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Growing Organic Rabbiteye Blueberries in Georgia, USA: Results of Two Multi-Year Field Studies

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South Georgia is a major blueberry production region located in the warm and humid northern subtropics. The region enjoys a favorable market window, but pressure from weeds, insects, and diseases raised questions as to whether organic production would be feasible in this climatic zone. Two multi-year field studies were conducted to determine the best practices for organic culture of blueberries and to compare yields with conventional production. Various methods of weed control were tested. While organic burn-down herbicides performed poorly on the grasses that are the dominating weeds in blueberry in southern Georgia, mulches and a rolling cultivator were successful in maintaining a weed-free strip on the side of the organic beds. Hand-weeding was needed at the interface between the mulches and the cultivated strip. Pine straw and pine bark mulch resulted in the lowest hand-weeding times, whereas pine bark and wheat straw were the highest-yielding treatments.

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Some other locally available plant-derived or synthetic mulches also performed well for organic blueberry establishment, hence, the decision as to which mulch to use can be based partly on availability of local resources. A separate 6-year study compared yields in conventional and organic production systems. Weed problems in year 1 caused the growth of the organically managed plants to fall behind those grown conventionally, but over time very good yields (ca. 5,900 kg/ha) were produced by the organic method using pine bark mulch, and net returns over the 6-year period were higher than conventional. Organic production of rabbiteye blueberries in Georgia appears commercially feasible.

KEYWORDS *blueberry, mulching, organic agriculture, yield, economic profitability, weed control*

INTRODUCTION

Organic agriculture is an important and rapidly growing segment of the food supply chain (Dimitri and Greene, 2007). Although some scientists do not believe in the concept in its purest form, the fact remains that the public at large is very interested in organic food. Thus, the challenge is to find methods of producing crops following organic regulations, while at the same time being profitable. Whereas the general guidelines are outlined in the National Organic Standards published in the U.S. Congressional Record, actual implementation of these standards is subject to interpretation by the Organic Materials Review Institute (OMRI) and the various organic certifiers involved in the process of regulating the organic industry (Thompson, 2007). Organic production is generally considered less challenging to implement in northern climates as the growing season is shorter and fewer generations of insects, plant-pathogenic fungi, and weeds are present each year (Granatstein and Mullinix, 2008). At the latitude of southern Georgia where this work was carried out, the growing season is typically 9 months in length, and severe weed pressure, especially from grasses, occurs for about 6 months each year. However, the cost of establishing organic blueberries in areas with the most favorable climate for organic production, such as Oregon, is estimated at $30,311 to 35,534 per ha (Strik et al., 2009). This gives southern states such as Georgia, where production costs can be considerably lower, a competitive cost-advantage. For example, good blueberry land can be purchased in Georgia for about $7,500 per ha. Furthermore, the organic blueberry crop in southern Georgia ripens from May through July, and at least during the first half of this period, there is little competing production from northern production regions.

There was little doubt from the outset that rabbiteye blueberries (*Vaccinium virgatum*), which are native to the southeastern Coastal Plain, can be produced organically in this zone (Scherm and Krewer, 2008), but whether high yields and favorable net returns could be obtained was uncertain. Several events came together to help build a fledgling organic blueberry industry in Georgia. These included growers dedicated to organic production, marketers and scientists with an interest in organics, and funding opportunities provided by the U.S. Department of Agriculture, the University of Georgia, and the Organic Farming Research Foundation (Krewer et al., 2005; Krewer and Walker, 2006).

Mulches have been used for a long time in conventional blueberry production to reduce weed growth, minimize soil temperature in summer, help maintain uniform soil moisture, and increase plant growth rate and yield (Clark and Moore, 1991; Darrow, 1957; Moore and Pavlis, 1979). However, limited data are available from organic blueberry production systems where problems with weed control and nitrogen availability can be much more severe. Sciarappa et al. (2008), working in New Jersey, reported in a 2-year study that 4 to 8 cm of organic mulch produced about 95% weed suppression, whereas a combination of black plastic ground cover with organic mulch on top resulted in near complete weed control. However, blueberry growth and yield data were not presented in this study. A previous study at the University of Georgia with organically grown 'Brightwell' rabbiteye blueberry demonstrated that pine bark mulch produced higher yields over a 7-year period following plant establishment than pine straw, black plastic ground cover, and an unmulched control (Krewer et al., 2009).

Since the latter study was initiated, questions concerning the use of additional mulches have been raised. Peanuts are being grown extensively in southeastern Georgia, and peanut shells are one of the few free or very low-cost mulching materials in this largely rural region. Wheat acreage has been increasing, and wheat straw is available at lower cost than pine straw. Furthermore, wheat straw releases allelopathic compounds that serve as natural pre-emergent herbicides (Cast et al., 1990). White-on-black plastic is less expensive than pine bark and tends to repel the blueberry leaf beetle, *Colaspis pseudofavosa* Riley (Tertuliano et al., 2009). Woven plastic ground cover has been used widely in conventional blueberry production with good results (Creech et al., 1990). Landscape fabric (i.e., non-woven Typar-type material) is another synthetic mulch that has not been investigated in organic blueberry establishment.

The first objective of our research was to determine the feasibility of organic rabbiteye blueberry production in south Georgia, focusing on an evaluation of locally available mulches for planting establishment and weed suppression. In a separate 6-year study we monitored inputs, labor requirements, yields, and economic returns in organic versus conventional rabbiteye blueberry systems.

MATERIALS AND METHODS

Mulching Trial

A study to evaluate the performance of locally available mulches on organic rabbiteye blueberry establishment was set up at the University of Georgia Bacon County Blueberry Research and Demonstration Farm near Alma, Georgia, in 2006. The site, a virgin Rigdon sand with a pH of ~4.8, was considered very good for blueberries. We applied 224 kg/ha of bone meal (1-13-0) in a 0.6-m band down the center of the bed prior to planting. This is equivalent to 175 kg of P_2O_5 per broadcast hectare. One "trade" gallon-size (2.7-L) 'Brightwell' rabbiteye blueberries were set in November on raised beds about 1.2 m wide and 0.3 m high, with a plant spacing of 1.5 m × 3.7 m within and between rows, respectively. Eight different mulching treatments were applied in a randomized complete block design with four replications and seven plants per replication (i.e., 28 plants total per treatment): (1) unmulched control, (2) coarse pine bark, (3) pine straw, (4) peanut shells, (5) wheat straw, (6) black landscape fabric (Typar-type material, non-woven), (7) black plastic ground cover (woven), and (8) white-on-black polyethylene plastic. The plant-derived mulches (treatments 2 through 5) were applied to achieve a layer 10 cm deep after settling. With the synthetic mulches (treatments 6 through 8), the hole around the plant (about 30 cm in diameter) was "sealed" with about 5 cm of pine bark mulch. Fertilization was conducted via this opening. Wheat straw required annual recharging and pine bark required recharging in year 3 (2009).

The site was overhead-irrigated as needed and fertilized with four applications of Nature Safe 8-5-5 (Griffin Industries, Cold Spring, KY, USA) during each spring and summer (2007, 2008, and 2009). Between 30 and 60 g of Nature Safe 8-5-5 were applied per plant at each application in years 1, 2, and 3, with the amount increasing as the plants grew larger. The same amount of fertilizer was applied to each plant at each application. Leaf analysis was used to monitor plant nutrient applications, and copper deficiency was corrected with copper sulfate. The organically approved insecticide Entrust 80 W (spinosad; Dow Agro Sciences, Indianapolis, IN, USA) was applied several times during the course of the study to control blueberry leaf beetles.

Weeds were controlled on the shoulder of the bed using a Hillside Cultivator (Hillside Cultivator Co., Lititz, PA, USA). In year 2 (2008), the synthetic mulches (treatments 6 through 8) were bypassed with the Hillside Cultivator because of potential for tangling with fabric mulches or damage to polyethylene mulch. Weeds in the aisles were controlled by periodic mowing. Weeds on the top of the bed were mostly hand-hoed or pulled. Manual weed control was conducted two to four times a year depending of weed infestation severity. During the first season, a native grass, identified as torpedo grass (*Panicum repens*), was highly problematic, especially on the unmulched control. At one point, the infestation was so severe that it became necessary to cut the grass with a string trimmer. In year 2, however, this grass almost disappeared and hand-hoeing could be conducted more easily. The mulching treatments were relatively easy to keep weed-free compared with the unmulched control. However, hand-hoeing the shoulder of the bed on the synthetic mulches was time-consuming. The time required to remove weeds was recorded during weeding events. Percent weed cover was also recorded periodically.

At the end of each growing season in 2007 and 2008 and at the end of harvest in 2009, a plant growth index was determined by measuring plant width in-row, width across-row, and height, then determining the mean of the three measurements for each plant. Plants were harvested three times during the 2008 and 2009 growing seasons to determine total yields. Mean fruit weight and soluble solids content were determined at the last harvest of the study in 2009 based on a sample of 50 berries and 5 berries per replication, respectively.

All data were subjected to analysis of variance for a randomized complete block design (PROC GLM in SAS v. 9.1; SAS Institute, Cary, NC, USA), and treatment means were separated using Fisher's protected LSD test and the LSMEAN statement.

Organic Versus Conventional Berry Yields

The study was conducted at the University of Georgia Alapaha Blueberry Research Station near Alapaha, Georgia, between 2004 and 2009. Two 60-m rows were used in the study. Management in each row was one-half conventional and one-half organic. The conventional treatment was maintained weed-free with herbicides, whereas the organic treatment had pine bark mulch as the primary weed control program. There were two replications with 20 plants per replication and treatment for a total of 40 plants per treatment. Pre-plant fertilization was conducted with banded applications of 448 kg/ha of 10-10-10 fertilizer for the conventional and 1,121 kg/ha of 4-3-3 pasteurized chicken litter (Perdue AgriRecycle, Seaford, DE, USA) for the organic treatment.

'Brightwell' rabbiteye blueberry plants were set in mid-March 2004, 1.2 m apart in the row and 3.7 m between rows. Conventional plants growing in the pine bark mulch were fertilized again in August with ~30 g of 10-10-10, whereas organic plants received ~60 g of Perdue 4-3-3 pasteurized chicken litter. Starting in year 2 (2005) the plots were maintained for 5 years using 10-10-10 for the conventional treatment and Nature Safe 8-5-5 for the organic treatment. Typically, plants were fertilized two or three times per year. As the plants increased in size, the amount of fertilizer was increased. A rate of ~30 g of fertilizer per 0.3 m of bush height up to a maximum of 120 to 180 g was applied per application. Weed control in the conventional plots was primarily with Rely (glufosinate sulfate; Bayer CropScience, Research

Triangle Park, NC, USA) post-emergent herbicide, whereas weed control in the organic plots utilized a combination of organically approved burn-down herbicides and hand-weeding. The beds were reshaped to improve drainage in January 2005, burying the pine bark mulch in the organic plots. At that time, pine bark mulch was reapplied only to the organic plots since they had significant problems with crabgrass (*Digitaria* sp.). A second application of pine bark to the organic plots was required after 3 years. Data analysis was as described above for the mulching trial.

RESULTS AND DISCUSSION

Mulching Trial

Manual weed control was a significant input in the organic plots (Table 1). Pine bark and pine straw had the lowest weed control times while weeding the unmulched control was the most time-consuming. At $10 per hour labor rate, weed control costs ranged from $1,028 per ha for pine bark (best treatment) to $3,039 per ha for the control (no mulch). However, the cost of pine bark mulch is estimated at $3,470 per ha plus installation. The inability to use the Hillside Cultivator on the synthetic mulches in years 2 and 3 increased hand-hoeing times (Table 1).

Despite the periodic weed problems in the first year (2007), the bushes grew very well and produced a good crop the second year (about 2,400 kg per ha for the conventional and 1,200 kg per ha for the organic). In 2007, wheat straw, pine bark, and plastic woven ground cover treatments produced significantly larger bushes compared with the unmulched control (Table 2). In 2008, wheat straw again produced significantly larger bushes. In 2009, growth index data were collected just after the final harvest, and no difference in plant size among treatments was observed; however, there was a trend for wheat straw, pine bark, and the unmulched control to produce larger bushes. The bushes mulched with peanut shells were smaller than

TABLE 1 Effect of Mulching Treatments on Weed Control Times per 10.5 Linear Meters of Row (Minutes per Year) in Organically Grown 'Brightwell' Rabbiteye Blueberries[z]

Treatments	2007	2008	2009	Total
Unmulched control	27.2 a	30.5 abc	13.5 ab	71.2
Pine bark	5.0 de	17.5 c	2.0 b	24.5
Pine straw	5.9 de	21.7 bc	3.0 b	30.6
Peanut shells	7.3 de	25.7 abc	29.5 a	62.3
Wheat straw	9.3 cde	37.3 a	6.5 b	53.1
Landscape fabric (non-woven)	14.2 bc	33.0 ab	18.0 ab	65.2
Ground cover (woven)	12.5 bcd	21.7 bc	4.0 b	38.2
White-on-black plastic	14.0 bcd	26.2 abc	11.0 ab	51.2

[z]Means within each column followed by the same letter are not significantly different according to ANOVA followed by LSD test ($\alpha = 0.05$).

TABLE 2 Effect of Mulching Treatments on the Vegetative Growth Index (cm) of Organically Grown 'Brightwell' Rabbiteye Blueberries[z]

Treatments	2007	2008	2009
Unmulched control	84.0 cd	138.2 bcd	153.6 a
Pine bark	95.0 ab	148.9 ab	151.8 ab
Pine straw	93.7 abcd	140.8 abc	148.6 abc
Peanut shells	93.3 bcd	130.7 cd	144.3 c
Wheat straw	104.0 a	150.7 a	153.9 a
Landscape fabric (non-woven)	83.3 d	131.2 cd	148.5 abc
Ground cover (woven)	95.0 ab	136.3 bcd	146.5 bc
White-on-black plastic	94.3 abc	143.4 abc	152.3 ab

[z]Means within each column followed by the same letter are not significantly different according to ANOVA followed by LSD test ($\alpha = 0.05$).

these treatments (Table 2). This may be due to the heavier crop on some treatments that may have suppressed vegetative growth.

In 2008, yield in the first and second harvest was not significantly different among treatments (Table 3). However, compared with the unmulched control, there was a trend toward a higher yield (by 34%) in the third harvest with woven ground cover treatment (data not shown). Total yield was highest with woven ground cover and pine bark treatments, both of which produced over 0.9 kg per plant (about 1,680 kg/ha), a good yield for the second-leaf plants even by conventional standards. The third-best treatment was pine straw, which also performed well for weed control. The latter mulch also has the advantage of being acidic in its decomposition, but it is expensive unless it can be raked at low cost. Peanut shells did not produce the largest plants, but had a good yield (~0.9 kg per bush). Blueberry roots grew into the rotting peanut shells although this material had a relatively high pH of 5.8. In 2009, the highest yield-producing treatment was pine bark, followed by wheat straw and landscape fabric; however the unmulched control was not significantly different from these treatments. Peanut shells had the

TABLE 3 Effect of Mulching Treatments on the Berry Yield (kg per Plant) of Second and Third-Leaf Organically Grown 'Brightwell' Rabbiteye Blueberries[z]

Treatments	2nd leaf (2008)	3rd leaf (2009)
Unmulched control	0.82	2.17 ab
Pine bark	0.93	2.64 a
Pine straw	0.68	2.13 ab
Peanut shells	0.89	1.65 b
Wheat straw	0.76	2.28 ab
Landscape fabric (non-woven)	0.81	2.22 ab
Ground cover (woven)	1.03	2.14 ab
White-on-black plastic	0.71	2.10 ab

[z]Means within each column followed by the same letter are not significantly different according to ANOVA followed by LSD test ($\alpha = 0.05$).

TABLE 4 Effect of Mulching Treatments on Berry Weight and Soluble Solids Content of Organically Grown 'Brightwell' Rabbiteye Blueberries at Third Harvest, 2009[z]

Treatments	Berry weight (g)	Soluble solids (%)
Unmulched control	1.8 ab	14.5 ab
Pine bark	1.8 ab	14.2 ab
Pine straw	1.9 a	15.3 a
Peanut shells	1.8 ab	15.4 a
Wheat straw	1.9 a	14.8 ab
Landscape fabric (non-woven)	1.7 b	13.6 ab
Ground cover (woven)	1.7 b	15.3 a
White-on-black plastic	1.8 ab	13.9 ab

[z]Means within each column followed by the same letter are not significantly different according to ANOVA followed by LSD test ($\alpha = 0.05$).

lowest yield (Table 3). Compared with the unmulched control there were no significant differences among treatments for berry weight and fruit soluble solids at the third harvest in 2009 (Table 4).

Organic Versus Conventional Berry Yields

The first year of the study (2004) was very rainy and the organic burn-down herbicides failed to control crabgrass. Pre-plant fertilization magnified the problem, and the organic plots were overgrown with crabgrass. A fine pine bark was used as mulch in this trial, and crabgrass emerging from the edges grew well on this mulch. The net result was a decrease in the growth index for the organic plots during the course of the study (Table 5). This also translated into reduced, but acceptable yields of organic plants (Table 6).

Overall, based on the results of the two experiments, the mulching trial showed that wheat straw and pine bark were the best treatments, although some of the other mulches also performed well for organic blueberry establishment. Thus, the decision which mulch to use can be based partly on availability of local resources. Because this study was conducted on very good blueberry soil, differences among treatments were probably minimized (Krewer et al., 2009). While yields among the treatments were

TABLE 5 Vegetative Plant Growth Index (cm) at the End of the Season in Organic Versus Conventionally Grown 'Brightwell' Rabbiteye Blueberry Plants[z]

Treatment	2004	2005	2006	2007	2008	2009
Conventional	58.5	101.5 a	134.6 a	157.2 a	—	186.9 a
Organic	34.8	68.1 b	106.7 b	144.4 b	—	173.9 b

[z]Means within each column followed by the same letter are not significantly different according to ANOVA followed by LSD test ($\alpha = 0.05$).

TABLE 6 Berry Yields (kg per Plant) in Organic Versus Conventionally Grown 'Brightwell' Rabbiteye Blueberry Plants[z]

Treatment	2nd leaf (2005)[y]	3rd leaf (2006)	4th leaf (2007)	5th leaf (2008)	6th leaf (2009)
Conventional	0.059 a	0.72 a	1.11 a	2.97 a	3.73 a
Organic	0.0014 b	0.24 b	0.57 b	2.15 b	2.71 b

[z]Means within each column followed by the same letter are not significantly different according to ANOVA followed by LSD test ($\alpha = 0.05$).
[y]Yield in organic treatments suppressed due to severe crabgrass infestation.

not significantly different, the difficulty of keeping the unmulched control relatively weed-free through hand-hoeing was almost insurmountable, especially given the high heat indexes (often exceeding 38°C) in south Georgia during the summer. Peanut shells appeared very promising the first year, but there was a trend toward more weeds and lower yields in years 2 and 3.

Pine straw mulch also performed well in terms of weed suppression and berry yields, but the high cost of the material may be prohibitive. A 2008 study on organic 'Brightwell' rabbiteye blueberry using pine bark mulch culture and assuming a price of $7.72 per kg of organic berries yielded a negative net return of −$1,880 per ha in year 3 and a positive net return of $31,050 in year 5. This same study showed a negative net return of −$2,144 and a positive net return of $20,027 for the same crop/cultivar in the same time period under pine straw mulching production system (Plattner, 2008; Fonsah et al., 2008).

In the long-term organic versus conventional yield comparison study, the delay in growth of the organic plants was quite serious, but subsequent mulching with coarse pine bark in years 2 and 5 largely solved the crabgrass problem. As the years passed, Bermuda grass (*Cynodon dactylon*) gradually became the main problem. Although hand-weeding was done each year it was virtually impossible to remove all of the rhizomes from the mulch. Thus, every effort should be made not to allow Bermuda grass to become established in organic blueberry systems. Despite the grass problems, perseverance paid off with rapidly increasing organic yields, which approached conventional toward the end of the study. Total yield during the 6 years was 8.6 kg per plant for the conventional and 5.7 kg per plant for the organic plots. This is equivalent to 19,248 and 12,699 total kg/ha, respectively. The price for a flat of organic blueberries has ranged from $18 to 28 over the past 3 years, whereas conventional production prices have generally ranged between $8 to 14 per flat (Sciarappa et al., 2008). Using 2009 prices from organic growers (about 50% higher than conventional) this is equivalent to a gross sales price of $69,580 per ha for the conventional and $68,858 per ha of the organic system (Table 7).

The reduced yields for the organic treatment lowered picking and packing cost, but there was an additional cost of mulching two times in 6 years

TABLE 7 Simplified Gross Return Calculations (Not Including Fixed and Miscellaneous Production Costs) in Organic Versus Conventionally Grown 'Brightwell' Rabbiteye Blueberry Plants Over a 6-Year Period after Plant Establishment

Item	Unit	Conventional	Organic
Yield	kg/ha	19,248	12,699
Sale price[z]	\$/kg	3.61	5.42
Gross sales	\$/ha	69,580	68,858
Hand-harvest cost (\$1.59/kg)	\$/ha	30,547	20,154
Packaging cost (1.15/kg)[y]	\$/ha	22,062	14,557
Pine bark mulch[x]	\$/ha	0	6939
Weed control[x]	\$/ha	2965	7354
Gross return	\$/ha	14,006	19,854

[z]Sale price considered 50% higher for organic production.
[y]Based on half-pint (0.28-L) container size.
[x]Calculations explained in text.

and hand-weeding four times per year in the organic treatment (Table 7). Mulching once with a layer of coarse pine bark 10 cm deep requires about 331 m^3 of bark per ha for a total of 662 m^3 per ha for two applications at \$10.48 per m^3 for at total of \$6,939. The utilization of a rolling cultivator alongside the beds and hand-weeding four to eight times per year is estimated to cost \$7,354 per ha over 6 years based on the previous mulching study. In contrast, weed control in the conventional system is estimated at \$2965 per ha for 6 years (Table 7). Although the cost of fertilizer is about twice as high for organic than for conventional production there are many foliar sprays applied to conventional bushes in a prophylactic manner that organic bushes do not receive. Thus, assuming similar total fertilizer and pesticide costs for organic and conventional, the net return (not including fixed and miscellaneous production costs) for the conventional and organic treatments over 6 years was \$14,006 and \$19,854 per ha, respectively.

In summary, results from the two studies have illustrated that organic rabbiteye blueberry production appears to be feasible and commercially attractive in south Georgia. These trials and grower efforts have resulted in the development of a significant organic rabbiteye blueberry industry in the region. Trials are now underway on the cultivation of organic southern highbush blueberries (*Vaccinium corymbosum* interspecific hybrids), an earlier-maturing and higher-value crop than rabbiteye blueberries that is very challenging to grow even by conventional standards.

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