

**Supplemental Foliar Nutrients Effects on Fruit Quality and Yield
of Two New Primocane Blackberry Cultivars**

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ABSTRACT

Supplemental foliar nutrient products are applied by some berry growers to improve sugar content, fruit quality and yield; however, there is insufficient evidence that these applications increase fruit quality or yield when applied at the recommended label rates. Virginia growers have limited information on two new thornless, primocane cultivars, ‘PrimeArk® Freedom’ and ‘PrimeArk® Traveler’. These cultivars, studied over two fruiting seasons, beginning in 2016, are considered compatible for hardiness zones 6-9. The study was conducted at the Hampton Roads Agricultural Research and Extension Center (USDA, Zone 8a) with thirty-six (36) PrimeArk® Freedom and PrimeArk® Traveler plants, respectively, established using white woven polyethylene ground cover on raised beds and supported by T-post trellises. The objective of the study was to determine if application of supplemental foliar treatments reflected increases in sugar content, yield and overall fruit quality. Three foliar nutrient treatments were applied using recommended label rates of: AgGrand (4-3-3); K-Ace (0-0-25); Sugar Express® (40-10-40). An untreated control that received no supplementary nutrient was included in the study. Six foliar application treatments were applied (April 17, May 5, May 27, June 11, June 25 and July 16 in 2017) at various growth stages from pre-bud to bloom through harvest. There were no significant differences between control and those that received foliar treatments, on plant growth, yield, sugar content or overall fruit quality. This study presents the results of foliar nutrient product effects on thornless, primocane varieties and will be repeated in the 2018 growing season.

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Background and Setting

Foliar products are applied by many blackberry (*Rubus subg. Rubus Watson*) growers to increase sugar content, improve fruit quality and yield quantity, without evidence that these applications achieve those goals. In a 2014 on-farm observational study in Virginia, Total Soluble Solids (TSS) values for ‘Ouachita’ and ‘Navaho’ were higher at the site location where berries received supplementary foliar applications of sulfur and potassium compared to the other locations (Conway and Samtani, 2016). Virginia growers lack data on blackberry cultivars that perform well in the state, especially new thornless, primocane cultivars, PrimeArk® Freedom (U.S. plant-patented as ‘APF-153T’) and PrimeArk® Traveler (U.S. plant-patented as ‘APF-190T’). The study findings provide valuable insight, assisting growers with cultivar selection and justification for decision making on foliar applications, as a method of increasing sugar content in berry production.

The study took place at the Virginia Tech Hampton Roads Agricultural Research and Extension Center (HRAREC), 1444 Diamond Springs Road, Virginia Beach, VA 23455. Study site has a coastal plain elevation of: 36.89, -76.18; GPS Coordinates. 36 ° 53’ 34” N, 76°10’37” W; elevation of 7.01 m (23 ft.); U.S. Department of Agriculture (USDA) hardiness zone 8a; estimated last freeze/first freeze dates 7 April/1 October, respectively (National Weather Service, 2018). Plot rows were oriented North to South in a 100% Tetotum loam soil (U.S. Department of Agriculture-Natural Resource Conservation Service [USDA-NRCS], 2016).

Introduction

Climatic requirements. Commercial blackberry production has increased in the southeastern United States (Strik Clark, Finn, & Bañados, 2007). Cultivars that are florican-

fruiting have been the primary production fruit in the blackberry industry with one season harvest. Primocane-fruited cultivars provide two-season harvesting in spring and late summer.

Both primocane cultivars, from the University of Arkansas, are rated compatible and marketed to the public for growing in hardiness zones 6-9 (Nourse, 2018). However, Virginia Beach, Virginia, is in the Coastal Plain and receives much more humidity in a temperate climate than other states located in USDA hardiness zone 8. For example, even though Austin, TX, in USDA hardiness zone 8, Texas has a much drier climate (U.S. Department of Agriculture-Agricultural Research Service, [USDA-ARS], 2012). The hardiness zone map is an essential tool for plant zone compatibility, it is not without flaws. Too much rain, little rain, humidity, wind, and unusual weather patterns that cannot be predicted are all factors that can affect growing. Additionally, temperatures can dip below those that are indicated on the map. Blackberries thrive in temperate climates with well-drained loose soil. Once established, caneberry plants have rather large root systems and are not susceptible to drought, however, caneberry plants are very sensitive to overwatering (Natural Resource, Agriculture, and Engineering Service [NRAES], 2008).

High humidity and repetitive storms in the 2016-2017 growing season, plagued the crop with fungal issues. Although Virginia Beach, Virginia, is in zone 8, the USDA Hardiness zone map considers averages of the lowest temperatures and does not take rainfall or humidity into consideration (USDA-ARS, 2012). Studies for this crop in the coastal plain will assist growers interested in blackberries in Virginia; since, there is very little data available.

In Clarksville, AR, primocane-blackberries produce only a small amount of fruit in the late summer, likely as a result of lack of heat tolerance of the flowers (Clark, 2008; Stanton, Scheerens, Funt, & Clark, 2007). In 2016, plants were established and yield was very low. During the warmer months of that year, July temperatures ranged from (the average to maximum) 94 – 102°F, and 92

– 100°F, in August. Temperatures for July in 2017, ranged from 88 - 96°F and for the month of August, 84 - 92°F (Weather Underground, 2017). Double berries were observed on PrimeArk® Freedom plants later in the harvest season. Heat issues over 85-90°F, may limit the ability to grow primocane fruiting varieties. With extreme summer heat during flowering, double berries may occur in fall (McWhirt, 2016). Yield for late season harvests were very low. When these same experimental cultivars were grown in Aurora, OR, harvest commenced in August and extended into October (Strik, Clark, Finn, & Buller, 2008).

Heat tolerance and chilling requirements are equally important components when considering cultivar selections for suitable regions. One of the previous primocane cultivars, ‘PrimeArk® 45’ developed in 2009, has a requirement of 300 chilling hours (McWhirt, 2016). There are various ranges of chill hours essential for various cultivars and from a personal observation by J.R. Clark, the latest cultivars, PrimeArk® Freedom and PrimeArk® Traveler, have not been fully defined for chilling requirements. In the University of Arkansas program, Prime-Ark 45 and ‘Natchez’ were observed to require 200 to 300 chill hours and for ‘Ouachita’, 400 chill hours were needed. These observations suggest that, PrimeArk® Freedom and PrimeArk® Traveler may have a chilling requirement in the range of 300 to 400 chill hours, but Prime-Ark Traveler also fruits on primocanes with no chilling, so it is possible that no chilling is required for fruit production (Clark & Salgado, 2016). To precisely determine the chill hour requirements, further observation is needed.

Vernalization is accomplished with a certain number of chill hours required, setting dormancy for the plant that in turn, promotes growth in the warmer spring temperatures, assuring blossom and fruit set. Bud break is promoted with warmer spring temperatures, but may be disrupted by fluctuating temperatures dipping at or below freezing. The Southeastern region has

received climate fluctuations as noted on February 8, 2017, when average temperatures dropped from 64°F to 32°F, with high wind chill, in a short amount of time. These extreme temperature fluctuations have become more common with continued warming and cooling also seen in the month of March of the same year. This study, conducted in the southeastern region of Virginia, received 922 chill hours (Below 45 °F Model) and 669 chill hours (Between 45 °F and 32 °F Model) for the 2017 harvest year (Weather Underground, 2017). Although this region allows for ample chill hours, significant temperature fluctuations in the coastal plain, during early growth stages and bud break can reduce yield. Results from this study will help determine if these cultivars are suitable to thrive in these climatic conditions.

Plastic mulch. White plastic polyethylene sheeting with reinforced fibers has been used to improve plant volume, increases leaf area and fruit yields in Texas (Makus, 2010). Along with the benefits of using white woven polyethylene ground cover, this tarp method is also helpful for weed mitigation. Foliar applications may be beneficial in correcting micronutrient deficiencies, when soil fertilizer applications are not possible, using plastic sheet mulch products. When soil nutrients are deficient, uptake of nutritional elements via root zone may be limited and prevent proper plant growth. Translocating foliar nutrients to fruit, using foliar feeding, may offer faster plant response possibilities in fruit bearing crops when soil is covered with white woven polyethylene ground covers. Foliar applications used in conjunction with white plastic ground covers may help plant nutrient deficiencies, and reduce herbicides used to control weed populations, improving long-term environmental health.

Nutrition of caneberries. In accordance with the Southeast Regional Caneberry Production Guide, nutritional protocol was followed in conjunction with soil and foliar analysis results. A total of 25 to 50 pounds of Nitrogen (N) per acre for the season. The initial application was incorporated

into the soil. After the installation of plastic mulch, the remaining N was administered through drip irrigation. In the second year, a total of 50 to 80 pounds of nitrogen should be administered as a split application. One half of the total amount applied in spring when primocanes emerged and the second application following harvest through drip irrigation. During the third and subsequent years, a total of 60 to 80 lbs. of actual N per acre will be distributed in accordance with the same protocol followed in the second year, using a split application (Fernandez, Garcia & Lockwood, 2015).

Proper plant growth and development, require a balance with macronutrients and micronutrients. During the fruit development stage, floricanes leaf Nitrogen (N) and Potassium (K) levels tend to decline most rapidly in all cultivars (Strik & Vance, 2017). Any nutrients added should be based on foliar and soil analysis. Nitrogen (N) is important for plant health and can be provided quickly with foliar feeding. Although phosphorus (P) is also an important macronutrient in the production of caneberries, it can slow the uptake of micronutrients and the location of this research does not require additional soil applications of P due to runoff concerns and existing high levels (Fernandez, Garcia & Lockwood, 2015). Improving the quality of fruit development with K may increase firmness and improve root growth. Sulfur is critical to berry plant health, helping the plant resist dehydration, disease and other stress effects. It also plays a role in protein synthesis that affects cell wall structure of plants. Potassium content fluctuates in leaves during the growing season, and it decreases as fruiting increases (Fernandez, Garcia & Lockwood, 2015). This may be why plants responded to foliar applications in a previous study, with increases in total soluble solids (TSS) in berry fruit when sulfur and potassium solutions were applied.

Thornless, primocane fruiting blackberries, with two harvests in one season, are becoming very popular; however, very little data is available for bountiful harvests in Virginia. There have

been effective studies using foliar applications in other fruit crops. Zinc (Zn) has been used successfully to correct micro deficiencies in grape crops (Christensen, 1982; 2005). Despite the growing popularity of this primocane crop, very little is known about the yearly nutritional needs for growth in Virginia. In the Pacific North West, Bernadine Strik researched foliar applications of Calcium (Ca) on primocane blackberry crops to promote longer shelf life and quality. Foliar treatments of Ca in cherries and apples, showed increases; however, at the suggested label rates, the applications for blackberries were not effective (Strik, Vance, Jones, 2016). It was not determined whether a shorter fruit development period and the number of applications were a factor in the results. Primocane leaf nutrient levels have been shown to vary over the growing season in florican-fruiting blackberry (Clark, Buckley, & Hellman, 1988; Mohadjer, Strik, Zebarth, & Righetti, 2001). Although foliar applications may be helpful in correcting micronutrient deficiencies, when soil applications are not possible, nutrient level variability in the leaves may be a timing issue of leaf development and translocating foliar nutrients to fruit.

Purpose of the Project

The objectives of this research were three-fold. First, to document yield of and determine if new primocane-fruiting blackberry cultivars are productive in the coastal plain of Virginia. Second, to examine the efficacy of foliar applications of potassium and sulfur products to promote increase of TSS. Third, to determine if the applied foliar products, improve yield, size and overall health of blackberry plants.

Definition of Terms

- **Total Soluble Solids (TSS)** – Measure the sugar content of a solution determined by the index of refraction.

- **°Brix** – Is a measured reading of sugar content using a refractometer with a scale based on the relationship with refractive indices at 20°C and the percentage by mass of total soluble solids of a pure aqueous sucrose solution.
- **Foliar feeding** – A technique of feeding plants by applying supplemental fertilizer sprays to the leaves where the nutrients enters the plant.
- **Yield** – The full quantity of a natural agricultural commodity harvested as a result of cultivation.
- **Primocanes** - first-season canes, that are usually vegetative in most blackberry cultivars, but in primocane-fruiting cultivars, can flower and fruit.
- **Floricanes** - are second season blackberry plant canes, which bear flowers and fruit.

Significance of the Problem

Blackberries are fruiting plants, enjoyed for their flavor and high profit margin potential; however, lack of empirical data to determine if this commodity will perform well in Virginia is needed and important for farmers interested in crop diversity. There is limited available information on PrimeArk® Freedom and PrimeArk® Traveler, two relatively new cultivars. Having data available will help farmers in Virginia with determining factors for growing these cultivars in this region. Although foliar feeding was discovered in the 1950's, there is little data available on what products are best suited for blackberry crops and the significance of foliar nutrients (Tukey, Ticknor, Hinsvark & Wittwer, 1952). There are standard cultural pruning and tipping practices; however, ongoing studies will continue to improve yield data with new methods. Foliar applications can assist with correcting nutrient deficiencies using the plant leaf as an organ for absorption; however, little data is available for products that perform well and promote yield and sugar content. Timing and transition from sink to source should be considered and may vary

with the ability of leaves to export foliar-applied nutrients, determined by cultivars and environmental conditions.

Review of Literature

Cultivated blackberries are estimated to grow in excess of 25,000 ha worldwide with many countries continuing to harvest wild blackberries (Strik et al., 2008). Primocane-fruiting blackberries seem like a rather new discovery; however, the first known recorded occurrence of a primocane-fruiting blackberry was a wild plant found by L.G. Hillquist of Ashland, VA, USA. Mrs. Hillquist provided this genotype to the New York State Agricultural Experiment Station (Geneva) in 1949 (U.S. Department of Agriculture-Agricultural Research Service [USDA], 2006), (Clark, Strik, Thompson, & Finn, 2012).

The growing environment and opportunities for value-added marketability are important factors to consider when growing primocane-fruiting blackberries and low chill requirements for these cultivars may be a good choice for growers. Blackberry fruit is limited in the U.S. from September to November, the period when most of the summer production in the U.S. is complete, but before substantial Mexican imports begin. This is also a time of higher fruit prices and potential grower profitability (Carvalho, Thomsen, & Clark, 2010). With this available window of opportunity, increasing farm profits are possible. Prompted by this marketing-timing interest, the University of Arkansas released the first commercially viable, primocane-fruiting blackberry, 'APF-45' (marketed as Prime-Ark 45[®]) (Clark and Perkins-Veazie, 2011). New releases, starting in the 1990's opened the door for grower and consumer interest.

The first primocane-fruiting selections in the University of Arkansas breeding program were made on 27 Sept.1997, in Fayetteville, AR, by J. Lopez-Medina, J.N. Moore, and J.R. Clark (Clark, 2008). Primocane-fruiting cultivars provided more blackberry availability and breeding

programs continued to improve with new cultivars PrimeArk® Freedom and PrimeArk® Traveler, available to the public in 2011 and 2016, respectively. PrimeArk® Freedom is the fourth in the University of Arkansas Prime-Ark® Brand primocane-fruited blackberry cultivar line following the release of ‘Prime-Jan’® and ‘Prime-Jim’® in 2004 (Clark, Moore, Lopez-Medina, Perkins-Veazie, & Finn, 2005) and ‘Prime-Ark® 45’ in 2009 (Clark & Perkins-Veazie, 2011).

Agritourism has sparked interest in pick-your-own options for consumers that are interested in knowing where their food is grown. Farmers markets have gained renewed interest and according to USDA's 2014, National Farmers Market Directory, Virginia is listed as one of the states with the most farmer's markets with 249 available to the public (U.S. Department of Agriculture [USDA], 2014). These farm markets can be very profitable in urban areas with large populations. Berries receive a premium price early and late in the season when demand is high and an extended season provides a bigger market share for farmers.

With a growing consumer interest, blackberries compliment other fruits and allow season extension with a nutritionally valuable crop. There has been an increased interest in blackberry fruit offering a tasty food option with healthy antioxidants benefits. Blackberries are sought after for their nutraceutical properties and consumers have shown increased interest in local foods and fresh produce, including berries from area growers. Community gardens are common in most inner cities with limited access to healthy foods; blackberries grown at these locations are a compliment to other fruit as an added health benefit, especially in food desert locations.

Blackberries thrive in temperate climates with well-drained loose soil. Once established, bramble plants have rather large root systems and are not too susceptible to drought, however, bramble plants are very sensitive to over watering (NRAES, 2008). Having blackberry crops in raised beds allows better drainage and helps prevent over watering issues.

The number of states producing berries in the United States has increased 11% from 2007 to 2012 (USDA, 2012). Oregon is the predominant geographic source of cultivated blackberry production in the United States and the only state that shows yields per acre, in the National Agricultural Statistic Service survey. In 2014, Oregon produced 45.4 million pounds of blackberries on 6,100 acres. Average blackberry yields per acre were 7,390 pounds (down 15 percent from 2013 and down 17 percent from 2012). 3.1 million pounds were sold as fresh berries and the remaining 41.9 million pounds were sold as processed product (National Agricultural Statistic Service [NASS], 2015). According to the 2012, U.S. Department of Agriculture's (2015) Census of Agriculture, North Carolina has more cultivated blackberry crop acreage with 405 acres compared to the bordering Commonwealth of Virginia, that produced 269 acres (NASS, 2015). Due to the lack of literature available for PrimeArk® Freedom and PrimeArk® Traveler in the Commonwealth of Virginia, disseminating yield data for these cultivars will be valuable to growers and substantiate the need for further research.

Targeted Population and Participating Audience

North American blackberry production was valued at \$50.1 million in 2014, with an increase from the previous two years. Fresh market sales earned \$4.91 million and \$45.2 million from processed sales (NASS, 2015). Consumers are more health conscious and appreciate the low-fat, antioxidant qualities that blackberries offer.

In this multitasking generation, the old adage 'working smarter and not harder', is the norm. Finding improved practices to make life more efficient for farmers and satisfy consumers, benefits the masses. Consumers tend to appreciate sweeter fruits and those berries that contain high sugar and acid typically taste better. When fruits are grown in warm, dry climates, with temperatures near 77° F (25° C) they contain less acid and are sweeter. Comparatively, growing

fruits in temperatures greater than 86° F (30° C) reduces fruit aroma and sugar content is reduced with continued wet weather (Bushway, Pritts, & Handley, 2008). New thornless, primocane-fruited blackberry cultivars, with improved size, flavor and storage qualities, provide an option with extended harvest seasons and less pain involved for those harvesting compared to arm-scratching, thorny plants. Thornless plants are also appreciated for consumers in pick-your-own venues. Floricane-fruited has been the basis of all blackberry production and commercial primocane-fruited cultivars did not exist prior to the release of 'Prime-Jim'[®] and 'Prime-Jan'[®] by the University of Arkansas in 2004 (Clark et al., 2005).

The added benefit of enriching dietary intake, allows consumers to appreciate blackberries and expect year-round grocery store availability. Considering the initial two-year establishment period, time from planting to economic return can be 3 to 5 years. For dollars invested, blackberries offer a high return due to a generally low supply and high demand in many regions in the United States. Blackberries provide crop diversity for Virginia farmers. Including blackberries in farm plans may allow grower operation extensions for a longer season harvests, increasing agritourism and sales; however, Virginia growers lack empirical data on blackberry cultivars that perform well in the state. Virginia growers also lack information on the role of supplemental foliar nutrients. Findings from this study will be beneficial to growers making variety selections in Virginia and other mid-and South Atlantic states with similar USDA hardiness zones.

Materials and Methods

The plants received standard recommended cultural practices for blackberries in this region, according to the Southeast Regional Caneberry Production Guide, with the addition of foliar nutrients in certain treatments applied in the second year after plants were established (Fernandez, Garcia & Lockwood, 2015). The study utilized a completely randomized design with

one factor of four treatments (three foliar treatments and one control) and one block factor of two cultivars PrimeArk® Freedom and PrimeArk® Traveler.

Field site was measured, soil samples were collected (in eight different locations at a depth of 8 inches) and sent for analysis to the Virginia Tech Soils Testing Laboratory on 26 October 2015. The soil pH of 5.4 was determined by a soil sample analysis on 29 October 2015. The soil was tilled twice and amended with dolomitic limestone at rate of 185 lbs./A (25.8 lbs./A of CaNo_3 applied through Dosatron® drip fertilizer injector) as per the soil test recommendations on December 2015. Four planting beds were oriented North to South, with dimensions of 2.5 ft. width by 100 ft. length and 8 in. height. Cultivars were planted in 2 ½' wide rows, 4' in-row spacing, and 17' treatment areas (including trellis posts) on April 24, 2016.

Virus-tested, two-year old, thornless primocane cultivars 'Prime-Ark® Freedom' and 'Prime-Ark® Traveler' were obtained from a commercial nursery on 6 April 2016 (Nourse Farms, Whately, MA) and established at the Virginia Tech Hampton Roads Agricultural Research and Extension Center (Virginia Beach, VA). Beds of dimensions 2.5 ft. wide by 100 ft. long were established on 14 April 2016 and covered with 5 mils T-55 white, woven, polyethylene tarp (Reef Industries, Inc., Texas). Furrow area was seeded with perennial ryegrass on 21 April 2016 (at rate of 1.3 lbs. per 1000 sq. ft.). A total of 36 blackberry plants for each of the two cultivars 'Prime-Ark® Freedom' and 'Prime-Ark® Traveler' (Nourse Farms, MA) were transplanted at 5' center spacing on 24 April 2016, with three plants per replicate. A 10' wide furrow spacing was maintained between two blackberry rows.

Drip irrigation was installed on 25 April 2016, using polytube with 2.0 gph pressure compensating emitters at planting hole (Berry Hill Irrigation, Buffalo Junction, VA).

After white plastic tarp installation on raised beds, blackberry plants were fertigated, using a Dosatron® drip fertilizer injector (Gempler's, Janesville, WI), set up on 22 June 2016. Blackberry plants were fertigated using 3.5 lbs. of calcium nitrate (15.5% N, 19% Ca, Southern Ag., Palmetto, FL) on 30 June 2016, to meet remaining nitrogen requirements of 185 lbs./A of nitrogen. On July 2016, a T-trellis system was installed. Vertical posts were secured 2 ft. into the ground (hole cut in plastic mulch for post insertion) with concrete. The lower guide wires on the T-post are at a height of 2 ft. and the upper wires are 5 ft.

Standard cultural practices for erect blackberry production were used including annual preemergence and postemergence herbicide applications. In the 2016 – 2017 growing season, all plants received dormant pruning in mid-February 2017, by removing dead floricanes and pruning laterals to approximately 3-4 ft. lengths. Previous year primocanes were thinned, leaving approximately 5-7 canes. Both Raspberry Cane Borer (*Oberea bimaculata*) and Raspberry Crown Borer (*Pennisetia marginata*), were detected through observational health ratings. Infested canes were removed when damage was observed and crown of plants treated with Brigade WSB (3pt./A), during dormancy and prior to green tip emergence.

Foliar nutrient treatments were applied, during the cooler, early morning hours to reduce leaf burn, using recommended label rates of: AgGrand (4-3-3) (Amsoil, Inc., Superior, WI) 16 lbs./A, Sugar Express® (40-10-40) (Miller Chemical and Fertilizer Corporation, Hanover, PA) 5 – 10 lbs./A, and K-Ace (0-0-25) (Big Bend Agri-Services, Cairo, GA) 1 – 3 lbs./A, (Table. 2). Treatments were applied six times between 17 April 2017 and 16 July 2017 using a rechargeable cart-tank sprayer at 30 psi (Master Manufacturing, Paynesville, MN) with a ConeJet X20 nozzle (TeeJet, Springfield, IL). No surfactants were utilized. Environmental conditions, including biotic

and abiotic stresses at the site on the day of applications are detailed including leaf ontogeny phases (Table 1).

All plants were allowed to produce floricanes and primocane crops. Tipping increases primocane yields on ‘Prime-Jan’[®] and ‘Prime-Jim’[®] (Strik et al., 2008). Early spring tipping (removal of the apical dominance of the shoot tip), was performed, removing about two inches of growth, when canes reached approximately 3’ in height, mid-May. When those branches that were soft tipped reached 1 ½’ in length, they were tipped again in August. Summer tipping was also accomplished in the same manner when flush of growth occurred. Blackberry plants were treated with 10 oz./A rate Brigade WSB to suppress damage from Japanese beetles (*Popillia japonica*) on 21 July 2016. Electric fencing (FarmTek, Dyersville, IA) was installed on 26 June 2017, to keep berry eating animals (raccoon, fox, geese) away from site and prevent pests from altering yield data. Yard Gard Electronic Animal Repellers (Gempler’s, Janesville, WI) were installed at perimeter corners of site, on 2 July 2016 as a pest deterrent. On 29 June 2017, Raspberry crown borer and Japanese beetles were detected and Brigade[®] WSB (FMC Agricultural Products), at the label recommended rate of 8 oz./A, was applied for insect control. Additional samples of cane, tip die back sections, and root ball, were shipped to Dr. Charles Johnson, Plant Pathologist at SPAREC for analysis. As per Dr. Charles Johnson, Ridomil Gold[®] (Syngenta Crop Protection, LLC) was dispensed at the recommended label rate of 3.6 pt./A (51.1 ml.), through a Dosatron[®] drip fertilizer injector, on 28 September 2017. Soil samples were collected and sent for analysis on 3 October 2017. Analysis indicated a pH level of 6.4 for this site. The optimum pH level should be between 5.8 and 6.8 (Fernandez et al., 2018). Appendix A provides a list of applicable instrumentation used in this study.

Study plants. New leaf growth emergence occurred from Mid-April to Late-May. Canes were trained using orchard ties (Midwest Vineyard Supply, Inc. Decatur, IL) on T-trellis guide wires. Both cultivars received the same tipping protocol; however, it was observed that PrimeArk® Freedom had a more erect habit than PrimeArk® Traveler, with more lateral shoot growth and smaller diameter canes. High rainfall, humidity and incidences of insects were detrimental to plant health. Plant leaf damage and fungal issues persisted throughout the growing season, prompting antifungal and insecticide sprays using integrated pest management (IPM) strategies to combat pests.

Plot description. The experiment was a completely randomized design with one factor of four treatments for each of the two cultivars PrimeArk® Freedom and PrimeArk® Traveler. Four planting beds were oriented North to South, with dimensions of 2.5 ft. wide by 100 ft. length. Cultivars were planted at 4' in-row spacing on April 24, 2016. The spacing for thorny blackberry varieties is 3 feet; for thornless blackberries, the spacing is 4 to 6 feet (Demchak 2013). The plot area available at this site allowed for 4' spacing between plants.

Program Design.

- Cultivars: PrimeArk® Freedom, PrimeArk® Traveler
- Four treatments and four replicates, three spray treatments and one control.
- Six treatments applied with battery powered regulated cart sprayer (Master Mfg. Paynesville, MN). Three treatments and a control.
- Fruit harvested every two days beginning in 2016 on 16 August with a final season harvest date of 15 November 2016. In 2017, fruit was harvested every two days beginning 31 May with last harvest date of 31 October 2017.

Treatments. Details of treatments are available, including product treatment trade names, macronutrient ratios, and sulfur and potassium contents (Table 6). Leaf analysis was completed to determine the concentration of macronutrients and micronutrient available to the plant through foliar applications on 10 April 2017, using a total of forty leaves (20 per cultivar). The results confirmed increases in nutrient levels made available through foliar feeding. No leaf burn was identified in this study with the recommended rates used.

Data Collection

Stand count and health ratings. Data including plant stand count and visual plant health ratings, were taken monthly beginning in April 2016. Plant health visual ratings were evaluated using a scale of 0 = dead plant, to 10 = very vigorous. Any incidences of disease or pests were noted on data collection sheets used during harvest and were addressed accordingly. For the 2016-2017 growing season, high humidity and repetitive storms with high rainfall plagued the crop with fungal issues. Although Virginia Beach, Virginia is located in zone 8, the USDA Hardiness zone map considers averages of the lowest temperatures and does not take rainfall or humidity into consideration (USDA-ARS, 2012). Inoculum levels were suppressed with an integrated pest management plan of rotated fungicide treatments, used after pruning events and as needed after scheduled monthly and regular maintenance of plant health observations.

Plant tissue analysis. Plant leaves were collected in accordance with oregonstate.edu foliar analysis guidelines and shipped to an independent laboratory (Waypoint Analytical, Richmond, VA.) for initial analysis on 10 April 2017. After three foliar applications were performed, plant leaves were collected on 31 May 2017. Environmental conditions, including biotic and abiotic stresses at the site on the day of applications are detailed including leaf ontogeny phases (Table 1).

To control Anthracnose (*Elsinoe veneta*), Ridomil Gold ® (Syngenta Crop Protection, LLC) was dispensed 3.6 pt./A (51.1 ml.) as per label rates through a Dosatron® drip fertilizer injector, on 28 September 2017.

Yield and fruit parameters. Harvest began as soon as ripe fruit was present in the spring and ended when no marketable fruit remained on plants. Blackberries were harvested two to three times a week by research personnel in the early morning hours and transported to the lab for data collection. Coolers with ice packs were utilized when needed to keep berries cool. Total yield, marketable yield, nonmarketable yield, average fruit size, and average fruit weight were calculated over the entire season.

Fruits were separated by categories of marketability. U.S. No. 1 berries are considered firm, developed but not overripe, and dark black in color. They are free from disease, decay, or damage by insects or other mechanical means. U.S. No. 2 berries are berries that fail to meet the requirements of U.S. No. 1 berries. They do not contain more than 10 percent, by volume, of berries, that are seriously damaged by any cause and not more than 2 percent of berries that are affected by mold and decay. Unclassified (unmarketable) berries cannot be used for processing or local or shipping markets (U.S. Department of Agriculture [USDA], 1997).

Berries were measured using a digital scale (Ohaus Corporation, Parsipanny, NJ) determining gram weight, segregated by marketability categories (U.S. No. 1, U.S. No. 2, and Unclassified). Total yields, divided by the number of plants per plot (3), were expressed as yield per plant (Table 2).

Degrees Brix was measured using a refractometer (MA 871, Milwaukee, WI) at 21°C for up to ten randomly selected sample berries per plot to determine differences due to foliar treatments and test total soluble solids (TSS). Berry Shape Index (BSI) was calculated as L/W

ratio, using a Vernier caliper (Neiko, Taiwan), measuring berry length and width (mm) of ten randomly selected sample berries (per plot) chosen from a good representation of each individual harvest for each variety (Table 3).

Statistical Design and Analysis

Prior to running the analysis of variance (ANOVA), data were checked for normality of residuals. Determination of the effects of foliar nutrient applications on yield, total soluble solids and size parameters were analyzed statistically with a one-way ANOVA, with one factor of four treatments for each of the two varieties using JMP Pro (version 13: SAS Institute Inc., Cary, NC). Mean separation was done using least significant difference (LSD) test at ($P \leq 0.05$) (Tables 3, 4 and 5).

Results

Study plots were planted in 2016 and yield was very low (data not shown). Harvest for 2017 was comparatively much higher for both cultivars (Table 2). Although these are primocane-fruited plants, it has been determined that for the florican-fruited blackberries, first-year yield data are lower than those in subsequent years (Fernandez and Ballington, 2010). Considering the first year as an establishment year, this may have been the determining factor for low yield in 2016.

Adaptability. Many factors may have reduced yield, including extreme temperature fluctuations during bloom and high humidity. These cultivars do not appear to adapt well to this climate; however, an additional year of harvest data is needed (Table 1).

Foliar application efficacy. Foliar applications of potassium and sulfur products did not show significant increases of TSS for the sixteen-week duration that foliar feeding occurred in accordance with recommended label rates (Tables 3 and 6).

Improvements. There do not appear to be significant improvements in yield, size or overall health of these cultivars. With limited yield data for the establishment period, data will be collected during the 2018 fruiting season to determine comparative results (Tables 2, 4, and 5).

Discussion

In Clarksville, AR (USDA hardiness zone 7a), primocane-blackberries produce only a small amount of fruit in the late summer, likely as a result of lack of heat tolerance of the flowers (Clark, 2008; Stanton et al., 2007). Though, when these same experimental cultivars were grown in Aurora, OR, harvest commenced in August and extended into October (Strik et al., 2008). Although Virginia Beach, Virginia is located in zone 8, the USDA Hardiness zone map considers averages of the lowest temperatures and does not take rainfall or humidity into consideration (USDA-ARS, 2012). A delay in receiving plant material for the new release of PrimeArk® Traveler and proper bedding equipment extended original planting dates for this study, delaying the initial spraying for the first season.

Humidity influences foliar absorption primarily through its effect on droplet size and persistence on the leaf surface in the liquid state. Humidity also alters leaf cuticular composition, its physical and chemical characteristics and has direct effects on leaf physiology and transport processes (Fernández, Sotiropoulos & Brown, 2013). Environmental conditions and treatments dates are provided in Table 4. Elevation may also play a role in the difference between plant survival and the ability to thrive. Low productivity was observed when primocane-fruiting experimental cultivars from two breeding programs were grown in observational plots at research stations in the Piedmont region (elevation 300-400 ft.). However, when primocane-fruiting blackberry cultivars were grown in Mills River, NC (elevation 2000 ft.), fruit production was much higher, both fruit size and number of fruit were greater than those observed in the Piedmont region

(Fernandez & Ballington, 2010). Compared to the above-mentioned elevations, this research was conducted at the Virginia Tech Hampton Roads Agricultural Research Center (HRAREC) in Virginia Beach, VA, (elevation of approximately 23 ft.).

Impact

There were many on-site challenges. Although the data presented lacks significant differences, these findings will provide information to Virginia growers, determining suitable crop choices for this climate. Treatment applications will be repeated in the 2018 growing season, to establish if production recommendations can be made based on the study outcome for the two primocane cultivars for Zone 8a in Virginia.

Program Outcomes

Findings from 2016 – 2017 research will be disseminated through extension avenues and scientific horticultural conferences. It is anticipated that manuscript publication after 2017-2018, will provide substantial comparative research data. This extended research will benefit Virginia growers with data that is currently limited.

Conclusions and Implications

Results implied that foliar applications of sulfur and potassium solutions in Sugar Express®, AgGrand and K-Ace, provide supplemental nutrients to plants. Although these provisions were not necessarily significant enough to impact yield nor increase total soluble solids in fruit at the recommended rates, another harvest season may show differences to justify the economic costs and returns for large production. Continued research with another year of harvest data, may change the end-result implications.

Recommendations

Foliar applications, at the recommended label rates as applied in this study, may not be a viable option for increasing °Brix in primocane-fruiting blackberries; however, an additional year of research is needed to determine conclusive recommendations. Foliar nutrient spray applications are an agricultural practice suited for crop production with soil limitations. Improved knowledge of factors affecting fruit susceptibility is needed for developing thresholds and risk prediction models for integrated pest management, especially with extreme weather condition fluctuations. No surfactants were employed and that may be a possible option.

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APPENDIX A: Instrumentation

- Master Manufacturing. Master Gardner spray applicator cart, Part number PCD-E3-009B-MM, Paynesville, MN (2010).
- Vernier Measuring Scale
- Ohaus weighing scale
- Dosatron - Fertigation
- Refractometer - Used to measure total soluble solids
- 2 gph. pressure regulator emitters – Berry Hill Irrigation
- Electric fencing – FarmTek

APPENDIX B: Supporting Documents

Table 1. Environmental conditions for treatment dates.

Date of Treatment	Light Conditions	Mean Temperature	Humidity	Wind Speed	Leaf Ontogeny
April 16, 2017 6:30am	Part Cloudy	77 °F	68%	10 mph (SW)	Leaf initiation
May 6, 2017 6:30am	Clear-Part Cloudy	59 °F	75%	13 mph (SW)	Full Leaf
May 27, 2017 6:30 am	Clear	74 °F	87%	5 mph (E)	Pre-bloom in floricanes
June 11, 2017	Clear	82 °F	68%	8 mph (SW)	Bloom
June 25, 2017	Scattered Clouds	80 °F	91%	6 mph (W)	Post-bloom
July 16, 2017	Clear	83 °F	91%	Calm	Fruit

Table 2. Effect of the three foliar nutrients on marketable crop yield of two new primocane cultivars. Yield data collection from 31 May through 12 October 2017.

Data collection from 31 May through 12 October 2017.					
Treatment	Nutrient Ratio	PrimeArk® Freedom		PrimeArk® Traveler	
		U.S. No. 1	U.S. No. 2	U.S. No. 1	U.S. No. 2
-----g/plant-----					
Sugar Express®	4-10-40	230.89	200.89	473.67	416.11
AgGrand	4-3-3	199.44	195.44	487.11	402.78
K-Ace	0-0-25	182.89	173.78	443.00	321.89
Nontreated	0-0-0	113.28	202.83	419.89	234.78

Table 3. Total Soluble Solid (TSS), °Brix 2017 and millimeter berry size averages for foliar nutrients treatments for PrimeArk® Traveler and PrimeArk® Freedom cultivars

Treatment	PrimeArk® Freedom	PrimeArk® Traveler	PrimeArk® Freedom	PrimeArk® Traveler
	-----°Brix-----		--U.S. No. 1, average berry size mm ² --	
Sugar Express®	10.00	9.79	828.57	577.58 AB
AgGrand	9.28	9.47	841.03	531.03 B
K-Ace	9.37	9.61	718.72	571.91 AB
Nontreated	8.80	10.01	737.82	615.67 A
P value; alpha = 0.05	.3151	.5654	.4718	.0390

Table 4. PrimeArk® Traveler Yield Data 2017

Treatment	PrimeArk® Traveler U.S. No. 1	PrimeArk® Traveler U.S. No. 2	Unclassified	Total Yield 2017
	-----g/plant-----			
Sugar Express®	473.67	416.11	219.33	1109.11
AgGrand	487.11	402.78	270.67	1160.56
K-Ace	443.00	321.89	231.11	996.00
Nontreated	419.89	234.78	224.67	879.34
P value; alpha = 0 .05	.9507	.0962	.6715	.5894

Table 5. PrimeArk® Freedom Yield Data 2017

Treatment	PrimeArk® Freedom U.S. No. 1	PrimeArk® Freedom U.S. No. 2	Unclassified	Total Yield 2017
	-----g/plant-----			
Sugar Express®	230.89	200.89	148.94	580.72
AgGrand	199.44	195.44	201.89	596.78
K-Ace	182.89	173.78	217.00	573.67
Nontreated	113.28	202.83	260.11	576.22
P value; alpha = 0.05	.4066	.9441	.4280	.8626

Table 6. Treatment names and nutrient content.

Treatment	Macronutrient Ratio	Product Rates	Sulfur Percentage	Potassium Percentage
Sugar Express®	40-10-40	20 ml. (.68 oz.)	7.4 %	40 %
AgGrand	4-3-3	88 ml. (3 oz.)	2 %	8 %
K-Ace	0-0-25	116 ml. (3.92 oz.)	0 %	25 %

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Disclaimer

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