle closest to blue (270°). In addition to color being an indicator of ripeness or post-harvest quality, deep-blue berries with a waxy coat, which produce a light-blue berry tend to be the most desirable (Austin and Bondari, 1993; Sousa et al., 2006). ‘Premier’ and ‘Tifblue’ both had colors that indicated high quality fruit in both years. Similarly, NeSmith (2006) indicated that ‘Tifblue’ was the most pleasantly colored berry of the cultivars tested in Georgia, and ‘Alapaha’ to be the least desirable. In Mississippi grown rabbiteyes, Silva et al. (2005) found that ‘Premier’ and ‘Tifblue’ had light berries with a hue angle indicating a highly blue colored berry as well. The pleasant colored berries found on ‘Powderblue’, ‘Premier’, and ‘Tifblue’ make them good candidates for sale at farmers markets and the fresh market. ‘Powderblue’ berries, however, tended to be small, which is not desirable for the fresh market. ‘Tifblue’ and ‘Premier’ produced large, pleasant colored berries.

Nothing can be concluded from the PGI from either year, as no differences were found. Leaf area and chlorophyll readings did not clearly indicate which cultivars were most vigorous. ‘Yadkin’ leaves were found to have the lowest chlorophyll but the highest leaf area, and conversely ‘Brightwell’ leaves were found to have the highest chlorophyll levels and were smaller across seasons.

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Figure 1. Percentage fully open flowers of selected blueberry cultivars, Cullman, AL, 2009.

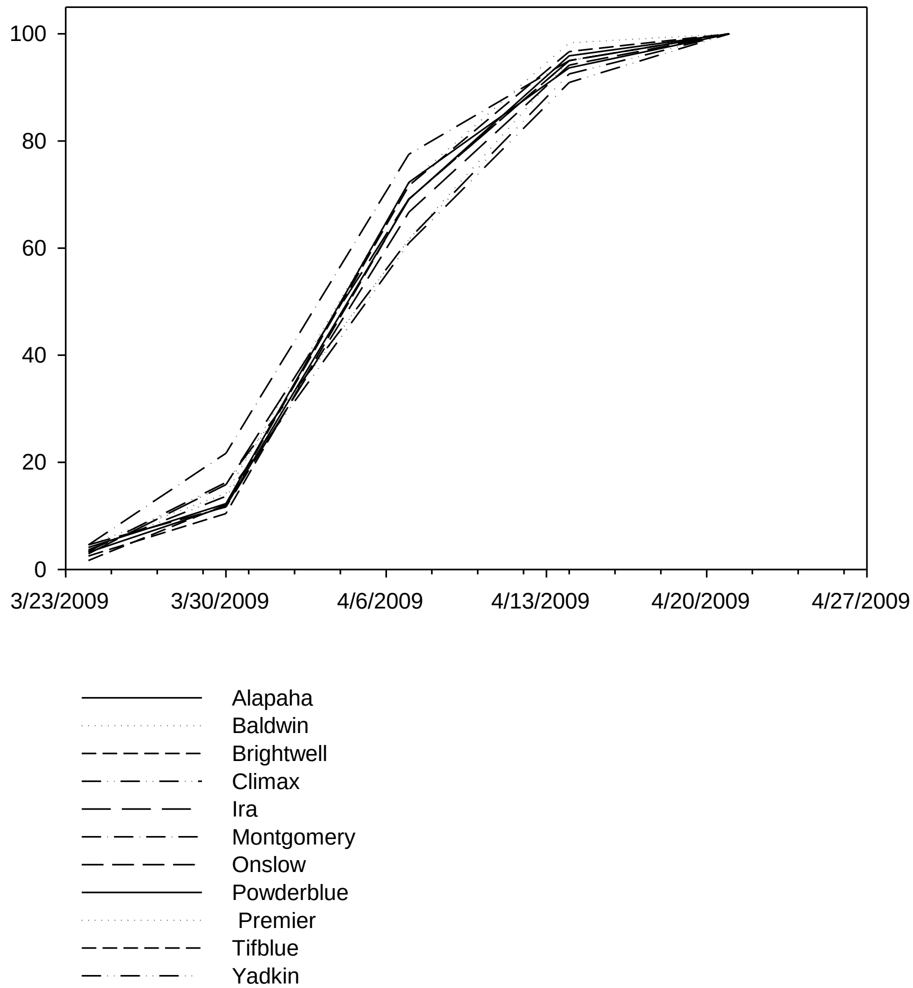

Figure 2. Percentage fully open flowers of selected blueberry cultivars, Cullman, AL, 2010.

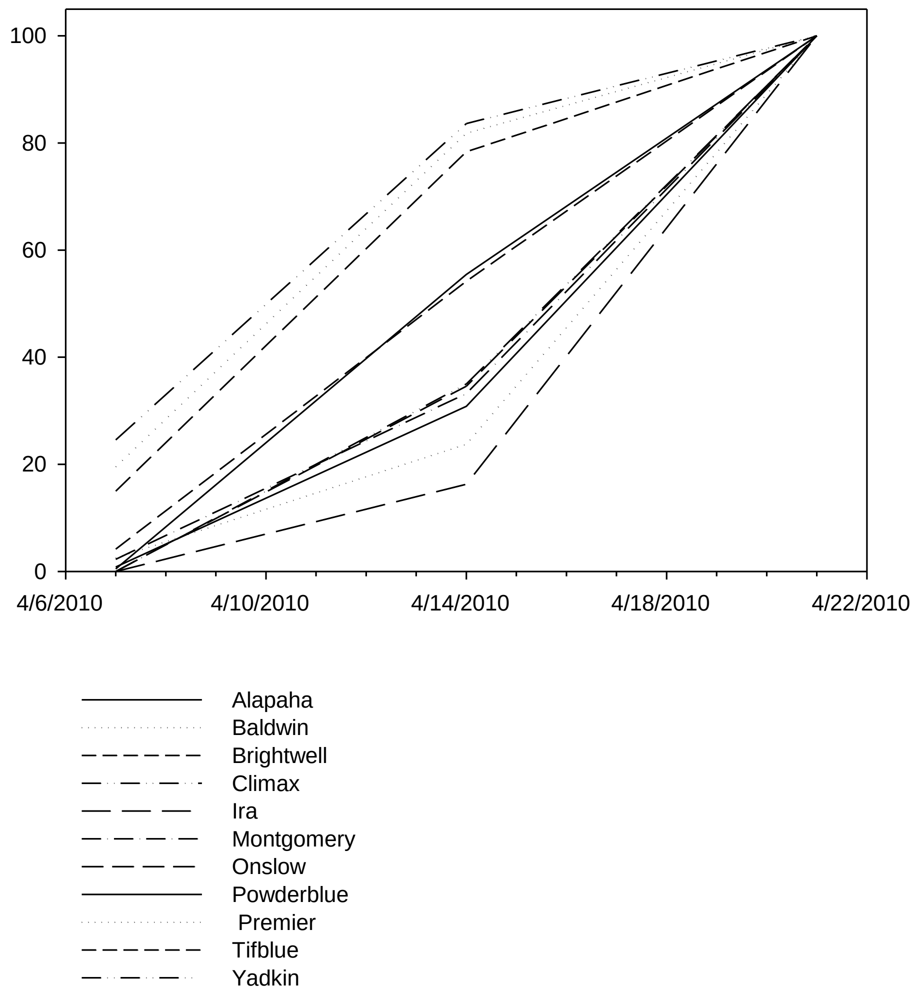

Table 1. Percentage frost damaged fully open flowers of rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2009.

Cultivar	Percentage frost damaged flowers[z]
Alapaha	0.1
Baldwin	0.8
Brightwell	0.8
Climax	0.6
Ira	0.2
Montgomery	1.1
Onslow	0.3
Powderblue	0.2
Premier	0.1
Tifblue	0.8
Yadkin	0.4
P-value	0.4413
Significance	N.S.

[z] 0=0-5%, 1=6-20%, 2=21-40%, 3=41-60%, 4=61-80%, 5=81-100%

N.S., *, **, *** Indicates nonsignificant and significant differences at $P \leq 0.05$, 0.01 or 0.001 respectively.

Table 2. Flower bud density, initial and final fruit set density of selected rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2009 and 2010.

Cultivar	No. flower buds/CCSA, cm^2	Initial no. of fruit set/fruiting wood $(cm)^z$	Final no fruit set/fruiting wood $(cm)^z$
	2009	2010	
Alapaha	0.22 abc	2.8 ab	2.7 ab
Baldwin	0.22 ab	3.2 a	3.0 a
Brightwell	0.16 abc	2.8 ab	2.6 ab
Climax	0.19 abc	2.3 bc	2.2 bc
Ira	0.14 bc	1.9 c	1.8 c
Montgomery	0.16 abc	2.4 bc	2.3 bc
Onslow	0.13 c	2.6 abc	2.4 abc
Powderblue	0.13 bc	2.3 bc	2.2 bc
Premier	0.24 a	2.1 bc	2.0 bc
Tifblue	0.22 ab	2.0 c	1.9 c
Yadkin	0.20 abc	2.5 abc	2.4 abc
P-value	<.0001	<.0001	<.0001
Significance	***	***	***

[z]Based on 2 canes per plant.

N.S., *, **, *** Indicates nonsignificant and significant at $P \leq 0.05$, 0.01 or 0.001 respectively.

Figure 3. Season of ripening of selected rabbiteye blueberry cultivars, Cullman, AL 2009.

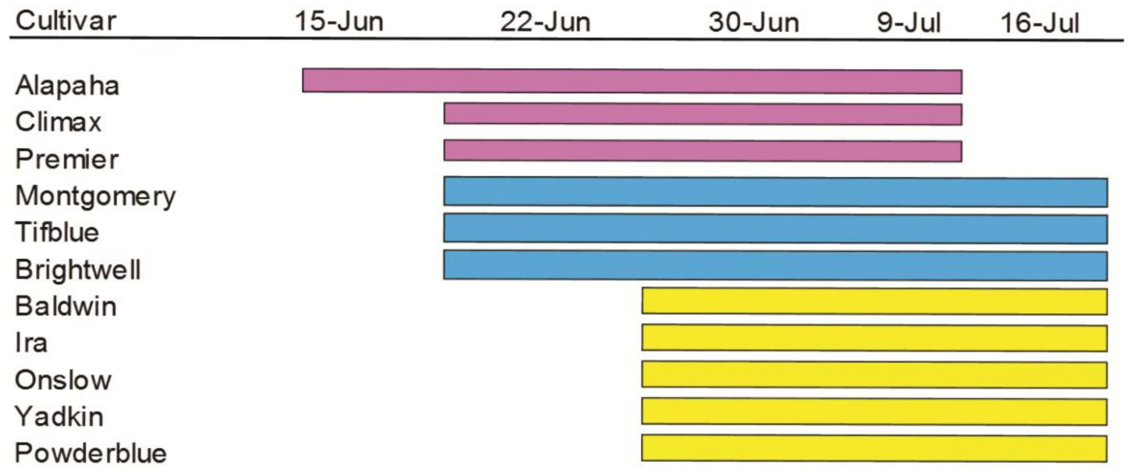

Figure 4. Season of ripening of selected rabbiteye blueberry cultivars, Cullman, AL, 2010.

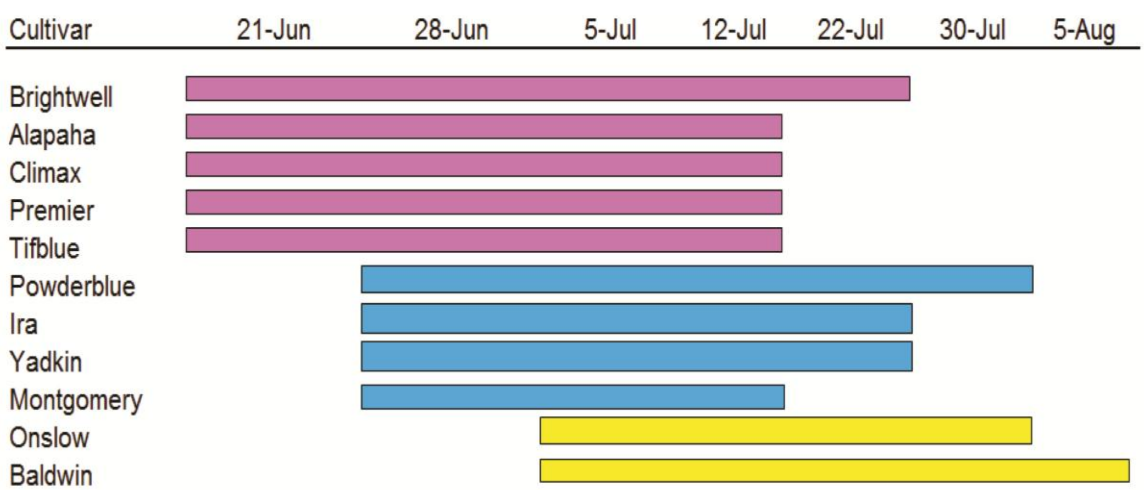

Table 3. Average yield, cumulative yield, mean berry weight, and mean berry dry weight of selected rabbiteye cultivars grown at the NAHRC, Cullman, AL, 2009 and 2010.

Cultivar	Average berry weight (g)[z]	10 Berry Dry Weight (g)	Average yield per bush (kg)	Cumulative yield per bush (kg)
	2009			
Alapaha	0.9 e	2.4 b	0.8	.
Baldwin	1.5 ab	2.5 ab	0.9	.
Brightwell	1.2d	2.6 ab	1.2	.
Climax	1.3 cd	2.7 a	1.1	.
Ira	1.1 de	2.5 ab	1.1	.
Montgomery	1.3 bcd	2.4 ab	1.1	.
Onslow	1.5 a	2.4 b	1.1	.
Powderblue	1.1 de	2.4 b	0.9	.
Premier	1.4 abc	2.6 ab	0.8	.
Tifblue	1.4 abc	2.5 ab	1.0	.
Yadkin	1.2 cd	2.4 ab	1.1	.
P-value	<.0001	0.0022	0.5	
Significance	***	**	N.S.	
	2010			
Alapaha	1.0 e	1.9 e	2.0 ab	10.4
Baldwin	1.2 de	3.0 bcd	1.6 b	8.9
Brightwell	1.4 ab	3.2 ab	2.0 ab	11.6
Climax	1.2 cde	2.6 d	2.0 ab	9.2
Ira	1.4 abc	3.2 abc	1.7 b	11
Montgomery	1.5 a	3.1 abcd	1.6 b	7.9
Onslow	1.5 a	3.4 a	1.6 b	8.7
Powderblue	1.2 de	2.8 cd	1.6 b	10.1
Premier	1.4 ab	3.1 abcd	2.3 ab	10.3
Tifblue	1.3 bcd	2.9 bcd	2.4 ab	11.3
Yadkin	1.3 bcd	3.0 abcd	1.7 b	10.3
P-value	<.0001	<.0001	0.0001	0.2015
Significance	***	***	***	N.S.

[z]Based on a 50 berry sample per plant.

N.S., *, **, *** Indicates nonsignificant and significant differences at P ≤ 0.05, 0.01 or 0.001 respectively.

Table 4. Wet stem scar and fruit firmness, of selected rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2009 and 2010.

Cultivar	Wet stem scar (%)[z]	Average fruit firmness (g/mm)[y]
	2009	
Alapaha	1.0 b	173 def
Baldwin	3.0 a	181 cde
Brightwell	1.6 b	205 a
Climax	1.4 b	202 ab
Ira	1.0 b	185 cd
Montgomery	1.4 b	164 f
Onslow	1.4 b	189 bc
Powderblue	0.9 b	177 de
Premier	1.7 ba	173 def
Tifblue	1.9 ba	172 ef
Yadkin	1.0 b	189 bc
P-value	<.0001	<.0001
Significance	***	***
	2010	
Alapaha	2.1 bc	169 f
Baldwin	3.4 a	179 de
Brightwell	1.9 bc	201 a
Climax	1.8 bc	194 ab
Ira	1.7 bc	185 cd
Montgomery	2.8 ab	172 ef
Onslow	1.6 bc	186 bcd
Powderblue	1.4 c	175 ef
Premier	2.0 bc	177 ef
Tifblue	2.4 abc	177 e
Yadkin	1.3 c	189 bc
P-value	<.0001	<.0001
Significance	***	***

[z]Percentage based on a 50 berry sample per plant.

[y]Average based on a 10 berry sample per plant.

N.S., *, **, *** Indicates nonsignificant and significant differences at P ≤ 0.05, 0.01 or 0.001 respectively.

Table 5. Soluble solids content, pH, total acidity, and SSC/TA ratio of selected rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2009 and 2010.[z]

Cultivar	pH	Soluble solids content (%)	Total acidity (%)	SSC/TA
		2009		
Alapaha	3.63 ab	14.5 ab	0.2 abc	62
Baldwin	3.34 c	12.0 bcd	0.4 a	27
Brightwell	3.54 abc	13.7 ab	0.3 abc	49
Climax	3.51 abc	15.2 a	0.4 ab	39
Ira	3.5 abc	10 d	0.3 abc	33
Montgomery	3.48 abc	13.0 abc	0.3 abc	40
Onslow	3.35 c	9.4 d	0.3 abc	30
Powderblue	3.43 bc	10.8 cd	0.3 abc	10
Premier	3.54 abc	15.4 a	0.3 abc	55
Tifblue	3.51 abc	14.6 ab	0.4 ab	37
Yadkin	3.65 a	13.5 b	0.2 c	60
P-value	<.0001	<.0001	0.003	
Significance	***	***	**	
		2010		
Alapaha	3.77 bc	15.1 bc	0.2	75
Baldwin	3.62 f	14.5 f	0.3	46
Brightwell	3.79 b	15.2 b	0.2	77
Climax	3.75 bcd	15.0 bcd	0.3	60
Ira	3.74 bcde	15.0 bcde	0.2	63
Montgomery	3.65 ef	14.6 ef	0.3	52
Onslow	3.69 cdef	14.8 cdef	0.2	61
Powderblue	3.67 def	14.7 def	0.3	57
Premier	3.80 b	15.2 b	0.2	84
Tifblue	3.80 b	15.2 b	0.5	34
Yadkin	3.91 a	15.6 a	0.2	86
P-value	<.0001	<.0001	0.50	
Significance	***	***	N.S.	

[z]Based on 20 g sample from each plant harvested.

N.S., *, **, *** Indicates nonsignificant and significant differences at $P \leq 0.05$, 0.01 or 0.001 respectively.

Table 6. Fruit lightness (L*), chroma (C*), and hue angel (h°) of selected rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2009 and 2010.[zy]

Cultivar	L*	C*	h°
		2009	
Alapaha	28.94 cd	2.22 d	233.0 b
Baldwin	27.67 e	2.88 c	263.8 a
Brightwell	27.95 de	2.94 c	263.5 a
Climax	29.6 c	3.40 b	258.9 a
Ira	26.56 f	2.28 d	260.2 a
Montgomery	29.19 c	2.89 c	260.5 a
Onslow	27.94 de	2.68 c	261.2 a
Powderblue	32.45 a	4.10 a	262.5 a
Premier	31.03 b	3.65 b	258.9 a
Tifblue	31.36 b	3.51 b	258.9 a
Yadkin	25.61 f	2.29 d	266.8 a
P-value	<.0001	<.0001	<.0001
Significance	***	***	***
		2010	
Alapaha	29.97 ef	3.63 g	280.2 abc
Baldwin	28.96 f	4.58 de	280.5 ab
Brightwell	31.41 cd	4.82 cd	281.6 ab
Climax	31.53 cd	4.53 de	276.7 de
Ira	30.61 de	4.45 e	278.3 cd
Montgomery	32.62 bc	4.92 c	277.3 de
Onslow	33.44 b	4.09 f	281.9 a
Powderblue	36.74 a	5.84 a	272.2 f
Premier	31.87 c	5.09 bc	276.0 e
Tifblue	31.49 cd	5.24 b	275.6 e
Yadkin	29.54 ef	4.39 e	279.7 bc
P-value	<.0001	<.0001	<.0001
Significance	***	***	***

[z]Measured in CIELAB. L*= lightness, C*= chroma, h°= hue angle (0°= red-purple, 90◦= yellow, 180°= bluish-green, 270°= blue)

[y]Average based on 10 berry sample from each plant harvested.

N.S., *, **, *** Indicates nonsignificant and significant differences at P ≤ 0.05, 0.01 or 0.001 respectively.

Table 7. Plant growth index, leaf area, and chlorophyll content of selected rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2009 and 2010.

Cultivar	Plant growth index (cm^3)	Leaf Area (cm^2)[z]	Chlorophyll[y]
		2009	
Alapaha	25644	13.1 bcd	46.6 ab
Baldwin	33337	13.0 bcd	40.3 bcde
Brightwell	32379	12.1 cd	48.0 a
Climax	32609	10.9 d	39.9 cde
Ira	34419	11.1 d	39.8 de
Montgomery	36913	12 cd	46.3 abc
Onslow	33477	12.9 bcd	46.9 a
Powderblue	27154	14.9 b	44.9 abcd
Premier	37723	13.9 bc	44.3 abcde
Tifblue	41039	13.9 bc	42.0 abcde
Yadkin	26275	17.4 a	38.0 e
P-value	0.1138	<.0001	<.0001
Significance	N.S.	***	***
		2010	
Alapaha	33273	10.7 1cd	46.2 ab
Baldwin	42007	11.5 bcd	40.5 abc
Brightwell	38413	10.0 d	46.8 a
Climax	38167	10.6 cd	36.9 bc
Ira	40225	11.1 cd	40.4 abc
Montgomery	43245	13.4 ab	46.4 ab
Onslow	41408	12.5 abc	46.4 ab
Powderblue	34069	11.0 cd	44.6 abc
Premier	49216	13.4 ab	44.4 abc
Tifblue	49400	12.4 abc	40 abc
Yadkin	35446	13.7 a	36.1 c
P-value	0.1005	<.0001	<.0001
Significance	N.S.	***	***

[z]Average of 30 leaves per bush, for a total of 132 plants.

[y]Average based on 10 leaves per plant.

N.S., *, **, *** Indicates nonsignificant and significant differences at $P \leq 0.05$, 0.01 or 0.001 respectively.

Table 8. Bush growth habit of selected rabbiteye blueberry cultivars grown at the NAHRC, Cullman, AL, 2010.

Cultivar	Bush form[z]
Alapaha	2.4 b
Baldwin	2.8 a
Brightwell	2.9 a
Climax	2.4 ba
Ira	2.8 a
Montgomery	3.4 a
Onslow	2.4 b
Powderblue	2.4 ba
Premier	2.4 ba
Tifblue	2.9 a
Yadkin	3.7 a
P-value	<.0001
Significance	***

[z] 1=Upright 5=Sprawling

N.S., *, **, *** Indicates nonsignificant and significant differences at P ≤ 0.05, 0.01 or 0.001 respectively.

CHAPTER THREE

Investigations to Determine the Ornamental Quality of Selected Rabbiteye Blueberry Cultivars for their Utilization as Edible Landscape

Abstract

Rabbiteye blueberries (*Vaccinium ashei* Reade) are the primary blueberry species produced in Alabama. Old and new rabbiteye cultivars ‘Alapaha', 'Baldwin', 'Brightwell', 'Climax', 'Ira', 'Montgomery', 'Onslow', 'Powderblue', ' Premier', 'Tifblue', and 'Yadkin' were evaluated at the North Alabama Horticulture Research Center, Cullman, AL (lat. 34° 11' N, long. -86° 47' E; USDA Hardiness Zone 7B) to evaluate and compare their ornamental qualities for use as functional landscape plants by analyzing fall foliage color, berry surface color, summer foliage color, and bush form. The results of our study suggest ‘Alapaha’ and ‘Yadkin’ had long lasting red fall foliage, with ‘Yadkin’ displaying a lighter, more intense fall color and ‘Alapaha’ having duller and darker fall color. ‘Ira’ and ‘Premier’ were found to have intense, long lasting yellow fall color. ‘Powderblue’ had the most waxy and attractive summer foliage and fruit appearance. The growth habit of all studied cultivars tended to be upright, with ‘Alapaha’ and ‘Onslow’ expressing the most upright plant growth habit.

Introduction

Rabbiteye blueberries (*Vaccinium ashei* Reade) possess a number of appealing ornamental qualities in addition to their fruit bearing qualities, which can include attractive waxy foliage, fall color, form, flowers, exfoliating bark, as well as the fruit itself. The ornamental blueberry market, although small by comparison, is becoming more important, and should be considered when evaluating new cultivars (Scalzo et al., 2009b). Merhaut (2003) states that some of the outstanding characteristics that will accelerate the customer desire for blueberry plants in the ornamental market are as follows: diversity, as there are many cultivars available with a range of growth habits, canopy, shapes, and leaf color; growth habit, as there are vigorously growing varieties as well as dwarfed varieties; leaf characteristics, as there are varying colors of leaves from green to glaucous blue; fruiting characteristics, as the fruit are good for both eating and as a landscape accent; and disease and drought resistance, as resistant varieties tend to require less input costs.

In the United States as well as internationally, there is increased interest in retail sales of blueberries for home use (Merhaut, 2003). Scalzo et al. (2009b) reported that in New Zealand, retail sales of blueberry plants has increased significantly in recent years, and this unprecedented demand is likely due to the healthful properties of blueberries. Additionally, current trends in New Zealand public gardens are toward decorative plants which are also functional (Scalzo et al., 2009b). This particular feature has likely fueled the interest in functional landscape plants. In Germany, 50% of blueberry plants are currently sold to home gardeners (Scalzo et al., 2009a). Some of the characteristics which tend to be most important to home gardeners are ease of management, attractive foliage and flowers, attractive growth habit, and good fruit production (Scalzo et al., 2009a).

Rabbiteye blueberries can possess a number of desirable ornamental qualities in each season. In early spring, rabbiteye blueberries produce small, white, bell-shaped flowers. Although the individual flower size is small, there are typically numerous flowers on a blueberry bush, which are quite attractive. The foliage of some blueberries possesses a blue to silver tinge

(Figure 1), giving a pleasant appearance to the bush. Some cultivars have a more pronounced white or bluish tinge than others. Berries also add to the ornamental characteristics, as they too can possess waxy coating (Figure 2). Aside from the benefits of having an edible landscape plant, the colors of the berries can make the appearance of the shrub more attractive. Some berries can have a waxy appearance, while others are darker blue to black colored. The color of fresh blueberries is dependent primarily on the extent of the waxy bloom present in the fruit (Sapers et al., 1984). Additionally, in the fall, the shrubs exhibit brilliant fall color, ranging from yellow to red (Figure 3), and the fall color can be as brilliant as some of the more popular shrubs with fall color such as nandina (*Nandina domestica*) (Figure 4, 5). Some blueberry cultivars have bushes with attractive exfoliating bark (Figure 6), which could add to their landscape appeal.

As home gardeners begin planting more blueberry bushes, science-based cultivar evaluation of plant ornamental characteristics will help homeowners select the best cultivars suited for use in the landscape as well as can provide nursery growers useful additional tools to market rabbiteye blueberry plants. By assessing both new and old rabbiteye cultivars, novel plant traits can be identified. Our study, aimed to evaluate 11 new and old rabbiteye blueberry cultivars and compare their ornamental qualities by analyzing an array of valuable ornamental plant features including berry color, fall color, summer foliage color, and bush form.

Materials and Methods

In 2007, eleven rabbiteye blueberry cultivars planted in Cullman, AL (lat. 34° 11' N, long. -86° 47' E), USDA Hardiness Zone 7B, at the North Alabama Horticultural Research Center in a randomized complete block design fashion with 6 replications and 2 plants per replication. The plants were arranged spatially with 1.5 m within rows and 3.1 m between rows. The plants were purchased as rooted cuttings in 2006 and grown in pots for one additional season prior to planting in the field. The older releases included in our test were ‘Baldwin, ‘Brightwell’, ‘Climax’, ‘Powderblue’, ‘Premier’, and ‘Tifblue’, and the newly released cultivars were ’Alapaha’ ‘Ira’, ‘Montgomery’, ‘Onslow’, and ‘Yadkin’. The blueberry orchard was established and maintained at or above commercially acceptable management practices (Himelrick, 1995).

Fall foliage color is caused by chlorophyll degradation and anthocyanin accumulation in the leaves, and decreasing temperatures and photoperiods play a role in fall foliage color progression and expression (Schaberg et al., 2003). Considerable within-species variation in anthocyanin expressions have been documented in other species (Schabetg et al., 2003). To evaluate the quality of the fall color between rabbiteye blueberry cultivars under test, 10 mature leaves from each experimental bush were collected for a five week period starting on November 15, 2008 and continuing until December 5, 2008. The same procedure was followed in 2009, and fall color was monitored from October 30 through November 25. Mature leaves located below the fifth node from the terminal bud were collected. The leaves were evaluated using a Minolta CM-2002 Spectrophotometer (Minolta, Tokyo, Japan) using the CIELAB color space (L*, a*, b*, C*, h°). The hue angle, or perception of red, orange, yellow, green, or purple and the chroma, which is the color’s departure from gray or the purity of the color (Voss and Hale 1998), were examined to determine the cultivars with the strongest fall colors. According to McGuire (1992), and Voss and Hale (1998), the CIELAB color space can be visualized as a three dimensional graph, and equal distances on this graph represent visually equal distances in color differences. L* indicates an objects lightness on a 0 to 100 scale, with 0 representing black and 100 representing white (McGuire, 1992; Voss and Hale, 1998), and can be visualized as the z axis. Hue is represented by a* and b*, and a* can be visualized as the horizontal coordinate (x axis), where a positive a* indicates purplish-red, a negative a* indicates bluish-green (McGuire, 1992; Voss and Hale, 1998). The b* represents the vertical coordinate (y axis), where a positive b* indicates yellow, while a negative b*indicates blue (McGuire, 1992; Voss and Hale, 1998). A more appropriate way to represent these readings is through the use of Chroma (C*) and hue angle (h°), as these values are less likely to be misinterpreted (McGuire, 1992). The C* indicates a color's saturation or purity, and is also described as the degrees of departure from gray of the same lightness, and the C* value represents the distance from the origin to the (a*, b*) coordinates (McGuire, 1992; Voss and Hale, 1998). The intensity of the color across the fall period (expressed as weeks 1 to 5) can likely help indicate cultivars with more consistent as well as more striking fall color. The hue angle (h°) is easier to visualize than a* and b* values, as on a 360° color wheel red-purple corresponds to an angle of 0°, yellow corresponds to an angle of 90°, bluish-green corresponds to 180°, and blue corresponds to an angle of 270° (Sapers, 1984; McGuire, 1992). A consistent h° can be used to indicate a cultivar with a more uniform fall color across the season.

In September, 2010, 10 mature leaves were collected from each experimental bush to evaluate the presence of a waxy coat on leaves. Mature leaves were collected from the fifth node from the terminal bud. Ten leaves from each of the two bushes per replication were collected (120 readings per cultivar), and the leaf samples were evaluated using a Minolta Spectrophotometer CM-2002 (Minolta Camera Co., Ramsey, NJ), where L* values were used to determine the lightness of each leaf in the sample. C* and h° values were also analyzed to interpret the color of the leaves.

During the 2009 and 2010 harvest seasons, a 10 berry composite sample from each cultivar grown on both soil types were evaluated for lightness of their skin in order to evaluate the presence of a waxy coat on the berry. The light-scattering effect of the wax on the berry surface is responsible for the fruit's color (Sapers et al., 1984). Additionally, C* and h˚ values were investigated on berry surface color. The berry samples were also evaluated using a Minolta CM-2002 Spectrophotometer (Minolta, Tokyo, Japan) with CIELAB color space (L*, a*, b*, C*, h˚).

The overall growth habit of the bushes was evaluated using a five point scale with 1 indicating an upright growth habit, and 2 – 5 values indicating a more sprawling habit as values increase (Scalzo et al. 2009a, b; Ehlenfeldt and Finn, 2007). Additionally, any distinct characteristics, such as exfoliating bark were recorded for each experimental plant.

The data on leaf color, berry color, and growth habit were analyzed using the GLIMMIX procedure in SAS 9.2 (SAS institute, Inc., Cary, NC). Mean separation was conducted on the berry color and bush form using Bonferroni mean separation test at a=0.05. The GLIMMIX procedure in SAS 9.2 (SAS institute, Inc., Cary, NC) was also used to examine variance in fall color measurements across dates in both 2008 and 2009. If only the main effect was significant, mean separation was conducted on the berry color and bush form using Bonferroni mean separation test. If cultivar by date interaction was significant, polynomial contrasts and paired comparison contrast were used to test simple effects at $P \geq 0.05$.

Results and Discussion

The fall leaf color on all 11 rabbiteye blueberry cultivars in our study tended to get darker and redder as the seasons progressed in both 2008 and 2009 seasons as indicated by the

L* values and h° angle (Table 1, 3). L values can range from black = 0 to white = 100, and h° of 0 is red while 90 is yellow (Voss and Hale, 1998). At the beginning of the 2009 season, the cultivars with the highest L* values also had the highest h° indicating that the leaves are most yellow and reflective at the beginning of the season (Table 1). Additionally h° tended to be highest (most yellow) in the first two weeks in 2008, then decreasing, becoming increasingly red over the next three weeks (Table 3). In 2008, the h° for week one and two ranged from 70.0 to 83.4, and eventually decreased to a range of 43.3 to 56.0 at week five. In 2009, the leaf hue was not affected by the cultivar by date interaction, so the mean interaction between h° across all cultivars and dates was analyzed, and a highly significant quadratic response was observed indicating all cultivars became more red and less yellow as the fall season progressed (Table 3). The h° indicate more yellow foliage in all cultivars in the first three weeks in 2009, ranging from 72.3 to 77.3, and becoming progressively redder with a range of 51.5 and 60.7 during the fifth week. In 2008, the chroma value (C*), tended to peak on November 13 for all cultivars tested, and was the highest for 'Tifblue' (24.14) and lowest for 'Baldwin' (19.44) (Table 2). The leaf chroma value in 2009 tended to increase as the season progressed, peaking on November 19.

'Ira' was found to have consistently light fall colors across 2008 and 2009, and 'Alapaha' was found to have consistently darker fall color across both years (Table 1). In 2008, 'Ira' L* values ranked high across the season and showed linear response with respect to lightness of the leaves – the leaves became darker as the season progressed, but in 2009 'Ira' leaf lightness showed a quadratic timing response as the season progressed. 'Alapaha' was found to consistently have a low L* values, or darker foliage in both years. In 2008, a linear relationship between dates was observed, and in 2009 a quadratic relationship between dates was observed.

'Ira' was the blueberry cultivar which had consistently had high color intensity as expressed by the C* value across both years, as well as 'Yadkin' (Table 2). 'Ira' fall color changed in a linear fashion in 2008 and in a quadratic fashion in 2009, and a quadratic relationship was observed to affect 'Yadkin' chroma over both years. This suggests that 'Ira' and 'Yadkin' may hold a more intense fall color for an extended period of time. 'Alapaha' and 'Onslow' tended to have a consistently low fall leaf chroma across both seasons. A quadratic relationship between cultivar and timing was found accountable for the effect on color intensity in 2008 for 'Alapaha', while the relationship was linear in 2009. 'Onslow' C* measurements exhibited a quadratic relationship between dates across both seasons. These findings suggest that 'Alapaha' and 'Onslow' also may hold fall color for an extended period of time, although they likely exhibit a less intense fall color than 'Ira' and 'Yadkin'.

A quadratic relationship between cultivar and timing was found accountable for low h° angle of 'Yadkin' fall color in 2008 (Table 3). This cultivar was the most consistently red cultivar among all tested cultivars throughout the whole season. In 2009, 'Yadkin' had the second lowest h° angle value of 64.5, and was not found to differ from any of the other cultivars with respect to h°. The h° angle values for 'Alapaha' showed a linear relationship between cultivar and timing within the season and were consistently red in 2008, ranging from 50.5 to 73.6. 'Alapaha' had a mean h° angle value of 59.5 in 2009 and was the cultivar shown to have the reddest leaves. 'Premier' was found to have consistent fall color in the more yellow range, with an h° values ranging from 52.0 to 80.0 in 2008 and with a mean h° value of 66.9 in 2009. 'Baldwin' showed the most yellow leaves in 2008, with an h° angle value ranging from 53.9 to 78.3. 'Premier' was found to have a consistently more yellow fall color in 2008, and among the most yellow colored cultivars in 2009.

‘Powderblue’ had the lightest berry in both 2009 and 2010, with lightness (L*) measurements of 32.45 and 36.74 respectively (Table 4). ‘Baldwin’, ‘Ira’, and ‘Yadkin’ had consistently darker berries across 2009 and 2010 with berry L* ranging from 25.61 to 30.61 (Table 4). ‘Powderblue’ had the most intensely colored berries, or highest chroma (C*) in both seasons, 4.10 in 2009 and 5.84 in 2010 (Table 4). ‘Premier’ and ‘Tifblue’ additionally had intensely colored berries across both seasons. ‘Alapaha’ berries were found to have the lowest C* in both years, 2.22 and 3.63 respectively. In 2009, the h˚ of the berries fell between bluish-green (180˚) and blue (270˚) (Table 4). ‘Yadkin’ had the most blue berry in 2009, and ‘Alapaha’ berries were more green. Berry color of other cultivars was not different than the berry color of ‘Yadkin’. In 2010, the h˚ of the berries was between blue (270˚) and red-purple (360˚). ‘Powderblue’ berries were the most blue in 2010, and ‘Onslow’ was the most red-purple. ‘Alapaha’, ‘Baldwin’, and ‘Brightwell’ were not different than ‘Onslow’ with respect to hue angle in 2010.

The summer season green leaves of studied cultivars all had hue angles falling within the quadrant between yellow (90˚) and bluish-green (180˚) (Table 4). ‘Powderblue’ and ‘Yadkin’ leaves were found to be the lightest green, lighter than ‘Premier’, ‘Onslow’, ‘Tifblue’, ‘Ira’, and ‘Baldwin’. ‘Baldwin’ had the darkest summer leaves, with an L* of 47.63. (Table 4). ‘Onslow’ had the most bluish-green leaves among all studied cultivars, with a hue angle value of 123.8, which differs from all other cultivars (Table 5). ‘Onslow’ had the least intense colored leaf, with a chroma value of 9.9 (Table 5). The hue angle value indicates that ‘Yadkin’ has the most yellow and least bluish-green summer leaves of all cultivars tested. ‘Ira’ also had bluish-green summer leaf color, with a h˚ of 122.1, and ‘Ira’ did not have as intensely colored foliage. ‘Yadkin’ summer leaves have the highest color saturation, with a C* value of 15.35.

The overall form of the bush was assessed in 2010, and all bushes were determined to be rather upright (Table 5). 'Alapaha' and 'Onslow' have the most upright growing habit, with a bush form index of 1.2 and 1.3 respectively. 'Baldwin', 'Ira', 'Tifblue', 'Brightwell', 'Montgomery', and 'Yadkin' were all more sprawling in nature, ranging from 2.4 to 3.7 in bush form index.

Conclusions

Fall color on rabbiteye blueberry leaves tended to be lighter and more yellow, and as the season progressed, the foliage became redder and darker. Additionally, the fall color ranged from yellow to orange to red in varying intensities and for varying lengths of time in different cultivars. Generally, consistently high chroma across the fall season indicates a cultivar that will produce more intensely colored fall foliage over a longer period of time. Additionally, consistency of the hue angle indicates a more uniform fall foliage color across the season.

In Northern Alabama, 'Ira', 'Powderblue', 'Premier', 'Tifblue' and 'Yadkin' ranked consistently high in chroma, which indicates more intense colors. On the other hand, 'Alapaha' and 'Onslow' were found to have less intense coloration, but 'Alapaha' had consistent fall color intensity while 'Onslow' did not. 'Yadkin' had consistently light, intensely red fall foliage across the seasons; on the other hand, 'Alapaha' fall color was also consistently red but was duller and less intense. Despite the low lightness and chroma, 'Alapaha' had a more consistent, longer lasting, and more uniform fall color period than nearly any other cultivar observed. 'Ira', 'Onslow', and 'Premier' both ranked highly and consistently in the yellow range, and 'Premier' and 'Ira' tended to have a light, more consistently intense fall color.

‘Powderblue’ was found to have the lightest, bluest colored berries as well as the lightest colored green foliage, while ‘Alapaha’ and ‘Yadkin’ had dark berries and leaves. Color lightness values were found to be a good indicator of both berry and leaf wax, and furthermore, likely the best indicator of leaf or berry attractiveness. Generally, lighter leaves and berries are desirable for landscape use, as the wax on the light berries as well as leaves help them stand out. ‘Tifblue’ and ‘Premier’ have a pleasant colored berry in addition to their fall color.

No considerable difference was observed between the growth forms. As may be expected, most cultivars tended to be more upright, as this trait has been selected for historically. ‘Powderblue’, ‘Climax’, and ‘Premier’ were found to be slightly more sprawling in nature, and ‘Alapaha’ and ‘Onslow’ were determined to be the most upright. Additionally, the exfoliating bark is a pleasant feature found on many bushes. Based on our observations, it did not seem that the bark varied by cultivar.

Which cultivars are best suited to the landscape largely depend on the intended function of the bush in the landscape. ‘Powderblue’ is a good selection for its spring and summer ornamental features, the waxy leaves and waxy, light blue berries. ‘Alapaha’ and ‘Yadkin’ seem to have consistent, long-lasting red fall color, and ‘Ira’ and ‘Premier’ are good selections for long-lasting yellow fall foliage color in North Alabama. Fall foliage color, green leaf color, berry color, and bush form are ornamental features of rabbiteye blueberries that vary across cultivars. Scientific testing and documentation of these features in current and upcoming rabbiteye selections will serve to increase their marketability and their success in the landscape.

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Table 1. Effect of blueberry cultivar on fall foliage color lightness in 2008 and 2009, NAHRC, Cullman, AL[z]

Cultivar	L*	L*	L*	L*	L*	Significance	P-value
			2008				
	5-Nov	13-Nov	21-Nov	26-Nov	5-Dec		
Alapaha	36.78 bc	35.83 e	35.37 c	30.65 f	31.52 e	L***	<.0001
Baldwin	36.17 c	37.34 bcd	35.73 c	30.98 ef	33.10 bcd	L***	<.0001
Brightwe	37.26 abc	38.84 a	36.15 bc	31.45 def	32.77 cd	L***	<.0001
Climax	37.83 ab	38.06 abc	36.3 b	32.00 cd	32.96 cd	L***	<.0001
Ira	37.56 ab	38.77 a	36.84 ab	32.00 cd	33.79 abc	L***	<.0001
Montgomery	38.01 a	38.38 ab	36.87 ab	32.4 bcd	32.21 de	L***	<.0001
Onslow	37.17 abc	38.24 abc	37.34 ab	31.53 de	33.19 bcd	Q*	0.0155
Powderbl	36.45 c	38.26 abc	36.43 b	32.14 cd	33.09 bcd	Q**	0.0058
Premier	37.19 abc	37.96 abc	36.55 b	32.79 abc	34.21 ab	L***	<.0001
Tifblue	36.89 bc	36.75 d	37.17 ab	33.45 a	34.37 ab	L***	<.0001
Yadkin	37.19 abc	37.05 cd	37.67 a	33.21 ab	34.87 a	L***	<.0001
			2009				
	30-Oct	6-Nov	11-Nov	19-Nov	25-Nov		
Alapaha	34.70 e	34.26 f	36.01 f	33.71 f	33.03 e	Q**	0.0052
Baldwin	35.97 cd	38.13 bc	38.93 abc	38.91 bcd	38.54 a	Q***	0.0005
Brightwe	35.44 de	36.47 de	37.67 cde	37.63 d	36.03 cd	Q***	<.0001
Climax	36.29 bc	36.8 cd	37.34 de	34.81 ef	33.98 e	Q***	<.0001
Ira	37.55 a	40.73 a	39.88 a	40.99 a	37.11 bc	Q***	<.0001
Montgomery	36.94 abc	37.56 bcd	39.15 ab	40.03 ab	36.68 bc	Q***	<.0001
Onslow	35.15 de	35.64 e	37.18 ef	35.85 e	33.76 e	Q***	<.0001
Powderbl	37.06 ab	38.28 b	38.79 abc	38.91 bcd	37.08 bc	Q***	0.0001
Premier	37.06 ab	37.29 bcd	38.43 bcd	39.52 abc	36.98 bc	Q***	0.0007
Tifblue	37.4 a	38.19 b	39.81 a	39.05 bc	37.31 ab	Q***	<.0001
Yadkin	37.41 a	38.26 b	39.62 ab	37.99 cd	37.71 ab	Q**	0.0015

[z]Measured in CIELAB. L* = lightness, C* = chroma, h° = hue angle.

N.S., *, **, *** Nonsignificant and significant at $P \leq 0.05$, 0.01 or 0.001 respectively. Diffences between cultivars between dates were determined using single pair contrasts α=0.05.

Table 2. Effect of blueberry cultivar on fall foliage color chroma in 2008 and 2009, NAHRC, Cullman, AL[z]

Cultivar	C*	C*	C*	C*	C*	Significance	P-value
			2008				
	5-Nov	13-Nov	21-Nov	26-Nov	5-Dec		
Alapaha	16.69 bc	22.18 b	18.22 c	10.50 cd	12.51 f	Q***	<.0001
Baldwin	14.28 d	19.44 c	19.06 c	11.11 bcd	14.66 de	Q***	<.0001
Brightwe	16.96 abc	20.97 bc	21.09 ab	11.65 bc	15.78 cde	Q***	0.0004
Climax	16.9 bc	21.47 b	19.55 bc	10.87 bcd	15.17 de	Q**	0.0083
Ira	19.0 a	22.31 ab	21.17 ab	12.63 ab	17.18 bc	L***	<.0001
Montgomery	16.94 abc	22.88 ab	22.58 a	13.05 ab	15.64 cde	Q***	<.0001
Onslow	15.57 cd	22.1 b	21.22 ab	9.63 d	13.68 ef	Q***	<.0001
Powderbl	16.16 bcd	22.52 ab	19.64 bc	11.62 bc	14.06 def	Q***	<.0001
Premier	17.13 abc	23.98 a	19.69 bc	13.74 a	18.38 ab	Q*	0.0215
Tifblue	17.82 ab	24.14 a	21.53 ab	14.75 a	18.32 ab	Q***	0.0003
Yadkin	18.11 ab	22.86 ab	22.10 a	14.13 a	19.67 a	Q*	0.0404
			2009				
	30-Oct	6-Nov	11-Nov	19-Nov	25-Nov		
Alapaha	17.52 c	17.12 e	20.73 e	21.85 c	20.06 c	L***	<.0001
Baldwin	19.35 b	24.04 bcd	27.49 abc	33.4 a	31.94 a	Q**	0.0014
Brightwe	18.75 bc	22.34 cd	25.79 bcd	29.79 b	27.05 b	Q***	0.0002
Climax	20.22 b	22.08 cd	23.68 d	23.16 c	21.77 c	Q**	0.0033
Ira	22.93 a	28.89 a	29.94 a	30.94 ab	27.05 b	Q***	<.0001
Montgomery	23.15 a	23.18 bcd	27.58 abc	31.82 ab	26.38 b	Q**	0.0052
Onslow	17.67 c	20.52 d	25.25 cd	24.3 c	20.32 c	Q***	<.0001
Powderbl	22.74 a	25.54 b	27.73 abc	29.67 b	28.16 b	Q**	0.0063
Premier	22.77 a	21.97 cd	28.79 ab	32.7 ab	28.3 b	Q**	0.0048
Tifblue	24.08 a	24.4 bc	29.28 a	29.52 b	28.15 b	Q**	0.0184
Yadkin	22.91 a	25.46 b	30.08 a	32.2 ab	28.62 b	Q***	<.0001

[z]Measured in CIELAB. L* = lightness, C* = chroma, h° = hue angle.

N.S., *, **, *** Nonsignificant and significant at $P \leq 0.05$, 0.01 or 0.001 respectively. Diffences between cultivars between dates were determined using single pair contrasts α=0.05.

Table 3. Effect of blueberry cultivar on fall foliage color hue angle in 2008 and 2009, NAHRC, Cullman, AL[z]

Cultivar	h°	h°	h°	h°	h°	Significance[y]	P-value
				2008[x]			
	5-Nov	13-Nov	21-Nov	26-Nov	5-Dec		
Alapaha	72.6 bc[x]	72.2 bc	66.3 bc	51.4 d	50.5 abc	L***	<.0001
Baldwin	78.3 abc	75.6 abc	62.5 c	59.5 abc	53.9 ab	L***	<.0001
Brightwell	74.7 bc	71.5 bc	69.9 abc	53.4 cd	45.4 c	Q*	0.0114
Climax	74.8 bc	75.2 abc	68.8 abc	60.9 ab	44.6 c	Q***	0.0009
Ira	72.0 c	76.6 abc	73.2 ab	56.1 abcd	53.6 ab	Q**	0.0085
Montgomery	83.4 a	75.7 abc	66.9 bc	54.2 bcd	46.9 bc	L***	<.0001
Onslow	75.3 bc	81.7 a	72.7 ab	57.8 abcd	56.0 a	Q*	0.0312
Powderblue	78.2 abc	78.6 ab	75.7 a	55.6 bcd	54.0 a	L***	<.0001
Premier	80.0 ab	72.8 bc	73.7 ab	60.7 abc	52.0 ab	L***	<.0001
Tifblue	77.2 abc	73.5 bc	70.7 ab	62.4 a	49.8 abc	Q*	0.0202
Yadkin	71.2 c	70.0 c	69.5 abc	56.0 abcd	43.3 c	Q***	0.0006
				2009[w]			
Alapaha	59.5c			Date	h°		
Baldwin	66.8ab			30-Oct	77.3		
Brightwe	70.0ab			6-Nov	74.2		
Climax	67.1ab			11-Nov	72.3		
Ira	70.4ab			19-Nov	60.7		
Montgomery	68.1ab			25-Nov	51.5		
Onslow	71.4a			Significance[v]	Q***		
Powderblue	64.9abc						
Premier	66.9ab						
Tifblue	69.6ab						
Yadkin	64.5bc						
Significance[y]	***						

[z]Measured in CIELAB. L* = lightness, C* = chroma, and h° = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green, and 270° = blue).

[y]N.S., *, **, *** Nonsignificant and significant at $P \leq 0.05$, 0.01 or 0.001 respectively.

[x]Diffences between cultivars between dates were determined using single pair contrasts α=0.05.

[w]Only main effect significant in 2009.

[v]Differences between cultivars were determined using Bonferroni means separation, where α=0.05.

Table 4. Effect of blueberry cultivar on berry surface color in 2008 and 2009, NAHRC, Cullman, AL[z]

Cultivar	L*	C*	h°
	2009		
Alapaha	28.94 cd	2.22 d	233.0 b
Baldwin	27.67 e	2.88 c	263.8 a
Brightwell	27.95 de	2.94 c	263.5 a
Climax	29.6 c	3.40 b	258.9 a
Ira	26.56 f	2.28 d	260.2 a
Montgomery	29.19 c	2.89 c	260.5 a
Onslow	27.94 de	2.68 c	261.2 a
Powderblue	32.45 a	4.10 a	262.5 a
Premier	31.03 b	3.65 b	258.9 a
Tifblue	31.36 b	3.51 b	258.9 a
Yadkin	25.61 f	2.29 d	266.8 a
P-value	<.0001	<.0001	<.0001
Significance	***	***	***
	2010		
Alapaha	29.97 ef	3.63 g	280.2 abc
Baldwin	28.96 f	4.58 de	280.5 ab
Brightwell	31.41 cd	4.82 cd	281.6 ab
Climax	31.53 cd	4.53 de	276.7 de
Ira	30.61 de	4.45 e	278.3 cd
Montgomery	32.62 bc	4.92 c	277.3 de
Onslow	33.44 b	4.09 f	281.9 a
Powderblue	36.74 a	5.84 a	272.2 f
Premier	31.87 c	5.09 bc	276.0 e
Tifblue	31.49 cd	5.24 b	275.6 e
Yadkin	29.54 ef	4.39 e	279.7 bc
P-value	<.0001	<.0001	<.0001
Significance	***	***	***

[z]Measured in CIELAB. L* = lightness, C* = chroma, h° = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green, 270° = blue).

N.S., *, **, *** Nonsignificant and significant at P $\leq$ 0.05, 0.01 or 0.001 respectively.

Table 5. Effect of blueberry cultivar on summer foliage surface color and bush growth habit in 2010, NAHRC, Cullman, AL

	Leaf surface color[z]			
Cultivar	L*	C*	h°	Bush form[y]
Powderblue	49.85 a	12.60 bc	119.0 bc	2.4 ba
Yadkin	49.79 a	15.35 a	117.5 c	3.7 a
Brightwell	49.67 ab	13.59 bc	120.5 bc	2.9 a
Climax	49.18 abc	13.88 ab	117.8 c	2.4 ab
Alapaha	49.03 abc	12.15 cd	119.1 bc	1.2 b
Montgomery	48.63 abcd	13.29 bc	119.1 bc	3.4 a
Premier	48.31 bcd	12.44 bc	119.2 bc	2.3 ab
Onslow	48.29 cd	9.91 e	123.8 a	1.3a
Tifblue	48.04 cd	13.08 bc	117.9 c	2.9 a
Ira	47.89 cd	10.74 de	122.1 ab	2.8 a
Baldwin	47.63 d	12.75 bc	119.6 bc	2.8 a
P-value	<.0001	<.0001	<.0001	<.0001
Significance	***	***	***	***

[z]Measured in CIELAB. L*= lightness, C*= chroma, h°= hue angle (0°= red-purple, 90°= yellow, 180°= bluish-green, 270°= blue).

[y]Bush form ratings based on a 5 point scale: 1 = upright, 2 = less upright, 3 = intermediate, 4 = more sprawling, 5 = sprawling.

N.S., *, **, *** Nonsignificant and significant at P $\leq$ 0.05, 0.01 or 0.001

Figure 1. Waxy coating on ‘Climax’ rabbiteye blueberry foliage, NAHRC, Cullman, AL, 2009.

Figure 2. Waxy coating on ‘Powderblue’ rabbiteye blueberry fruit, NAHRC, Cullman, AL, 2010.

Figure 3. Rabbiteye blueberry fall foliage color range across cultivars, NAHRC, Cullman AL, November, 2009.

Figure 4. ‘Tifblue’ rabbiteye blueberry fall color, NAHRC, Cullman AL, November, 2009.

Figure 5. ’Yadkin’ rabbiteye blueberry fall color, NAHRC, Cullman, AL, November, 2009.

Figure 6. Exfoliating bark on ‘Premier’ rabbiteye blueberry, Cullman AL, NAHRC, 2009.

CHAPTER FOUR

Evaluation of Vegetative Growth and Cropping Potential of Selected Rabbiteye Blueberry Cultivars Grown on Old Crop versus Pasture Land

Abstract

'Austin' and 'Climax' rabbiteye blueberries grown on two soil types in Columbia, AL (lat. 31˚ 15' N, long. -85˚ 9' E; USDA Plant Hardiness Zone 8A) were compared with respect to vegetative growth, yield, and fruit quality in order to evaluate the effect of the soil quality based on land's prior use. The soil previously used for crop production was found to have above the recommended 2% soil organic matter, and the soil previously left to pasture was found to have approximately twice as much organic matter. Foliar analysis revealed little difference in the elemental content of the leaves from plants grown on old crop land and pasture land. Fruit set was higher on blueberry plants grown on pasture land, and yields were found to be as much as three times higher than that of plants grown on old crop land. Plants grown on pasture land were also found to be noticeably more vigorous in comparison with plants grown on old crop land. Higher plant vigor and yields may be a result of the alleviation of establishment stress provided by the higher organic content found on the pasture land.

Introduction

Rabbiteye blueberries (*Vaccinium ashei* Reade) are the most common blueberry species used for commercial production in Alabama, and generally require highly acidic soils with minimal nutrition (Dozier, 1991). Rabbiteyes are native to the Southeast, provide abundant yields, and they tend to be more tolerant to heat and drought, more resistant to diseases and insects, grow on a wide range of soils, and have a longer shelf life than highbush or other blueberry species (Esendugue et al., 2008; Miller-Butler et al., 2009). Rabbiteye blueberry bushes are vigorous and can grow to a height of 3.1 meters or more. Rabbiteye berries are small to medium-large berries ranging from black to light blue in color (Austin and Bondari, 1993). Commercial rabbiteye yields typically range from 2,268 to 3,629 kg/acre on well-maintained fields, sometimes reaching yields of 4,536 kg/acre (Esendugue et al., 2008).

Primarily rabbiteye blueberries are grown commercially in Alabama, and according to the USDA National Agricultural Statistics Service (2010), 320 acres were harvested in 2008, yielding 513 kg/acre. Alabama ranks 13th in the United States in harvested acres, yield per acre, utilized production, as well as the value of utilized production according to the New Jersey Agricultural Statistics service (2007). The blueberry acreage almost doubled by 2009, when an additional 275 acres were established in the Dothan area alone (Clint Smith, president of the Wiregrass Blueberry Growers Association, personal communication). Alabama farm gate value has increased by approximately 13% from 2000 to 2008 (USDA National Agricultural Statistics Service, 2010).

Rabbiteyes grow on a wide range of soils including sandy clay loam, loam, loamy sand, and sand soil series (Esendugue et al., 2008). Well drained upland soils with low nutrient and waterholding capacity and a pH between 4.0 and 5.2 are needed to provide optimal growth of rabbiteye blueberry plants (Brinen et al., 1986; Spiers, 1996). Usually, when grown on sandy soils, the pH should be adjusted to a range of 4.0 to 5.3, and a pH level of 4.5 to 5.3 is recommended for successful rabbiteye production on clay type soils (Esendugue et al., 2008).

According to Esendugue et al. (2008), growth is not as good on land previously farmed when compared to virgin land unless a large amount of organic matter is worked into the soil. If the soil organic matter is found to be below 2%, it is recommended that pine bark mulch or peat moss is added (Esendugue et al., 2008). Optimum and early yield are largely based on first year growth in rabbiteye blueberries. Studies by Spiers (1983) found that the incorporation of peat moss increased plant vigor, height, shoot weight, leaf chlorophyll, and yield on young rabbiteye plants. Furthermore, moisture stress plays a key role in rabbiteye plant establishment, and this appears to be where much of the benefits of sufficient levels of organic matter come from (Spiers, 1983). Soil organic matter is associated with a decrease in the soluble salt content as well as contributes to an increase in moisture availability to the plant due to its high cation exchange capacity, and its high water holding capacity (Spiers, 1983). Incorporating organic matter, irrigation, and mulching practices help alleviate water stress. These cultivation practices are considered expensive, but a study by Spiers (1983) provided evidence of yield increase as much as 5 times when these soil amendment practices were combined.

In general, woodland soils with a pH above 5.5 are not well suited for growing blueberries commercially (Brinen et al., 1986). When the soil pH levels are above 5.2, iron deficiency symptoms are observed (Spiers and Braswell, 1992), new leaves appear chlorotic and often shoot dieback is observed on the blueberry plants (Brinen et al., 1986). According to Spiers and Braswell (1992) excessive calcium (Ca) and sodium (Na) absorption, common at higher soil pH levels, may impede blueberry growth. Calcium fertilizer-induced iron deficiency, or lime-induced chlorosis, has been documented in soils that have been raised to a pH above 5.5, and growth and yields have also been documented to be negatively affected by a high soil pH (Spiers and Braswell, 1992). Spiers (1984b) found that although more iron was available in the soil at a lower pH, foliar analysis indicated that as soil pH increased, leaf iron content increased linearly. Additionally, Spiers (1984b) found excessive sodium (Na) uptake at high pH levels and excessive levels of manganese (Mn), to the point of toxicity, in the leaves of bushes grown at low soil pH.

Soils with a history of liming, but native pH inside the acceptable range (4.0 – 5.2) can be planted after incorporation of sulfur to correct the pH (Brinen et al., 1986). S is used in commercial blueberry production to lower pH levels and lime to raise pH levels in the soil (Spiers, 1984a; Spiers and Braswell, 1992).

Spiers and Braswell (1992) found water quality to be an extremely important factor with regards to the effects on plant growth and vigor from Ca and Na uptake. Rabbiteye blueberries, irrigated with water containing moderate amounts of Na and Ca, were treated with various levels of S to lower the soil pH (Spiers and Braswell, 1992). Highly carbonate water can raise the soil pH when a crop is heavily irrigated, but if care is taken not to over-irrigate, this effect can be minimized (Brinen et al., 1986). Sulfur irrigation injections can neutralize the bases (Brinen et al., 1986), but Spiers and Braswell (1992) found that this was not always the case. Even when applied at high rates, S treatments were not sufficient to counteract the effects of the Ca and Na in the irrigation water, and when higher S levels did lower the soil pH to more acceptable levels, plant growth and vigor were not affected (Spiers and Braswell, 1992). The cations of importance with regard to water quality are the levels of Ca, Mg, and Na; additionally, the anions Cl, SO_4, and CO_3 and the combinations of Na with Cl and HCO_3 which form salts that are harmful to plant growth (Haby et al., 1986).

This study was aimed at evaluating the effect of the soil quality based on land's prior use on growth and development of selected rabbiteye blueberry cultivars. Vegetative growth, yield, and fruit quality of rabbiteye blueberry cultivars grown on old crop land were compared to the same cultivars planted on pasture land.

Materials and Methods

The experiment was conducted on a grower's site located in Columbia, AL (lat. 31° 15' N, long. -85° 9' E; USDA Plant Hardiness Zone 8A). The blueberry orchard was planted in fall of 2007 on sandy soil (Cation Exchange Capacity (CEC) < 4.6 $cmol_c kg^{-1}$) with a history of multiple year peanut crop production. As a result, pH of the soil was high on this particular site in combination with high phosphorus levels and low organic matter. A 2008 soil test showed the soil pH was 5.6 and phosphorus levels were found to be over three times the upper end of the mid-range soil phosphorus levels of 13.6-27.2 kg/acre suggested by Krewer and NeSmith (2001). Soil organic matters were found to be less than half the suggested 2.0% at 0.9%. The grower attempted to adjust the soil pH level in previous seasons to acceptable ranges by utilizing soil amendments such as 10.2 cm pine bark mulch incorporated into the soil, and sulfur injections at a rate of 1% sulfuric acid applied through the supplemental irrigation system. Supplemental irrigation water for this region comes from the Floridan Aquifer, which is a limestone aquifer and can contain dissolved bicarbonates. Groundwater pH levels in most counties in the Wiregrass area range from 6.3 to 8.7, and thus cause the pH to rise when the water is used for irrigation. The bushes were fertigated with a 12-0-6 N P K fertilizer with 1% sulfur. Additionally, this site also has an area planted at the same time with rabbiteyes that was formerly left to pasture. The old crop land (OCL) site and a former pasture land (PL) site planted to 'Climax' and 'Austin' rabbiteye blueberry cultivars were included in our study to determine the effect of soil type on blueberry growth and development. Twelve plants of each of the two cultivars, with similar growth were selected for this experiment. To determine the differences in soil nutrient content of OCL and PL, soil samples were collected and analyzed by the AU soil testing lab.

Plant nutrient content was determined by collecting a 30 leaf samples on June 28th from each experimental plant. Mature leaves located at least 5 nodes from the terminal bud were collected in late summer from each cultivar grown on each soil type. Bushes from the 12 representative plants were sampled and combined to make a composite sample of 30 leaves total. Nutrient analysis in blueberry plant tissue was performed by the Soil Testing Laboratory at Auburn University.

Blueberry flowering was recorded by visually rating the percentage of fully open flowers on each bush at 7 day intervals. A flower was considered fully open when the pistil was observed protruding from the bell of the flower, and observations began when all cultivars were estimated to have at least 5% of the flowers fully open and continued until all experimental bushes reached 95% open flowers.

To determine flower bud density, diameters of 2 canes per bush, with a diameter between 0.9 and 1.8 cm, were measured and flagged, and the number of flowers was counted on each cane. Flower bud density was determined as a number of flower buds per cane cross sectional area (cm^2) in 2009. Due to an increase in plant size and crop load, this method was not feasible in the 2010 season, when fruit set was determined by flagging 2 fruiting shoots (with a range between 25-55 cm length) on each bush. The length of each fruiting shoot was measured and the number of fruit set on each shoot was counted. To obtain the initial fruit set, data were collected in May, and fruit set on the same shoots was counted again just before harvest in late June to determine the final fruit set. Additionally, the crop load was estimated on each experimental plant. A subjective, 3-point system was implemented where 1 = light crop load, 2 = moderate crop load, and 3 = heavy crop load.

At the time of the first commercial harvest as per owner's (growers) assessment, 3 plants from each cultivar were randomly selected per cultivar and soil type. All ripe fruit were harvested and combined to form a composite sample. This composite fruit sample was used to determine yield/plant and berry fruit quality. In 2009, all cultivars were harvested on June 16, and in 2010, plants were harvested on June 7. Harvested fruit were placed in a cooler on ice, transported to Auburn University, and placed in cold storage at 4˚ for 24-48 hours before analysis. A 20 g subsample from each fruit sample was stored at -80˚ for later processing to determine soluble solids content (SSC), titratable acidity (TA), and pH of blueberry cultivars.

To perform fruit quality analysis, data on berry surface color were taken, along with fruit width, fruit weight, berry firmness, percent fruit with wet scar, berry dry weight, soluble solids content (SSC), titratable acidity (TA), the SSC/TA ratio, and fruit pH level were collected. The average berry weight was determined on a 50 berries subsample. Fruit firmness was determined on a 10 berry subsample/cultivar from each soil type using a handheld FT 02 penetrometer (McCormick Scientific, Richmond, IL) using a 1.5 mm probe. Berries that have firmness exceeding 175 g/mm are considered suitable for mechanical harvesting (NeSmith, 2009). To record the berry firmness, fruit were held stationary on a flat surface between the thumb and index finger in one hand, and the probe was pressed against the fruit in a slow and steady motion until the berry was pierced. A 50 berries subsample was used to determine the percentage of berries with wet picking scar. Berry dry weight (g) was determined after drying a 10 berry subsample at 77˚ C in a Grieve model sc-350 oven (Grieve Corporation, Round Lake, IL, USA) for 48 hours, and then the berry weight was recorded.

Fruit SSC, TA, and pH were determined using a method described by Vinson et al. (2010). SSC was determined by first pureeing approximately 20 g of frozen fruit and 20 ml of HPLC water, obtained from a Millipore Direct-Q 5 filter system (Millipore Corp., Bedford, MA), using a ceramic mortar and pestle into a homogeneous liquid (Vinson, 2010). The resulting liquid was analyzed using a digital refractometer (Pal-1 Atago, Co., Tokyo, Japan) to determine the % brix at room temperature. To determine TA, the homogeneous liquid was clarified using a centrifuge at 15,000 g_n at 4˚C for 20 minutes (Model J2-21; Beckman Centrifuge, San Antonio, TX), and the supernatant was filtered through double-layered cheese cloth. The resulting supernatant was brought to a final volume of 40 mL with HPLC water and thoroughly mixed, after which 5 mL of supernatant was removed and combined with HPLC water to reach a final volume of 30 mL, which was used to determine TA with an automated titrimeter (Metrohm Titrino Model 751GDP and Metrohm Sample Changer; Metrohm Corp., Herisau, Switzerland). The titrimeter was maintained at 10˚C with a Fisher Scientific refrigerated chromatography chamber (Model Isotemp Laboratory Refrigerators; Fisher Scientific, Raleigh, NC). A 0.1 M solution of NaOH was titrated to an end point of pH 8.1. The results were expressed as citric acid equivalent through the following formula: [(mL NaOH x 0.1 N x 0.064 meq·g^{-1} of juice) x 100]. SSC/TA ratio was determined by dividing SSC by TA. The titrimeter also determines the pH of the sample (Vinson, 2010).

A ten berry subsample from each cultivar from both soil types was analyzed to determine the external fruit color. A Minolta CM-2002 Spectrophotometer (Minolta, Tokyo, Japan), using the CIELAB color space (L*, a*, b*, C, h˚) was utilized. According to McGuire (1992), and Voss and Hale (1998), the CIELAB color space can be visualized as a three dimensional graph, and equal distances on this graph represent visually equal distances in color differences. L* indicates an objects lightness on a 0 to 100 scale, with 0 representing black and 100 representing white (McGuire, 1992; Voss and Hale, 1998), and can be visualized as the z axis. Hue is represented by a* and b*, and a* can be visualized as the horizontal coordinate (x axis), and a positive a* indicates purplish-red, a negative a* indicates bluish-green (McGuire, 1992; Voss and Hale, 1998). The b* represents the vertical coordinate (y axis), and a positive b* indicates yellow, while a negative b*indicates blue (McGuire, 1992; Voss and Hale, 1998). A more appropriate way to represent these readings is through the use of Chroma (C*) and hue angle (h°), as these values are less likely to be misinterpreted (McGuire, 1992). Chroma indicates the saturation or intensity of the color, and the C* value represents the distance from the origin to the (a*, b*) coordinates (Voss and Hale, 1998). The hue angle (h°) is easier to visualize than a* and b* values, as on a 360° color wheel red-purple corresponds to an angle of 0°, yellow corresponds to an angle of 90°, bluish-green corresponds to 180°, and blue corresponds to an angle of 270° (Sapers, 1984; McGuire, 1992). The berry wax was evaluated by analyzing the L* values (Austin and Bondari, 1993; Sapers, 1984), and the color of the berries were evaluated by analyzing the C* and h° (Austin and Bondari, 1993).

Plant growth index (PGI) and leaf area data were recorded in April both seasons to determine blueberry plant vegetative growth. Each blueberry plant height and two diagonal plant width were measured to determine the plant growth index (Sloan, et al., 2003). Leaf area measurements were based on 30 mature leaves/plant collected at least 5 nodes from the terminal bud, using a LI-3100 Area meter (Licor, Inc, Lincoln, NB, USA).

The experimental data was not statistically analyzed, since the experiment was designed as a preliminary observational study. Instead, treatment means were used to compare the data and analyze the results.

Results and Discussion

Comparison of the soil sample results from the two blueberry production sites revealed that the amount of the organic matter content accounted for the primary difference between the (OCL) soil and PL soil (Table 1). Although both soil types had more than the recommended 2% organic matter, as shown in Table 1, the soil sample from the site where 'Austin' and 'Climax' cultivars were grown on PL had 4.7 and 5.2% organic matter respectively, and was about two folds higher than the organic matter content found on OCL. The soil pH was found to be similar for cultivars grown on old crop and PL, with the pasture land having a slightly lower pH (Table 1). The OCL soil had a pH of 4.3 to 4.4 while the PL soil had a pH ranging from 4 to 4.1. Krewer and NeSmith (2001) reported 14-27 kg/acre to be the mid-range of acceptable phosphorus (P) levels in Georgia. The soil P level of the OCL was 26-29 kg/acre, at the upper end of the suggested range. PL soil was found to have a P level above this range, with 32-41 kg P/acre (Table 1). An 8:10 kg/acre ratio of calcium (Ca) to magnesium (Mg) has been suggested for rabbiteye blueberry (Krewer and NeSmith, 2001). Both soil types were found to be outside this range, but the results are conflicting. The 'Austin' soil on OCL had nearly three times as much Mg as the 'Climax' soil on the same site, and on the PL site, 'Climax' soil was found to have nearly twice as much Mg as the 'Austin' soil. Calcium (Ca) levels were found to be similar across soil types, with the OCL and PL soil containing 60-79 and 53-78 kg/acre respectively.

Little difference was observed between the foliar elemental content between the bushes grown on both soil types. The blueberry foliar analysis (Table 2) showed that all of the cultivars on both soil types contained adequate levels of N, ranging from 1.42 to 1.77%, as Krewer and Nesmith (2001) indicate that levels between 1.20 to 1.70% are considered acceptable.

Phosphorus levels were found to range between 0.065 and 0.074%, below the acceptable level of 0.17 to 0.80% (Krewer and NeSmith, 2001). K was found to be present in levels ranging from 0.23 to 0.30%, and 0.21 to 0.60% are considered acceptable (Krewer and NeSmith, 2001). Calcium levels, with acceptable ranges between 0.24 and 0.70% (Krewer and NeSmith, 2001), were found at levels ranging from 0.46 and 0.57%. Mg levels were found to be above the accepted range of 0.14 and 2.0% (Krewer and NeSmith, 2001), with Mg levels ranging from 0.36 and 0.47%. Foliar analysis above the upper acceptable thresholds for the minor nutrients boron (B), copper (Cu), manganese (Mn), and zinc (Zn) were observed in all cultivars across soil types, and iron (Fe) levels were observed to be within the accepted ranges described by Krewer and NeSmith (2001). These trends were true across the soil types, and do not appear to be a result of differences in the soil types.

In 2009 'Climax' grown on OCL had a considerably higher percent open flowers on March 13, not only in comparison with 'Climax' grown on PL, but in comparison with 'Austin' grown on both soil sites (Figure 1). 'Climax' blueberries grown on PL flowered at a noticeably lower rate, and showed a similar flowering rate to that of 'Austin' grown on OCL. 'Austin' grown on PL had the most delayed flowering. 'Climax' grown on PL was found to be at the most advanced stage of flowering on March 26, 2010, and 'Austin' grown on PL was found to be the least advanced on the same date (Figure 2). The percent open flower followed this trend for the entire flowering season, with 'Climax' flowering at a more rapid rate on PL, and 'Austin' flowering more rapidly on OCL site.

In 2009 both blueberry cultivars grown on PL site had higher flower bud densities than the same cultivars grown on the OCL (Table 3). PL site grown 'Austin' plants produced 0.18 fruit/CCSA (cm^2), while old crop site grown plants produced 0.14 fruit/CCSA (mm^2). 'Climax' plants also had higher flower bud densities when grown on PL. In 2010, there was no discernable trend for the average number of fruit set with regards to soil type (Table 3). The results suggest there that the bushes grown on PL hold their fruit better than the blueberry bushes grown on OCL.

In 2009, estimated crop load was higher on both cultivars when grown on PL in comparison with the same cultivars grown on OCL, (Table 4), with ‘Austin’ producing twice as many berries on PL as on OCL. In 2010, the crop load was similar for ‘Austin’ and ‘Climax’ grown on both soils.

In both years of this study, ‘Austin’ and ‘Climax’ blueberries grown on PL had higher average yields than the same cultivars grown on OCL (Table 4). In 2009, ‘Climax’ produced 0.3 kg/bush on average when grown on PL, and 0.1 kg/plant on average when grown on OCL, which is a 3 folds higher crop. ‘Austin’ produced 0.4 kg/bush in 2009, which was double the crop produced on the OCL. In 2010, on PL, ‘Austin’ and ‘Climax’ produced 0.7 and 0.5 kg/bush respectively, and were found to have about 30 to 40% lower yields when grown on OCL (Table 4).

Average berry size (g) of both blueberry cultivars did not seem to be affected by soil type in 2009. In 2010 the cultivars grown on OCL had larger berries than the respective cultivars planted on PL (Table 4).

During both years of our study, ‘Austin’ bushes produced firmer blueberries when grown on PL in comparison with ‘Austin’ and ‘Climax’ plants grown on OCL (Table 4). ‘Climax’ berries produced on OCL were firmer in both seasons than those produced on PL.

In both years, the pH of the berries produced on both soil types ranged within the acceptable level of 2.25 to 4.25 with fruit produced on PL found to have slightly higher pH level than the berries produced on OCL (Table 5).

Most of the berries in this study were found to have lower than the acceptable soluble solids content (SSC) of 10% in 2009 (Table 5). In 2009, ‘Austin’ and ‘Climax’ berries produced on OCL had a SSC of 7.0%. ‘Austin’ and ‘Climax’ berries produced on PL had 47 and 27% higher SSC respectively. In 2010, ‘Austin’ berries produced on PL had less SSC (11.8%) than ‘Austin’ grown on OCL (13.2%) (Table 5), while ‘Climax’ berries produced on PL had higher SSC (13.8%) than ‘Climax’ berries grown on OCL (12.6%).

In 2009 and 2010, the total acidity (TA) for the fruit grown in both soil sites tended to have marginal values, or was slightly below the acceptable TA range of between 0.3 to 1.3%. (Table 5). Generally, TA was found to be lower on berries produced on PL in both seasons, with the exception of ‘Austin’ in 2010. ‘Austin’ berries produced on PL had a TA of 0.28%, while the berries produced on crop land had a TA of 0.20%.

A high SSC/TA ratio is typically an indicator of a good tasting berry, and a high correlation has been found between this ratio and blueberry storage quality (Austin and Bondari, 1993). In 2009, ‘Austin’ grown on OCL site had a SSC/TA ratio within the acceptable range of 10 to 33, while ‘Climax’ berries had an acceptable SSC/TA ratio when grown on OCL (Table 5). None of the berries grown on either soil type were found to have an acceptable SSC/TA ratio in 2010.

No clear trend was observed between the soil type and the percentage of berries with wet stem scar (Table 5). All cultivars were found to produce berries with a 2% occurrence of wet stem scar damage in 2009, with the exception of ‘Climax’ grown on PL, in which 8% of berries were found to have wet scar damage. Neither cultivar, regardless of soil type, was showing wet scar damage in 2010.

No clear trends were apparent with respect to berry lightness (L*), chroma (C*), or hue angle (h˚) measurements across seasons for ‘Austin’ or ‘Climax’ grown on either soil type (Table 6).

In both experimental years, ‘Austin’ and ‘Climax’ plants grown on PL had a considerably higher plant growth index (PGI) than the plants from the same cultivars grown on OCL (Table 7). In 2009, the PGI of ‘Austin’ cultivar grown on PL was more than double that of the bushes grown on OCL, and the plant growth of ‘Climax’ bushes was approximately 40% higher on PL than that of ‘Climax’ bushes grown on OCL. In 2010, the PGIs of ‘Austin’ and ‘Climax’ bushes grown on OCL were 16,849 cm^3 and 13,985 cm^3, and the PL grown ‘Austin’ and ‘Climax’ bushes had PGIs of 21,746 cm^3 and 17,048 cm^3 respectively. Average leaf area in 2009 was larger on ‘Austin’ bushes than on the ‘Climax’ plants regardless of the soil type (Table 7), while in 2010 Climax cultivar had larger leaf area regardless of soil type.

Conclusions

The primary differences between the soil deemed OCL and that deemed PL is likely the organic matter levels and a slightly lower soil pH level. Organic matter levels above 2% are recommended for rabbiteye production and pH on sandy soils should range from 4.0 to 5.3 (Esendugue et al., 2008). pH ranged between 4.0 and 4.1 on the PL and 4.2 and 4.6 on the crop land, fell in the acceptable range in 2010. Organic matter levels, ranging from 4.7 to 5.2% on the PL site and 2.6% on the OCL site are also sufficient.

Spiers (1983) found that moisture stress, a key limiting factor in rabbiteye establishment and performance, is alleviated through the use of supplemental organic matter and was shown to likely be the key benefit gained from organic matter in the soil, and studies by Korcak (1986) on various soil types with varying levels of organic matter indicated that increased soil CEC played a role in increased performance as well. The relief of moisture stress in establishment has been shown to improve plant establishment and performance (Spiers, 1983), and likely plays a major role in the differences in plant performance observed between these field types. Spiers (1983) found organic matter to be crucial for rabbiteye blueberry establishment, and optimum and early yield are largely based on first year growth in rabbiteye blueberries. The PL soil likely had a higher level of organic matter at planting than OCL, which was found to have less than half of the recommended organic matter in the soil before efforts were made to increase the organic matter and to lower the pH. This higher organic matter present in the PL likely aided in the establishment and subsequently resulted in higher vigor and yield. It is likely that the higher organic matter alleviated stresses related to establishment and may be responsible for the increased vigor and higher yields found on the PL.

High P levels were observed on PL, and have been indicated as an antagonist to Fe uptake (Krewer and NeSmith, 2001) and decreased yields (Spiers, 2001). High phosphorus did not cause a decrease in yield and no signs of iron chlorosis were observed in our studies, nor were low Fe levels detected in the cultivars studied regardless of soil type. Similarly Korak (1986) did not find that high P levels caused Fe deficiencies in a study of blueberries grown on various soil types. Korak (1986) also found that blueberries can grow in a range of soil with widely different levels of K, Mg, and Ca. Krewer and NeSmith (2001) reported that 8 to 10 kg/acre of Ca should be present for every 1 kg/acre Mg. While the results of the ratio of Ca/Mg in the soils in our studies were conflicting for cultivars and soil type, differences in the foliar elemental content were not detected between the blueberries growing on different soil types.

Differences in nutrient levels of leaves of ‘Austin’ and ‘Climax’ blueberries grown on OCL and PL sites show that nutrient levels in the soil are not likely a defining factor for nutrient uptake. Both cultivars on both soil types were found to have N and Ca levels within acceptable range. Tissue P and K levels were found to be lower than the acceptable range in all cultivars regardless of the soil type, while Mg was found to be higher. Foliar micronutrients were also quite high, with the exception of Fe, which was within the accepted range. Soil P and K levels were found to be higher on OCL. Despite differences in soil mineral content, foliar analysis did not indicate differences, thus it likely was not the determining factor for differences in plant performance across soil types in this study.

The percentage of fully open flowers recorded for ‘Austin’ and ‘Climax’ cultivars, did not indicate a clear effect of the soil type on flowering. Investigations into the effect of soil type on the fruit set of two blueberry cultivars indicate that bushes grown on PL tend to have higher fruit set, and retain more fruit to maturity. This higher fruit set translated into much higher yields on ‘Austin’ and ‘Climax’ bushes grown on PL as opposed to that grown on crop land in both seasons.

Additionally, in our study, both blueberry cultivars studied tended to respond with more vigorously growing plants when grown on PL as compared to the same cultivars grown on OCL.

This study indicates that ‘Austin’ and ‘Climax’ rabbiteye blueberries produced on PL grow better, have higher yields, and produce higher quality berries than when grown on OCL. In this case, the OCL had a history of peanut production and soil with a history of high pH, high P, and very low organic matter. This is believed to be largely because the organic matter in the soil plays a large role successful and expedient establishment. If this is the case, proper soil preparation, prior to planting, may serve to alleviate some of the observed differences in plant performance.

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Table 1. Soil elemental and organic matter analysis of old crop land and pasture land sites, Columbia, AL, 2010.

Cultivar	pH	Organic Matter (%)	Soil mineral composition (lbs/acre) P	K	Mg	Ca
		Old crop land				
Austin	4.4	2.6	57	43	44	174
Climax	4.3	2.6	63	40	17	132
		Pasture land				
Austin	4	4.7	90	61	22	117
Climax	4.1	5.2	71	50	38	173

Table 2. Effect of old crop land and pasture land sites on foliar tissue nutrient content of 'Austin' and 'Climax' blueberry cultivars in Columbia, AL, 2010

Cultivar	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Al (ppm)	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Na (ppm)	Zn (ppm)
						Old crop land						
Austin	1.6	0.1	0.25	0.49	0.45	203	38	32	63	176	479	21
Climax	1.4	0.1	0.30	0.48	0.36	135	30	18	40	165	432	15
						Pasture land						
Austin	1.6	0.1	0.23	0.57	0.47	221	37	33	69	209	470	15
Climax	1.6	0.1	0.27	0.46	0.44	201	38	48	54	191	460	28

Figure1. Effect of old crop land and pasture land sites on percent fully open flowers of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2009.

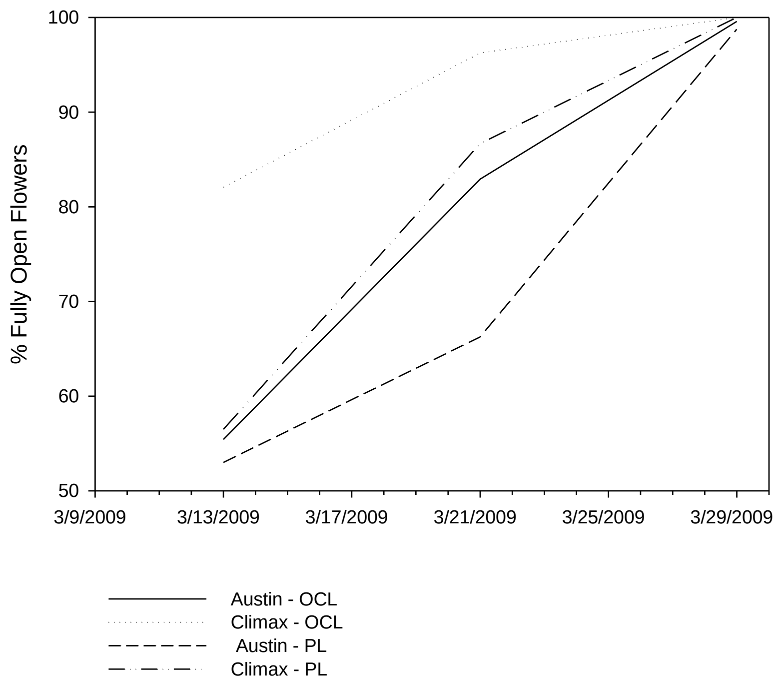

Figure 2. Effect of old crop land and pasture land sites on percent fully open flowers of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2010.

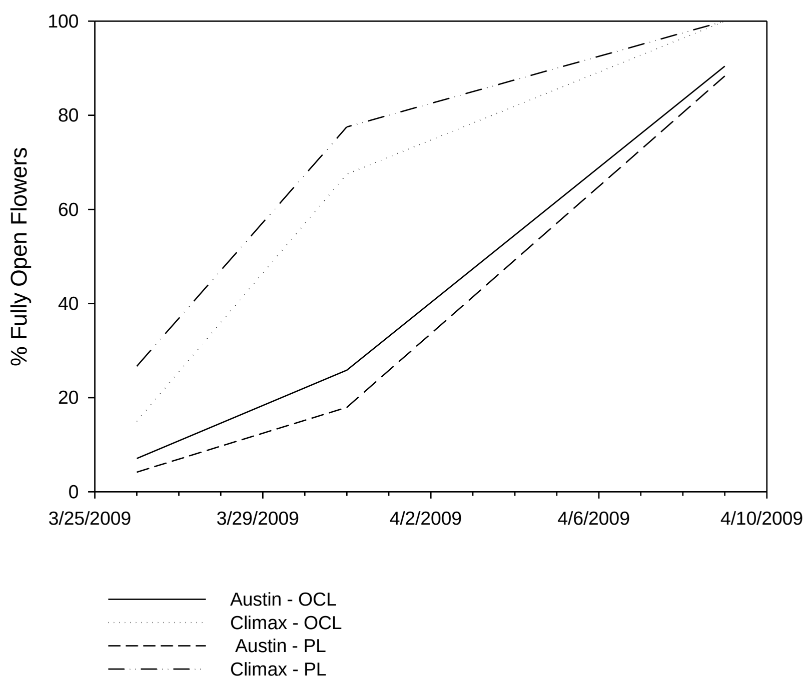

Table 3. Effect of old crop and pasture land sites on flower bud and fruit set density of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2009 and 2010.

Cultivar	Flower bud density (Number of flower buds/mm^2 CCSA)[z]	Initial fruit set density (Number of fruit set/cm shoot length)[z]	Final fruit set density (Number of fruit set/cm shoot length)[z]
	2009	2010	
		Old crop land	
Austin	1.4	2.6	2.5
Climax	0.5	2.7	2.2
		Pasture land	
Austin	1.8	2.7	2.7
Climax	0.7	2.0	1.8

[z]Based on 2 canes per bush and 12 bushes per cultivar per treatment

Table 4. Effect of old crop land and pasture land sites on crop load, yield per plant, and mean berry size of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2009 and 2010.

Cultivar	Crop load[z]	Average yield per plant (kg)	Average berry weight (g)[y]
		2009	
		Old crop land	
Austin	1.3	0.19	1.5
Climax	1.2	0.07	1.0
		Pasture land	
Austin	2.7	0.38	1.5
Climax	2.0	0.29	1.0
		2010	
		Old crop land	
Austin	2.6	0.52	2.1
Climax	1.8	0.29	1.8
		Pasture land	
Austin	2.4	0.70	1.9
Climax	2.1	0.47	1.5

[z]Based on a 1-3 scale; 1=light crop load, 2=moderate crop load, and 3=heavy crop load.

[y]Based on a 50 berry sample per harvest date.

Table 5. Effect of old crop land and pasture land sites on fruit firmness, percent wet scar, SSC, pH, TA, and SSC/TA raio of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2009 and 2010.

Cultivar	Average fruit firmness (g/mm)[z]	Wet scar (%)[y]	pH[x]	Soluble solids content (%)[x]	Total acidity (%)[x]	SSC/TA[x]
			2009			
			Old crop land			
Austin	168	2	3.55	7.0	0.30	23.3
Climax	175	8	3.52	7.0	0.30	23.5
			Pasture land			
Austin	181	2	3.73	11	0.22	28.7
Climax	172	2	3.62	8.4	0.29	49.3
			2010			
			Old crop land			
Austin	168	0	3.75	13.2	0.20	66.9
Climax	171	0	3.55	12.6	0.27	46.8
			Pasture land			
Austin	197	0	3.57	11.8	0.28	41.9
Climax	167	0	3.64	13.8	0.23	60.5

[z]Based on a 10 berry sample per harvest date.

[y]Based on a 50 berry sample per harvest date.

[x]Based on a 20 g sample per harvest date.

Table 6. Effect of old crop land and pasture land sites on fruit lightness, chroma and hue angle of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2009 and 2010.

Cultivar	L*	C*	h°
		2009	
		Old crop land	
Austin	31.3	5.7	265.6
Climax	31.7	4.4	261.1
		Pasture land	
Austin	31.2	4.1	264.0
Climax	34.8	5.0	263.4
		2010	
		Old crop land	
Austin	36.7	5.9	265.3
Climax	30.5	4.3	264.7
		Pasture land	
Austin	33.8	5.4	264.7
Climax	32.4	4.8	272.6

Table 7. Effect of old crop land and pasture land sites on plant growth index and leaf area of 'Austin' and 'Climax' blueberry cultivars grown in Columbia, AL, 2009 and 2010.

Cultivar	Plant growth index (cm^3)	Leaf Area (cm^2)
	2009	
	Old crop land	
Austin	5677	7.2
Climax	6641	7.0
	Pasture land	
Austin	11999	7.9
Climax	10854	7.0
	2010	
	Old crop land	
Austin	16848	6.7
Climax	13985	7.3
	Pasture land	
Austin	21746	6.5
Climax	17048	7.2

CHAPTER FIVE

Final Discussion

Proper cultivar selection is one of the most important decisions a grower of any crop can make. Rabbiteye blueberries (*Vaccinium ashei* Reade) can continue to be productive for 30 years or more (Esendugue et al., 2008), and thus, the consequences of cultivar selection will be experienced for many years. In other words, a grower executing proper cultivar selection can reap the benefits for decades. On the other hand, improper cultivar selection can lead to issues such as reoccurring frost damage, lower yields, increased maintenance costs, higher incidences of pests and disease, among other problems. Strong scientific data on cultivar performance is particularly important as blueberry farms and farm cooperatives increase in size, as even slight differences in yield or maintenance costs greatly impact production costs and profits as farm size and competition increase. Prior to this study in Cullman, AL (34° 11' N, -86° 47' E; USDA Plant Hardiness Zone 7B), the most recent data on rabbiteye blueberry cultivar performance in Alabama was nearly two decades old (Dozier, 1991), and no data on the performance of newer rabbiteye blueberry releases was available. Additional studies in other regions of the state, as well as the continued monitoring of the current rabbiteye blueberry planting in Cullman, AL at the North Alabama Experiment Station would be beneficial to the Alabama blueberry industry. The plants in our study were relatively young and just entering the commercial production stage, thus the continued monitoring of these plants will serve to paint a more accurate picture of cultivar performance over time.

Flowering and ripening season, yield, method of harvest, and the intended market for sale are among the most important factors that growers consider when selecting cultivars. Early season crops fetch higher prices, but early ripening cultivars tend to flower earlier, exposing them to the risk of floral damage from late spring frost. In our study, ‘Alapaha’, ‘Climax’, and ‘Premier’ were indicated to be early flowering and ripening cultivars, while ‘Alapaha’ flowered slightly later than ‘Climax’ and ‘Premier’, providing additional protection from possible late spring frost damage. Late ripening cultivars can serve to extend the harvest season. ‘Baldwin’ and ‘Onslow’ were found to have late ripening seasons in North Alabama, and can be utilized when a late season crop is desirable.

While no differences were seen across cultivars in 2009 with respect to yield per bush or in cumulative yield across both seasons, 2010 yield data indicate that ‘Alapaha’, ‘Brightwell’, ‘Premier’, and ‘Tifblue’ were all high yielding cultivars. It is likely that with continued observation, differences in yield levels would become more apparent as the plants approach full production levels.

‘Baldwin’, ‘Brightwell’, and ‘Powderblue’ were found to have extended harvest seasons, which suggests they may be well suited for production at pick-your-own operations. ‘Baldwin’ berries are not well suited for shipping, as they likely have a shorter shelf life than other cultivars tested, as indicated by low berry pH and high occurrence of picking scar, and likely should be considered primarily for pick-your-own type of operations.

For mechanical harvesting, plants should exhibit concentrated ripening periods, moderate vigor, a moderate number of narrowly growing upright canes (which could be trained into a narrow hedge row to fit a mechanical harvester), a large number of flower buds, a high resistance to wound pathogens, small to moderate fruit size, a light blue color, small scars, loose fruit clusters, moderate ease of fruit removal, crisp flesh texture, a firm berry, tough/elastic skin, and desirable sugar/acid ratio to assure extended shelf life (Ballington, 1990). As labor becomes less available and farms as well as farm co-operatives increase in size, mechanical harvesting is becoming more widespread. Thus, a cultivar's suitability for mechanical harvesting is becoming more important. Due to the greater berry firmness of 'Brightwell' and 'Climax' these cultivars may be better suited for mechanical harvesting as compared to the other cultivars tested. 'Alapaha', 'Montgomery', and 'Premier' each had soft berries over both seasons and likely could not be suitable for mechanical harvest. Additionally, 'Alapaha', 'Onslow', and 'Yadkin' were indicated to have a more upright growth habit in 2010, as this growth habit lends itself to mechanical harvesting. Studies in Alabama focused specifically on identifying cultivars best suited for mechanical harvesting would be beneficial to the Alabama blueberry market.

In some states, such as Georgia, nearly all of the blueberries produced are shipped (Spiers, 1990). In such cases, berries need to be both firm and have good shelf life. 'Brightwell' and 'Yadkin' berries may be well-suited for the shipped fresh market, as they have firm berries and a high pH level. Firm berries ship well, and a high berry pH indicates a good shelf-life.

Ornamental qualities of these eleven rabbiteye cultivars were also investigated in order to evaluate and compare cultivar characteristics for use as functional landscape plants by analyzing berry fall foliage color, berry surface color, summer foliage color, and bush form. The identification of various landscape qualities can help increase the marketability of rabbiteye blueberry when selling plants for home use. 'Alapaha' and 'Yadkin' had long lasting red fall foliage, with 'Yadkin' displaying a lighter, more intense fall color and 'Alapaha' having duller and darker fall color. 'Ira' and 'Premier' were found to have intense, long lasting fall color that was more yellow. 'Powderblue' had the most waxy and attractive summer foliage and berry. It would be advantageous to perform concurrent subjective and instrumental studies on fall color to determine how lightness, chroma, and hue angle correlate to those cultivars deemed to have the most pleasant fall color through subjective rankings.

Our studies in Columbia, AL (lat. 31° 15' N, long. -85° 9' E; USDA Plant Hardiness Zone 8A) were aimed to determine the effect that the previous use of land planted with rabbiteye blueberries had on vegetative growth, yield, and fruit quality. Old crop land (OCL) and land previously left to pasture (PL) were found to differ most strikingly in levels of organic matters. While some differences between the mineral levels in the soils were observed, these differences were not reflected in the foliar analysis of the plants grown on each soil type. 'Austin' and 'Climax' rabbiteye blueberries grown on PL were found to have greater fruit set, which translated into yields as much as three times that of the same cultivars on OCL. Additionally, plants grown on PL were found to have more vigor than those on OCL. It is widely accepted that rabbiteye blueberries do not grow as well on land previously used for crop production, but the scientific data is lacking.

Although both OCL and PL soil were shown to have above the recommended 2% organic matter, PL soil was found to have over twice the level of organic matter present in the soil. Soil tests performed in 2008 indicated organic matter levels of less than half the recommended level on the OCL, but soil tests were not performed on the PL at that time. It is very likely that the organic matter present in the PL was higher at planting, thus aiding the PL plants to establish faster, leading to increased yields and vigor. Spiers (1983) found that higher organic matter levels increased young rabbiteye plant establishment in both irrigated and non-irrigated plants, likely due to the alleviation of moisture stress. It would be useful to study various soil characteristics as factors affecting the establishment of rabbiteye blueberry plants at planting on soils with differing usage histories. Subsequently, the plants should be evaluated after establishment to determine if differences in plant performance can be attributed to establishment stresses from planting, or if other factors are accountable for plant establishment. Additional studies could be conducted to determine what steps can be taken at differing stages of plant development and establishment to alleviate detrimental effects caused by the previous use of the land.

Rabbiteye blueberries have a narrow germplasm, as nearly all nuclear genes come from the following four selections: ‘Myers,’ ‘Black Giant,’ ‘Ethel,’ and ‘Clara’ (Ballington, 1990). We were interested to determine if cultivars with similar parentage had similar growth, yield, or ornamental characteristics. We were unable to identify any noticeable trends between the genetic origin and cultivar performance in our study. Despite this lack of clear trend, it could be beneficial to further investigate the relationship between rabbiteye blueberry cultivar parentage and important plant characteristics . This information could be beneficial for breeding purposes as well as cultivar selection. It is possible that cultivar performance could be inferred in cultivars lacking scientific data on their performance.

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