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The effects of shade on primocane fruiting blackberries in the field

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Abstract

Primocane fruiting blackberry production in Arkansas is limited by heat during the flowering and early fruiting season. Shade could be used to delay flowering and fruiting to more favorable growth period. This study was designed to test three levels of shade (0% [control], 30% and 50% shading) applied at three times during the growing season that examined the growth, development, physiology of flowering, and fruiting of 'Prime-Ark® 45' blackberries. The seven treatments were as follows: 1) an untreated control (CK), 2) early shade 30% (ES30), mid shade 30% (MS30), 4) late shade 30% (LS30), 5) early shade 50% (ES50), 6) mid shade 50% (MS50), and 7) late shade 50% (LS50). The 30% and 50% treatments were implemented 16 June (ES) and left on for 95 days, 1 July (MS) and left on for 80 days, and 15 July (LS) and left on for 66 days. All shade was removed 19 Sept. 2014. Foliar gas exchange using CIRAS®-3 portable gas exchange monitor and estimated chlorophyll content (Minolta SPAD®) were measured weekly. Beginning at maturity, fruit was harvested biweekly to determine fruit yields per plot. Plant growth was measured destructively at the end of the study period. The cumulative berry weight was greatest for LS50 and LS30 which was not different from the CK or MS50, while ES30, MS30, and ES50 berry weights were significantly less. The cumulative marketable weights were greatest for LS30 and CK, while ES30 and MS30 were less than the CK. Shade altered flower and fruit production, but was not found to result in higher fruit quantities compared to the control. Some ES treatments reduced cropping compared to LS treatments.

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Meet the Student-Author

Olivia Caillouet

I am from Little Rock, Arkansas, and graduated with honors from Little Rock Central High in 2012. I will graduate in December 2016 with a degree in Horticulture and minor in Sustainability. I was awarded 1st place in the southern regional American Society for Horticultural Science (ASHS) undergraduate oral paper competition February 2016 and received 3rd place in the poster competition at the National ASHS conference August 2015. Furthermore, I was awarded 2nd place in the Arkansas Academy of Science (AAS) oral undergraduate competition and received 3rd place in the Honors College Student Board Poster Competition in 2016. I am a State Undergraduate Research Fellowship (SURF) grant recipient for work in Fayetteville, Arkansas and Mozambique, Africa. During my time at the University of Arkansas I have served as the Horticulture Club treasurer and vice president; worked as the Bentonville Farmer's Market Assistant Manager; completed an internship on a certified organic citrus farm in Big Sur, California; and was a summer intern at a farm in Adjuntas, Puerto Rico. I plan to pursue graduate school after graduation and then embark upon my career focused on food security at the local as well as global scale.

I would like to thank Jason McAfee for all his help and guidance throughout this research process. Curt Rom was instrumental in this journey and his advice and support is appreciated. I would also like to thank my Honors Thesis committee members, Curt Rom, John Clark, Elena Garcia, and Lawton Nalley for the time and energy provided to make this process enjoyable and fulfilling. Lastly, thank you to my team Luke Freeman, Spencer Fiser, Julia Stover, and Heather Friedrich.

Introduction

When temperatures are above 29.4 °C, heat stress has been found to be detrimental to flower and fruit production of autumn bearing primocane blackberries (Stanton et al., 2007). This limits the production of the new cultivars of primocane blackberries for production in Arkansas which begin flowering in July or August during times of high temperatures. Observations and a preliminary study in 2013 indicated that shading may be used to delay and synchronize bloom to a cooler, more favorable environment in autumn-bearing primocane blackberries. A field study was conducted 2014 to evaluate the effects of various levels of shade applied at different times throughout the growing season on 'Prime-Ark® 45' blackberries in order to confirm previous observations.

Blackberry demand and production worldwide are increasing by advanced cultivars, and with high tunnel and field production systems (Strik et al., 2007). Small fruit crops, blackberries in particular, are economically viable and could serve as a sustainable income for farmers while supplying consumers in the southern region with local produce. Traditional blackberries are a biennial plant with the first year cane—the primocane—arising from a perennial root system, remaining vegetative. After a winter dormant period, the second-year cane—the floricane— flowers in spring, fruits, and dies. A new genotype of an autumn-bearing fall harvested primocane fruiting blackberries have been developed at the University of Arkansas System Division of Agriculture. Superior cultivars of the primocane fruiting autumn-producing blackberries are being released and being grown. This has significantly expanded the blackberry production and market season.

Although very productive in cooler climates, these new genotypes have limited adaptability in Arkansas due to high temperatures during the flowering and fruit set period of July and August. It has been suggested that shade cloth could reduce fruit temperatures while also increasing fruit size and the amount of marketable berries with crop season extension (Makus, 2010). Therefore, there are two proposed methods for improving fruit of primocane cultivars: one method is to shade fruit, while a second is implement shade during flower production to shift fruit to a time where heat is avoided. The light treatments during flower formation were not meant for fruit temperature reduction in this study. It has been thought that shade may delay flowering of primocane-bearing cultivars to a more favorable season, although the research is scarce. The purpose of this study was to use light as a means of shifting the flower and fruit fruiting sequence of primocane blackberries to avoid heat.

Based upon previous work, light saturation of blackberries occurred at 750-900 umoles/m^2/s light flux which is approximately equivalent to 50% full sun on an average Arkansas day. Shade treatments would generally have allowed at or near light saturation allowing achievement of near maximum average photosynthesis rates (Curt Rom, pers. comm.). It is well studied that light is the driving energy source for photosynthesis which influences the rate of growth as well as development of plant organs (Janick, 1986). Plant organs such as stems, leaves, and flowers reach a genetically programmed minimal age of development, which varies by species and determines when the plant is capable of flower formation (Durner, 2013). However, Janick (1986) states that when a plant reaches maturity, it is capable of flowering, but will not make the transition from a vegetative stem primordia into floral primordia unless the environment it is exposed to at the time of maturity is conducive.

A study on apple trees, another rosacea species implemented three treatments: a nonshaded control, continuous 80% shade, and intermittent shade that provided both full sun and full shade (Barden, 1977). The experiment by Barden (1977) found that plant growth was dependent upon accumulated photosynthetically active radiation rather than the level of light provided. A study on blackberries in a greenhouse tested a full sun control, 20%, 50%, and 70% irradiance to full sun (Gallagher et al., 2014). Gallagher et al. (2014) reported the flower and fruit period were more concentrated when 70%-100% irradiance to full sun was implemented during initiation, meaning lower light levels may result in delayed flower differentiation and or incomplete development. It is proposed in this experiment that the use of 30% and 50% shade isolated the light intensity factor and would not reduce the photosynthetically active radiation required for growth, but delay vegetative bud development.

Flower bud initiation of several primocane fruit blackberry cultivars under field conditions was statistically different when number of nodes reached 25 between 14 and 28 May 1997 (Lopez-Medina et al., 1999). This research was the first of its kind and provided the foundation to further understand primocane blackberry flower initiation development under nonshaded conditions, which may be used to manipulate flower development in the future (Lopez-Medina et al., 1999). This previous research gave insight for determining when shade treatments (ES, MS, and LS) would be implemented in the field for this experiment. Rotundo et al. (1998) found that 40% shade reduction cloth extended the fruiting period 25 days for eight-year-old plantings of ‘Black Satin’ floricane blackberries and 28 days for ‘Smoothstem’ blackberries compared to the unshaded control in the Basilicata region of southern Italy at an altitude of approximately 630 m. Furthermore when shade was implemented in late July 1996 until late October, these two blackberry cultivars had an increased cumulative fruit production the following year, 1997, by 9% and 12%, respectively, compared to the control (Rotundo et al., 1998). Through increasing or decreasing levels of light, it is thought that the development of flower formation during the first three vegetative states—induction, initiation, and differentiation—may be manipulated to shift primocane blackberry flower development. The objective of this study was to determine if various levels of shade (30% and 50%) used at different times of the pre-flowering season (ES, MS, and LS) could alter the flowering and fruiting season of a new genotype of autumn-producing primocane fruiting blackberries in Arkansas. The hypothesis was that shade applied pre-flowering would delay bloom and harvest.

Materials and Methods

Location

The field experiment is located in the organic block of the University of Arkansas System Division of Agriculture’s Agricultural Research and Extension Center in Fayetteville, Arkansas (Latitude: 36°6'8" N; Longitude: 94°10' 17" W). The field was managed using National Organic Production (NOP, 2014) standards which enforce regulations on organic food production in the United States.

Plant Materials and Experimental Design

An experimental planting ‘Prime-Ark® 45’ primocane fruiting blackberry was established in spring 2011; and in 2013, a study evaluated cultural practices related to primocane production. ‘Prime-Ark® 45 plants were obtained from Boston Mountain Nurseries. Plants were grown in the field with Captina (Fine-silty, siliceous, active, mesic Typic Fragiudult) silt loam soil. Plants were planted in 6 rows, at 30.5-cm intervals within the row with 2.7 m between rows.

Plot Management

Canes were cut back to the crown each winter after harvest and new primocanes which emerged approximately 1 April were thinned to approximately five canes per crown in the spring with others being removed by pruning. Canes were tipped (removing the growing tip) one time on 6 June when canes were approximately 1 m in height to encourage lateral bud break. The field plot was irrigated as needed according to Irrometers®. The irrigation was inline drip tube with 30.5-cm spacing and a flow rate of 1.9 L/hour. Plants were fertilized every spring using Bradfield Organics® Luscious Lawns Mix (3-1-5) which was applied in banded rows. For seasonal pest control, plants were sprayed for spotted winged drosophyla using (Spinosad, Naturalyte® Insect Control) at a rate 0.01 L/0.40 ha.

The study was designed to test three levels of shade (0% [control], 30%, and 50% shading) applied for 95-, 80-, and 66-day periods at three different times during the summer growing cycle (Fig. 1). The field study had seven treatments with various levels of shade and differing dates of treatment implementation as follows: 1) an untreated control (CK), 2) early shade 30% (ES30), 3) mid shade 30% (MS30), 4) late shade 30% (LS30), 5) early shade 50% (ES50), 6) mid shade 50% (MS50), and 7) late shade 50% (LS50). There were five replication plots for all treatments. The 30% and 50% treatments were implemented 16 June (ES), 1 July (MS), and 15 July (LS) during the 2014 summer season. Buffer plots were established between treatment plots to isolate treatments. Shade structures were placed over 1.8-m row sections. Size and dimension of shading structure were 1.5 m (L) × 1.2 m (W) × 2.1- 2.4 m (H). Any previously formed flowers at the onset of treatments were removed from canes under shade treatments when cloths were implemented on 16 June. This was done to ensure uniformity among treatment plots and provide accurate observations regarding effects on shade flower and fruiting formation. The experiment was designed in a 3 × 3 factorial of shade by time treatments plus an untreated control with five replicated plots of each treatment in a completely randomized design.

Research Variables and Data Collection

Two healthy, vigorous canes in each treatment plot were tagged as sub-samples. The primocanes were selected for uniformity, growth, and overall health, and as a representative sample of the plot.

Measurements began approximately 1.5 hrs after sunrise beginning at 7:30 AM (CDST) lasting until 12:00 PM or until all plots were recorded in a randomized order. The center most leaflet of the blackberry pentafoliate on a leaf located four to five nodes from the tip was used for each reading. Chlorophyll estimates were made with the Minolta model SPAD-502 Plus® monitor measured on the same leaf used for foliar gas exchange measurements.

Plots began to fruit 60 days after first shade treatment beginning on 18 Aug. Fruit was harvested from plots twice every seven-day period (Fig. 2). Days after treatment (DAT) is the number of days since ES was implemented on 16 June and is used to describe measurements as well as fruit harvest data. Towards the end of the study period, the ripe fruit was harvested once every seven-day period. The total berry weight (g) for each treatment was recorded (Fig. 2). The study harvest period lasted 50 days.

Fig. 1. Collecting CIRAS®-3 portable gas exchange monitor measurements after implementation of early shade (ES) and middle shade (MS) cloth of 'Prime-Ark® 45' blackberry as affected by seven shade treatments while grown in the field, at the University of Arkansas System Division of Agriculture's Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas, 2014.

The blackberries were sorted into marketable and unmarketable fractions based upon observed fruit quality and characteristics. Criteria for the marketable berries were firmness, size, without disease or mold and limited punctures to druplets. Once graded, the total weight of unmarketable berries and total weight of marketable berries for each plot was recorded. Then the weight of 25 randomly selected marketable berries for each plot was recorded and used to determine the average weight per marketable berry. Twice during the harvest collection of berries, 29 Aug., and 12 Sept., five randomly selected marketable berries were measured for the soluble solids content.

After the conclusion of fruit harvest on 19 Oct., the tagged canes were destructively harvested for growth measurements which included: cane diameter (6 cm above the soil line) (mm), cane shoot length (cm), number of nodes, number of lateral branches formed after pruning, number of flower clusters per cane, and the number of fruit clusters per cane.

Results and Discussion

The estimated chlorophyll content at 36 DAT of plants in the LS50 treatment was statistically greater than all other treatments except CK and LS30 (Table 1). At DAT 36, there were no treatments that had chlorophyll contents significantly different from the CK. However, at DAT 45, the CK, MS30, LS30, and LS50 had greater chlorophyll contents than MS50, while ES30 was not different from any other treatments. These data indicate that over the course of the experiment, there were only two days out of eight when statistical differences were measured for chlorophyll content among treatments (Table 1).

Fruits were harvested beginning at 60 days after the onset of the experimental treatments. There was no apparent difference in the dates of first harvest among the treatments. Plants in the LS30 and LS50 treatments produced greater cumulative yield berry weight than ES30, MS30, and ES50 treatments, while all treatments were not different from the CK (Fig. 3). The cumulative harvested berry

Fig. 2. Fruit harvests of 'Prime-Ark® 45' blackberry as affected by seven shade treatments while grown in the field, at the University of Arkansas System Division of Agriculture's Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas, 2014.

Table 1. Estimated leaf chlorophyll content measured by Minolta SPAD-502 Plus® monitor of 'Prime-Ark® 45' blackberry as affected by seven shade treatments while grown in the field, at the University of Arkansas System Division of Agriculture's Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas, 2014.

	SPAD Estimated leaf chlorophyll content							
Treatment	**DAT[‡] 10**	**DAT 15**	**DAT 27**	**DAT 36**	**DAT 45**	**DAT 57**	**DAT 64**	**DAT 69**
Control	38	35	37	40.7abc[†]	42.3a	44	47	47
Early shade 30%	40	31	36	36bc	38.9abc	43	45	47
Middle shade 30%	38	35	36	39bc	41.9ab	44	48	49
Late shade 30%	41	36	39	41ab	41.3ab	42	46	48
Early shade 50%	37	28	37	35c	38bc	44	44	44
Middle shade 50%	35	37	38	35c	36c	43	45	45
Late shade 50%	41	35	41	45a	42.4a	44	47	49
Prob > F	0.5	0.1	0.3	0.01	0.03	1	0.5	0.1

[†] Mean comparisons among treatments were calculated using SAS Proc GLM least significant difference. Means followed by a similar letter are not different. ($\alpha < 0.05$, n = 5).

[‡] DAT = Days after treatment.

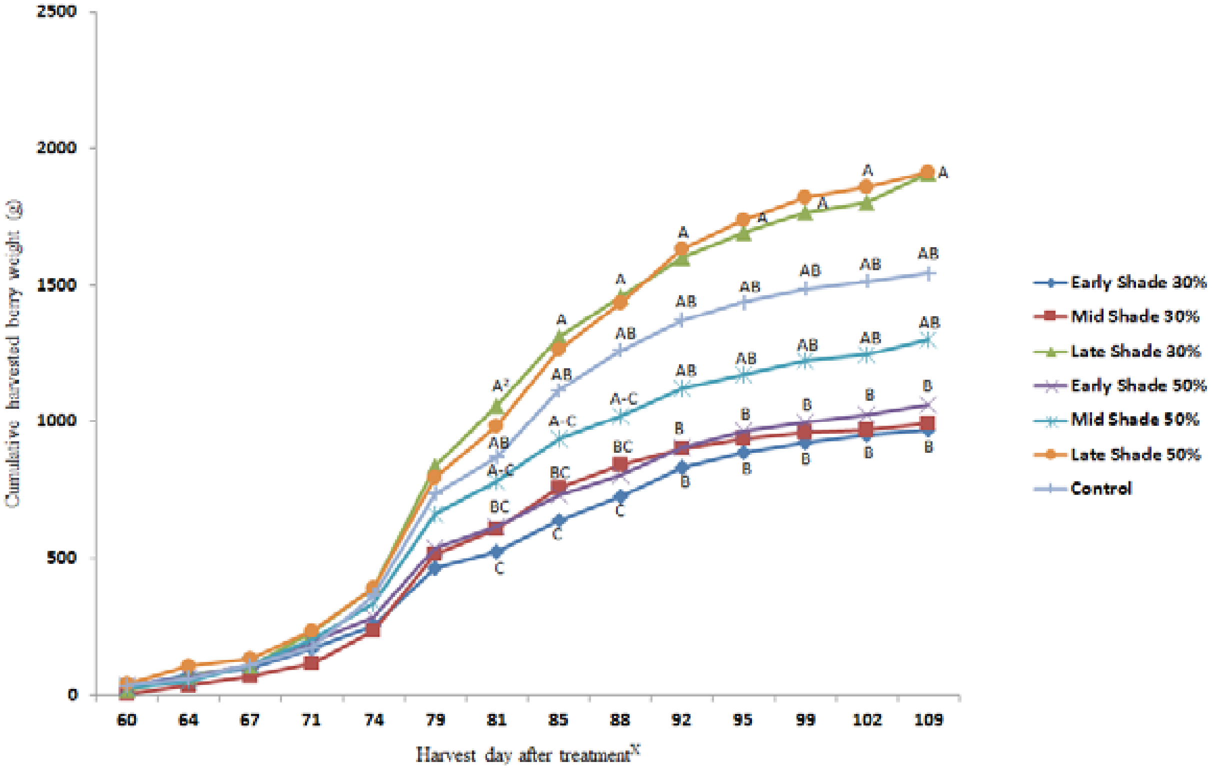

Fig. 3. Cumulative harvested berry weight (g) of 'Prime-Ark® 45' blackberry as affected by seven shade treatments while grown in the field at the University of Arkansas System Division of Agriculture's Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas, 2014. Mean comparisons among treatments were calculated using SAS Proc GLM LSD. Means followed by a similar letter are not different. ($\alpha < 0.05$, n = 5). DAT= Day after treatment.

weight which was greatest for LS30 and LS50 began to differentiate in harvest berry weight from ES30 starting 80 DAT and continued until the conclusion of the experiment, 110 DAT (Fig. 3). At approximately 95 DAT, both LS30- and LS50-treated plants had average yields above 1500 g per plot compared to ES30, MS30, and ES50 that had average berry yields less than 1000 g (Fig. 3).

After sorting fruit to segregate marketable and nonmarketable fruit, the mean cumulative marketable yields were 269% greater for LS30-treated plants compared to ES30-treated plants which were the least (Table 2). There were no statistical differences among treatments for soluble solids, cumulative unmarketable or culled berry weights (data not shown).

No significant difference for cane length, cane diameter, node number, internode length, number of lateral branches or number of fruit clusters was observed among treatments (data not shown). The short-term shade treatments were made after canes were tipped, setting their final height, and after lateral bud break had occurred. Therefore, shade did not affect gross growth in this experiment.

The hypothesis was that that shade would affect flower formation and subsequently fruit formation of primocane blackberries in the field. There was no effect on plant growth, and some shade treatments did reduce yield. Treatments ES30, MS30, and ES50 had less fruit than LS treatments. Gallagher et al. (2014) stated that flower and fruit were more concentrated when lower light levels were implemented during the flower initiation stage. Since previously formed flowers were removed prior to the ES treatments, it is possible that shade was not applied early enough during the vegetative stages of initiation. This could explain why there was no difference in plant growth, but yields were lower in some ES treatments. If that was the case, in the future shade should be applied 1 May as opposed to 16 June. Earlier shade could be coupled with season-extending high tunnel systems to protect fruit against freezing autumn weather that would end field production. This is the first research of its kind and more work needs to be completed to determine if shade is a possible management tool for delaying flower formation and cropping. The potential of shading in combination with high tunnels may provide an opportunity for primocane fruiting, autumn-bearing blackberries in Arkansas and the southern region of the United States.

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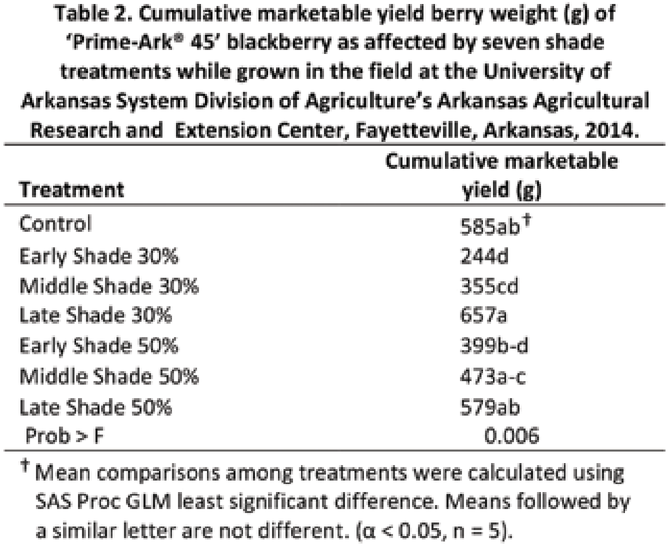

Table 2. Cumulative marketable yield berry weight (g) of 'Prime-Ark® 45' blackberry as affected by seven shade treatments while grown in the field at the University of Arkansas System Division of Agriculture's Arkansas Agricultural Research and Extension Center, Fayetteville, Arkansas, 2014.

Treatment	Cumulative marketable yield (g)
Control	585ab†
Early Shade 30%	244d
Middle Shade 30%	355cd
Late Shade 30%	657a
Early Shade 50%	399b-d
Middle Shade 50%	473a-c
Late Shade 50%	579ab
Prob > F	0.006

† Mean comparisons among treatments were calculated using SAS Proc GLM least significant difference. Means followed by a similar letter are not different. ($\alpha < 0.05$, n = 5).

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