Title: Establishment and growth of blueberry (*Vaccinium spp*.) affected by pine bark and irrigation

Progress Report

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Research Proposal

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Objective: 1) To identify the effect of varying levels of pine bark mulch and irrigation method on growth

Justification: In 2014, blueberry production from the reporting southeastern states (AL, AR, FL, GA, MS, and NC) produced 31% of the total national production at 81,184 metric tons, which was 36% of the total acreage in the nation. The farm gate value for the region was $283M, totaling 34% of the total national blueberry market (USDA, 2015). The realization that blueberry is a profitable cash crop has not gone unnoticed. In Georgia alone, the harvested acres from 2012-2014 has increased by an average of 12% per year. Total production acreage over the same time period has increased by 22% (USDA, 2015). National blueberry production has also increased in acreage, over this same three year period, from 76 K to 84 K, a 10% increase. In the southeastern states, the average price per pound, fresh and processed, over the last three years was $2.10. For AL, AR, FL, GA, and NC over the 10 year period of 2002-2011 the average price/lb was $2.15. Using the Bureau of Labor Statistics consumer price index inflation calculator (http://www.bls.gov/data/inflation_calculator.htm), purchasing $1.00 USD of goods in 2005 will cost $1.22 USD in 2015, this represents an inflation rate of 18%. Presently, average price/lb for blueberry in the Southeastern US has remained essentially flat over the last 10 years, suggesting returns to the farm are not keeping up with inflation. As profit margins decrease and input costs increase, the grower must find ways to alleviate establishment and productions costs. However, there is no compromise for precocity and gaining the earliest possible return to the farm.

With increasing competition from Mexico, California, and within the Southeastern U.S., blueberry growers will need to identify tools that will minimize establishment costs, provide production precocity, and promote plant health. Presently, growers are using pine bark culture to

produce blueberry. Pine bark is an excellent source for maintaining the appropriate soil pH for blueberry production, mulch for weed management, soil organic matter, and soil moisture retention. Along with pine bark, most blueberry plantings are irrigated, usually with low volume drip tape.

The objective of blueberry production is to enter the market at the highest possible monetary return to the farm by utilizing good cultural practices, early maturing, and precocious cultivars with good fruit quality. Blueberry breeding programs in the Southeastern U.S. have recently released varieties that are purported to have characteristics that are suitable for production. However, questions concerning the best management practice for establishment to realize the cultivar's potential are left unanswered.

This proposal involved an investigation of pine bark, irrigation type, and blueberry cultivar response on establishment and growth.

Methods:

For establishment see progress report 2014-18. In 2015, the flowers were removed from the southern highbush ('Camillia' and 'Suziblue') and rabbiteye ('Titan' and 'Vernon') blueberry plants in all the treatments to allow for vegetative growth. Fertilizer was applied four times throughout the season: 10-10-10 at 1 oz plant^{-1} in Apr, June, Aug, and Sept. Weed, disease, and insect control were applied in accordance with the IPM manual for blueberry at smallfruit.org. For each cultivar, a row of single line drip tape (0.25 gph at 12" spacing), double line of drip tape (each line 0.25 gph at 12" spacing), or a single drip line with micro emitters (blue Maxijet® 10.5 gph with a 280° fan angle) set at every other plant or 10 ft spacing and were irrigated based on a total of 1 inch of water per week throughout the season (Georgia automated environmental monitoring network: http://weather.uga.edu/). Agricultural practices for irrigation, pest and weed management are carried out by the UGA Blueberry Research Farm crew managed by Shane Tawzer. In May, the Campbell Scientific wireless sensor network (Campbell Scientific, INC. Logan, UT) was deployed and collected environmental data (air temperature, soil moisture, soil temperature) until August. In August, the University of Georgia Alapaha blueberry research farm received a lightning strike that effectively disabled the wireless monitors. The wireless sensors were placed at the base of a plant with the probes set 6 inches into the root zone. There was one sensor positioned in each treatment of the 'Suziblue' planting (9 soil monitoring sensors total). On Sept. 25, all the plants were evaluated for growth: plant volume (m^3) was the measure of the height x width perpendicular to the bed x width in line with the bed, chlorophyll (CCM-200 plus, Opti-Sciences, Hudson NH), canopy temperature (Fluke 566 IR thermometer, Everett, WA), photosynthetically active radiation (PAR; µmol s^{-1} m^{-2}, LI-COR, LI-190 Quantum Sensor, Lincoln, NE), and rated for vigor, 1-5 (1 = very poor, 2 = poor, 3 moderate, 4 = good, and 5 = very good vigor). PAR readings were collected at1.5" from the north and south of the bush's main stem, which is in line with the bed and calculated as an average. Temperature of each plant was measured at the base of the main stem in the shaded portion of the bush. The day was partly

cloudy and readings were capped at 500 μmol s^{-1} m^{-2} to minimize measuring degree of cloud cover. Further attempts to gather data for PAR on a clear day did not occur until mid-Oct and the plants had begun to senesce, suggesting that volume and PAR measurements would not be representative. All data analyses were performed in SAS 9.3 as Proc GLM (SAS Institute Inc. Cary, NC). Means were separated at $P<0.05$ level using Fisher's least significant difference (LSD) test.

In the early season, before herbicide applications, hand weeding was timed within a treatment and compared as no-mulch, 3" and 6" pine bark mulch. Weeding was done with a hoe, a hand cultivator (Garden Weasel 4-in-1 Cultivator, Kansas City, MO), and by hand as needed within the treatments. Starting the last week of March to the third week of April, weekly weeding was performed. In the pine barked mulched treatments, weeds were removed and pine bark was replaced over the bare soil. In the no-mulch treatments, the weeds were removed by hand around the base of the plants, larger weeds were hoed and the beds were cultivated, precautions were employed to not disturb the rooting zone of the plants e.g. hand pulling of weeds and light cultivation.

Results

The 2014 late planting did not appear to set back growth through spring to early summer. However, in July all treatments of 'Camilla' began to show signs of stress with flaccid necrotic leaves and weak growth. None of the other cultivars exhibited a similar response except in the no-mulch treatments regardless of irrigation type. In general, mulched treatment plants had higher vigor ratings, single drip line showed the best establishment response with only 4 dead plants (all 'Camilla'), and the most vigorous combination, eliminating 'Camilla', for 'Suziblue', 'Titan', and 'Vernon' was single drip line with 3 inch pine bark mulch. In addition, the mulched beds had considerable eroding of the bark chips, suggesting more work is needed to identify a cost effect way to keep the bark on the beds.

Environmental monitoring. The data shows that the irrigation treatments without mulch at the point of lowest soil moisture content just prior to an irrigation event can be as little as 17% less soil moisture to 123% less soil moisture for non-mulched treatments compared to mulched treatments. The treatments with a single drip line showed the greatest difference in soil moisture content between mulched and non-mulched beds. Soil temperature measurements were also similar. The soil temperatures in non-mulched treatments were 25% warmer than the mulched treatments during the warmest part of the day. The temperature differences observed within the different irrigation systems only varied by an average of 11% within a mulch treatment.

Hand Weeding: In late March an experiment was concurrently conducted to identify the cost of no-mulch establishment compared with mulching in relation to weed control. Over a 4 week period hand weeding and cultivation was timed for each 50 ft bed section of each treatment of mulch once a week. The cumulative average time for no-mulch, 3", and 6" mulch was 18.4, 5,

3.3 min, respectively. Assuming 200 ft rows with 18 rows per acre, this equates to 22.05, 1.5, 0.99 hrs/A for no-mulch, 3", and 6", respectively. Assuming $8.50/hr pay rate, this calculates to $187.43, $12.75, $8.45 per A/hr for no-mulch, 3", and 6", respectively, for one weeding event. Considering a load of pine bark, 20,000 lb, costs approximately $1000.00 and can effectively cover two acres of beds with 3" of mulch, it will take 2.7 hand weeding events to pay for the pine bark applied to one acre of blueberry beds. If the beds have 3" of pine bark applied, it will take 39.2 weekly weeding events to equal the cost of the pine bark applied.

'Camilla'. The plant volume and vigor ratings measured demonstrate plants in distress (Table 1). Plant loss was at 34% with 21 dead plants by Sept. 25. However, the single drip line had the least amount of plant death at 4 plants where double line and micro irrigation lost 6 and 11 plants, respectively. PAR readings suggest that no canopy shading was observed. Plant temperatures are a reflection of level of cloud cover and wind over any variation noted in irrigation type or mulch.

'Suziblue'. Plant volume measurements show the single line 6" mulch had the most volume with 0.79 m^3, which is 24% more than the second highest volume measured in the micro 3" mulch treatment at 0.60 m^3 (Table 2). Both the single and double line irrigation treatments across the pine bark treatments show similar descending trends in volume (Fig 2). However, the micro-irrigated treatments show the 6" mulch is 23% less in volume than the 3" mulch treatment, though not significant, this was the only treatment to lose a plant. The environmental data did not demonstrate that the micro-irrigated treatments were impacting growth, the soil and moisture reading did not show a clear separation continuously. Possibly, the 6" mulch is too deep for establishment with micro-sprinklers causing plants to be stunted or die. Plant vigor ratings show the plants thrive in both levels of mulch; however, the plants without mulch were negatively affected. The lowest rating observed was in the single line no-mulch (2.5) and the highest rating observed is in the single line, 6" mulch, a 36% difference in rating. Chlorophyll measurements in the single line treatments display a trend of decreasing chlorophyll with mulch, whereas this trend is not significantly noted in the other treatments. Fertilization was delivered in granular form, with micro and double line irrigation the area wetted is greater than with the single line, suggesting that nutrients were not as accessible by the plant in the single line no mulch. Differences in temperature between irrigation treatments are a response to wind and cloud cover. The PAR readings show significance, the single 6", double 3" and micro 6" were 173.1, 206.7, and 202.6 μmol s^{-1} m^{-2}, respectively. These readings were taken from a canopy that shaded the ground at the base of the bush and considering temperatures read across the single line treatments, this reflects the effect of shading on temperature. Single 6" mulch was 76.9 °F and single 3" mulch and single no-mulch were 79 and 80.2 °F, respectively. The plants in the single 6" mulch treatment had significantly larger volume, the highest vigor rating, most chlorophyll, lowest canopy temperature.

'Titan'. Plant volume showed a descending trend through mulch to no-mulch treatments in the single line and micro irrigation treatments; however, the double line treatment showed significantly greater volume in the 3" mulch at 3.7 m^3 when compared to 6" and no-mulch 2.1

m^3 and 1.0 m^3, respectively (Table 3). Vigor ratings followed plant volume measurements and were significantly less in no-mulch treatments than in mulched treatments. The PAR readings were not corrected and none of the readings were below 300 μmol s^{-1} m^{-2}. In addition, none of the temperatures taken were significantly different. The PAR and temperature measurements show that the plants did not develop a dense canopy. 'Titan' average height over all the treatments was 51.9"; the height of 'Camilla', 'Suziblue', and 'Vernon' were 31.5", 35.5", and 40.2", respectively. 'Titan' grew taller and branching was higher in the bush allowing light to penetrate to the bed surface, which accounts for the high PAR readings in relation to the large volume measured. Chlorophyll readings are also greater in 'Titan' than the other cultivars tested. However, 4 plants were lost, one in each treatment: double 6", double no-mulch, micro 6" and micro 3". There were no plants lost in the single line treatments regardless of pine bark mulch level.

'Vernon'. Plant volume measurements show the 3" mulch grew the greatest volume in consideration of irrigation treatment (Table 4). The greatest plant volume was in the micro 3" mulch at 1.26 m^3, which was 14% more in volume than the second greatest volume single 3" mulch, though not significant. Vigor ratings followed the trends noted in the volume measurements. However, the no-mulch treatments measured approximately 0.3 m^3 and the double 6" mulch measured 0.6 m3 and the vigor ratings were non-significant from 2.3 – 2.9, suggesting that double 6" establishment is not favorable for 'Vernon'. None of the PAR measurements were below 300 μmol s^{-1} m^{-2}, suggesting that canopy development did not shade out the bed surface. Further, temperature measurements tend to reflect wind and cloud cover. Chlorophyll measurements tend to be similar throughout the treatments with the exception of double 3" mulch and double no-mulch, where double 3" mulch had 17% more chlorophyll. Three plants were lost with 2 in double no-mulch and one in micro no-mulch. 'Vernon' established significantly better in single 3" mulch with 1.08 m3 plant volume and 3.7 vigor rating.

Table 1 represents the 'Camilla' growth measurement in volume (m^3), vigor rating 1 – 5 (1 = very poor, 2 = poor, 3 moderate, 4 = good, and 5 = very good vigor), and chlorophyll (CCI; chlorophyll context index), environmental readings of photosynthetically active radiation (PAR; µmol s^{-1} m^{-2}), temperature (°F), and the number of dead plants per treatment. SL = single drip line, DL = two drip lines, M = micro-irrigation, 6 = 6 inches of pine bark mulch, 3 = 3 inches of pine bark mulch, and 0 = no mulch. All statistics were calculated in SAS 9.3 as Proc GLM (SAS Institute Inc., Cary, NC, U.S.) and a different letter indicates significant difference at $P \leq 0.05$.

Camilla												
Treatment	Volume (m3)		PAR (µmol s-1 m-2)		Chlr (CCI)		Temp (F)		Vigor (1 - 5)		Plant loss
SL6	0.14	a	477.8	ab	29.8	a	82.9	c	1.8	b	2
SL3	0.15	a	500.0	a	29.0	a	82.5	cd	2.1	ab	2
SL0	0.12	a	440.8	b	31.8	a	81.4	cde	2.0	ab	0
DL6	0.12	a	500.0	a	33.8	a	99.9	a	2.1	ab	1
DL3	0.10	a	500.0	a	29.6	a	99.2	a	1.9	ab	2
DL0	0.15	a	441.2	a	30.2	a	93.8	b	2.6	a	3
M6	0.08	a	500.0	a	29.8	a	79.3	def	1.7	b	3
M3	0.15	a	500.0	a	28.2	a	78.3	ef	2.4	ab	5
M0	0.15	a	493.6	a	32.4	a	77.3	f	2.4	ab	3

Table 2 represents the 'Suziblue' growth measurement in volume (m^3), vigor rating 1 – 5 (1 = very poor, 2 = poor, 3 moderate, 4 = good, and 5 = very good vigor), and chlorophyll (CCI; chlorophyll context index), environmental readings of photosynthetically active radiation (PAR; µmol s^{-1} m^{-2}), temperature (°F), and the number of dead plants per treatment. SL = single drip line, DL = two drip lines, M = micro-irrigation, 6 = 6 inches of pine bark mulch, 3 = 3 inches of pine bark mulch, and 0 = no mulch. All statistics were calculated in SAS 9.3 as Proc GLM (SAS Institute Inc., Cary, NC, U.S.) and a different letter indicates significant difference at $P \leq 0.05$.

Suziblue												
Treatment	Volume (m3)		PAR (µmol s-1 m-2)		Chlr (CCI)		Temp (F)		Vigor (1 - 5)		Plant loss
SL6	0.79	a	173.1	e	42.1	a	76.9	c	3.9	a	0
SL3	0.52	bc	377.5	abc	39.9	ab	79	b	3.4	bc	0
SL0	0.24	e	438.75	abc	32.6	c	80.2	b	2.5	e	0
DL6	0.52	bc	245.7	bcd	39.5	ab	85.9	a	3.5	abc	0
DL3	0.46	bcd	206.9	de	38.5	ab	85.2	a	3.4	bc	0
DL0	0.33	de	322.1	bcde	38.4	abc	86.3	a	2.9	de	0
M6	0.46	bcd	202.6	de	39.3	ab	75.7	c	3.8	ab	1
M3	0.6	b	354.1	abcde	37.2	abc	76	c	3.7	ab	0
M0	0.28	e	502.1	a	34.1	bc	76.1	c	2.9	de	0

Table 3 represents the 'Titan' growth measurement in volume (m^3), vigor rating 1 – 5 (1 = very poor, 2 = poor, 3 moderate, 4 = good, and 5 = very good vigor), and chlorophyll (CCI; chlorophyll context index), environmental readings of photosynthetically active radiation (PAR; µmol s^{-1} m^{-2}), temperature (°F), and the number of dead plants per treatment. SL = single drip line, DL = two drip lines, M = micro-irrigation, 6 = 6 inches of pine bark mulch, 3 = 3 inches of pine bark mulch, and 0 = no mulch. All statistics were calculated in SAS 9.3 as Proc GLM (SAS Institute Inc., Cary, NC, U.S.) and a different letter indicates significant difference at $P \leq 0.05$.

Titan													
Treatment	Volume (m3)		PAR (µmol s-1 m-2)		Chlr (CCI)		Temp (F)		Vigor (1 - 5)		Plant loss
SL6	3.4	ab	500.8	bcd	61.2	bc	81.7	a	5	a	0
SL3	2.9	abc	608.2	bc	69.7	a	82.8	a	4.4	bc	0
SL0	1.5	de	898.9	a	56.3	c	83.4	a	3.6	d	0
DL6	2.1	cd	463.1	cde	53.3	c	83.6	a	4.1	c	1
DL3	3.7	a	501.2	bcd	59.0	bc	81.8	a	4.7	ab	0
DL0	1.0	e	584.8	bc	57.2	c	82.5	a	2.8	e	1
M6	3.0	abc	316.9	e	57.2	c	81.7	a	4.9	a	1
M3	2.6	bc	399.2	de	66.0	ab	81.9	a	4.6	abc	1
M0	1.5	de	413.5	de	53.6	c	81.8	a	3.2	de	0

Table 3 represents the 'Titan' growth measurement in volume (m^3), vigor rating 1 – 5 (1 = very poor, 2 = poor, 3 moderate, 4 = good, and 5 = very good vigor), and chlorophyll (CCI; chlorophyll context index), environmental readings of photosynthetically active radiation (PAR; µmol s^{-1} m^{-2}), temperature (°F), and the number of dead plants per treatment. SL = single drip line, DL = two drip lines, M = micro-irrigation, 6 = 6 inches of pine bark mulch, 3 = 3 inches of pine bark mulch, and 0 = no mulch. All statistics were calculated in SAS 9.3 as Proc GLM (SAS Institute Inc., Cary, NC, U.S.) and a different letter indicates significant difference at $P \leq 0.05$.

Vernon													
Treatment	Volume (m3)		PAR (µmol s-1 m-2)		Chlr (CCI)		Temp (F)		Vigor (1 - 5)		Plant loss
SL6	0.84	abc	389.1	bc	30.4	ab	83.3	c	3.6	a	0
SL3	1.08	abc	349.3	cd	33.2	ab	83.5	c	3.7	a	0
SL0	0.33	e	363.1	cd	32.4	ab	86.9	a	2.5	c	0
DL6	0.60	de	500.0	a	33.6	ab	84.8	b	2.9	c	0
DL3	0.77	cd	500.0	a	35.3	a	82.7	cd	3.3	ab	0
DL0	0.26	e	500.0	a	29.4	b	82.7	cd	2.3	c	2
M6	0.78	cd	311.9	de	32.9	ab	84.9	b	3.3	ab	0
M3	1.26	a	349.3	cd	35.3	a	82.9	cd	3.4	a	0
M0	0.31	e	441.3	ab	30.8	ab	82	d	2.3	c	1

Conclusions

This season's work identifies that mulching with pine bark can improve establishment of 'Suziblue', 'Titan', and 'Vernon'. 'Camilla' has shown to be non-responsive to irrigation system and pine bark mulching, which could be a response to the late planting in 2014. Omitting 'Camilla', plant lost over all the treatments of 'Suziblue', 'Titan', and 'Vernon' showed that no plants were lost in the single line treatments, regardless of mulch level. In addition, only 'Suziblue' expressed significantly larger plant volume in the 6" level of pine bark whereas, 'Titan' and 'Vernon' showed statistically equivalent growth in either 6" or 3" level of pine bark. Plant loss is to be expected and 'Camilla', Suziblue', 'Titan', and 'Vernon' had 34%, 1%, 4%, and 3% death, respectively. For 'Suziblue', 'Titan', and 'Vernon' the dead plants in 6", 3" mulch, and no-mulch were 3, 1, and 4, respectively. All considered, the optimal system approach to establishment in this experiment is 3" pine bark mulch using a single drip line (0.25 gph at 12" spacing).

Impact Statement: The identification of cultivar response to varying amounts of pine bark and irrigation method will allow growers to better manage establishment costs and minimize the length of time to production. Blueberry responded positively to single drip line irrigation with 3 inches of pine bark incorporated into the soil with 3 inches applied as mulch on the bed. There is significant savings in site preparation to be gained by using only one drip verses the added expense of a second drip line or a micro-sprinkler system. As for cultivar selection, 'Camilla' has shown to be difficult to establish.

Citations: None