Organic Highbush Blueberry Production Systems Research – Management of Plant Nutrition, Irrigation Requirements, Weeds and Economic Sustainability

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Abstract

A 0.4 ha planting was established in October 2006 to evaluate the effects of cultivar ('Duke' and 'Liberty'), bed type ("flat ground" and raised beds), weed management (sawdust mulch and hand weed control; compost plus sawdust mulch with acetic acid, flaming, and hand control used as needed; and landscape fabric (weed mat)) and type and rate of fertilizer (feather meal and liquid fish emulsion at 29 and 57 kg·ha^{-1} N) on plant growth, yield, fruit quality, and establishment and maintenance costs in highbush blueberry. The site was certified organic in 2008. Before planting, soil was a clay loam with 3.7% organic matter content and pH 4.9. Plants grown on raised beds were larger and produced greater yield than those on flat ground. However, raised beds, particularly with weed mat (which increased soil temperature by 5°C), required up to 269 L/plant/season more irrigation than flat ground plantings to maintain similar levels of soil moisture. Weeds never exceeded 20-25% coverage in any treatment in 2007-2009, although weed mat resulted in the fewest weeds while compost plus sawdust resulted in the most. Although flaming was used in the spring along with acetic acid applied every 3 weeks during the summer in plots mulched with sawdust and compost, hand-weeding was still required in all treatments including those with weed mat. In 2009, the third growing season, yield averaged 1.7 kg/plant and was highest with 29 kg·ha^{-1} N of fish emulsion or 57 kg·ha^{-1} N of feather meal and lowest with 57 kg·ha^{-1} N of fish emulsion. Yield was also higher with weed mat or sawdust plus compost than with only sawdust. Fruit firmness was likewise affected by fertilizer and mulch as fruits were firmer with fish and softer with weed mat. Cumulative net production costs (years 0-3) varied as much as 60% among treatments, ranging from -$ 32,690/ha to -$ 51,990/ha (net loss).

INTRODUCTION

Blueberries are long-lived perennials, requiring 7 or more years to reach full production. Establishment costs, through year 6, can surpass US$ 37,500 per ha to establish an 8 ha planting of highbush blueberries grown in a conventional system in Oregon (Eleveld et al., 2005). First year establishment costs of conventional, southern highbush blueberries in Georgia are over US$ 24,345 per hectare (Fonsah et al., 2007). We previously reported the establishment costs for the land preparation year and first growing season ranged from US$ 30,311 to 35,534 per hectare, depending on treatment (Strik et al., 2009).

Blueberries grow best on well-drained soils, high in organic matter, and with a pH of 4.2 to 5.5 (Strik et al., 1993). In most production regions, blueberry plants are grown on raised beds of about 0.3 m high to improve soil drainage in the root zone, and organic mulch is used (Strik, 2007).

Blueberries are shallow-rooted and thus readily susceptible to drought injury (Bryla and Strik, 2006); however, blueberries are also susceptible to over-irrigation, which often leads to problems with phytophthora root rot (Bryla and Linderman, 2007). A uniform and adequate supply of moisture is essential for optimum plant growth. Soil moisture level was the greatest factor affecting blueberry root growth in southern highbush, and high irrigation and low bed height significantly improved the growth of rabbiteye blueberry (Spiers, 1998, 2000).

Weed management in blueberries is critical for economic production (Pritts and Hancock, 1992; Strik et al., 1993). Pre-emergent and contact herbicides are commonly used in conventional production systems. In organic systems, chemical options are limited. Acetic acid (vinegar) at a concentration of 9 to 20% has been effective at controlling some weeds (Fausy, 2003; Miller and Libbey, 2007; Young, 2004). Most fields have a permanent grass cover in the aisles between rows to facilitate winter management and weed control (Strik, 2007).

Sawdust is also commonly applied as mulch on the soil surface in the row after planting, not only to improve organic matter content, but also for annual weed control. The mulch layer is maintained for the life of the planting. In some production regions, a weed barrier permeable to water or black plastic may be used in the blueberry row; whether these materials are cost effective is not clear (Pritts and Hancock, 1992). However, there are many successful plantings in which no mulch or weed barrier has been used.

Surface mulches generally improve growth in blueberry (Clark, 1991; Clark and Moore, 1991; Lareau, 1989; Moore, 1979; White, 2006). Douglas fir bark is commonly used in conventional and organic blueberry production systems in the Pacific Northwest, USA. However, this has become an expensive input and mulches like sawdust, with a high carbon (C) to nitrogen (N) ratio, make fertilizer management difficult. Sawdust mulch, for example, immobilizes N applied from conventional fertilizers (White, 2006). It is often more difficult and more expensive to compensate for N immobilization with organic fertilizer products. Young blueberry plants do not need much fertilizer N (Bañados, 2006; Bañados et al., 2006; Hart et al., 2006).

Well-composted organic materials (low decomposition rates in soil) released <10% of their total N during the first year in the field (Gale et al., 2006). In contrast, specialty fertilizers (fish meal, feather meal, or seed meals) decomposed rapidly (>50% decomposition in one month) and released plant-available N rapidly. High rate applications of organic materials can build soil N mineralization rates for 7+ years after application, suggesting that soils in Oregon may mineralize sufficient N for blueberry production if they receive periodic, high-rate compost applications (Cogger et al., 2001; Sullivan et al., 2003).

The long-term goal of this study is to develop organic production systems for highbush blueberry that maximize plant growth, yield, and fruit quality; facilitate weed, water, and nutrient management; and provide an economic benefit to growers.

MATERIALS AND METHODS

The research trial was established 9 October 2006 on a site in transition to organic production at the North Willamette Research and Extension Center (NWREC), Aurora, Oregon, USA. The climate at the site is cool and rainy in the winter and warm and dry in the summer. The soil was a clay loam with an organic matter content of 3.7% and a soil pH of 4.9. For more information on planting preparation and maintenance refer to Strik et al. (2009). Treatments compared were: i) planting into “raised beds” or on “flat ground”; ii) the cultivars ‘Duke’ and ‘Liberty’; iii) the mulching treatments a) Douglas-fir (*Pseudotsuga menziesii* M.) sawdust mulch (9 cm deep) and pulling weeds by hand, as required, b) compost (yard debris; 4 cm deep) plus sawdust (5 cm) mulch on top and weed management using vinegar (20% acetic acid) applied every 3 weeks, propane flaming, and hand pulling as needed; and c) landscape fabric (weed mat; Baycor TenCate Protective Fabrics, Union City, GA, USA) with sawdust mulch (5 cm) in the 20 cm diameter planting hole and hand-weeding; and iv) method and rate of fertilization: feather meal (Nature Safe, Cold Spring, KY) and fish emulsion ("Fish Agra", Northeast Organics Inc., Manchester-by-the-Sea, MA) at a rate of 29 and 57 kg of $N \cdot ha^{-1}$. The feather meal was divided into two equal portions and applied in April and May 2007 and early March and April 2008-2009. The fish emulsion was applied in seven equal portions every 2 weeks from mid-April to July; the product was diluted 10:1 (water: fish v/v) and applied as a soil drench considering fertigation was not possible in this study.

The experimental design was a split-split plot with five replicates. Plots were 4.6 m long with six plants at a spacing of 0.76 m in the row with 3 m between rows.

Plants were irrigated by a single lateral of drip tubing, with 2 $L \cdot h^{-1}$ in-line emitters spaced every 0.3 m. The system was designed so that raised and flat beds could be irrigated independently to adjust for differences in water use if needed. A second lateral was also installed in the weed mat plots to increase water application during high temperatures if needed. Percent soil moisture from the soil surface to 30 cm deep was maintained in a suitable range for blueberry (~24 to 28%) using TDR. Certified organic grass seed (*Festulolium braunii* K. Richt.) was planted between the rows. The research planting was certified as organic in May 2008 by Oregon Tilth (OTCO; Salem, Ore.).

RESULTS AND DISCUSSION

One plant per plot was evaluated for biomass accumulation at the end of the first and second growing seasons. Total plant biomass was greater for plants grown on raised beds than on flat ground and when using organic mulches (sawdust and compost+sawdust) compared to weed mat (data not shown). Fertilization with fish emulsion led to greater biomass production than using feather meal, in both cultivars and a higher shoot to root ratio, particularly in 'Liberty'. In the first growing season, it appeared that nitrogen (N) in the feather meal was not available to plants due to insufficient rainfall after application; application dates were moved earlier in subsequent years with better results. The best growth occurred when plants were fertilized with the low rate of N over the first two growing seasons confirming blueberry plants require relatively little fertilizer N (Bañados, 2006; Bañados et al., 2006; White, 2006).

Yield was greater for plants grown on raised beds than on flat ground in the second and third growing season (Table 1). Cumulative yield was 63% greater over two years when plants were grown on raised beds than on flat ground, corresponding to the measured improved plant growth in this system. Although the soil and the research site are considered to be well-drained, there was still an advantage to growing on raised beds. Work is underway to determine any impacts on root growth and physiology.

The highest yields were obtained when plants were fertilized with either the low rate of fish emulsion or the high rate of feather meal. Plants performed better when feather meal application was done in late winter rather than spring, allowing more time for release of nitrogen with rainfall in this drip irrigated field. After two growing seasons, the highest plant yield was observed in plants mulched with weed mat or compost+sawdust (Table 1). Fertilizer N may have been immobilized in the sawdust mulch treatment. In contrast, weed mat and compost+sawdust mulches may have improved growth as a result of higher soil temperatures leading to greater mineralized N and additional N available from the compost, respectively. Planting system had no effect on fruit firmness, but fruit were firmest when fertilized with the high rate of fish emulsion (Table 1). With weed mat mulch, fruit were less firm in both years (Table 1), perhaps due to changes in plant water status and irrigation scheduling.

Plants grown on raised beds required more irrigation water to maintain the same level of moisture in the top 30 cm of soil as those grown on flat ground in each of the three growing seasons. For example, with weed mat, raised beds required an additional 201, 269, and 61 L/plant/year in 2007, 2008, and 2009, respectively, compared to flat ground (Fig. 1). Irrigation water requirements also varied with mulch treatment. Plants mulched with weed mat required more than double the irrigation water to maintain the same soil moisture as plants mulched with sawdust. The need for more irrigation water with weed mat was likely due to higher canopy and soil temperatures (Allen et al., 1998). Daytime soil temperature at 5 cm was about 5°C higher under weed mat than under sawdust mulch, in the warmer and drier months of July and August, although soil temperature under weed mat was similar to that of bare soil (data not shown). Differences in irrigation requirement between these mulches may decrease as the plants mature and the canopy shades the weed mat.

Weed populations increased with planting age, although pre-planting management, including eliminating problem perennial weeds, use of a pre-plant cover crop, drip irrigation, and a between row grass crop, helped keep populations below 20-25% coverage. Weeds were fewest in the weed mat mulch, where they were only found around plants in the “planting hole” (Fig. 1) and greatest in the compost+sawdust mulch. Although the yard debris compost used contained no weed seeds, it is likely that any weeds blowing into these plots germinated readily in the moist, nutrient rich compost. Weeds were pulled by hand in the sawdust and weed mat mulch treatments. In the compost+sawdust treatment, propane flaming was not practical, as hot weather was required to improve effectiveness, yet there was risk of fire when using this method in the warm, dry summer months. A 20% acetic acid contact herbicide application was effective on younger weeds, particularly broadleaf weeds, when treatment was followed by a few days of hot weather. Hand weeding was done when the other weed management methods were insufficient.

Cumulative net returns ranged from -$ 32,690/ha to -$ 51,990/ha (net loss), depending on treatment. In comparison, updated costs for conventional blueberry production systems with a similar yield had a net cumulative return of -$ 35,540/ha (Julian, unpublished). While there was little difference between cultivar at this stage of the planting, use of fish emulsion had a net cost $ 8,075 more per hectare over the 3 years than use of feather meal. With regard to the mulches, weed mat had the least cost if the cost of the weed mat was amortized over an expected 5-year life. In contrast, use of compost+sawdust increased cumulative net costs by $ 7,895/ha compared to weed mat, as a result of high compost costs and increased weed management costs. The net cost of sawdust mulch was similar to compost+sawdust due to lower yields in this mulch treatment.

CONCLUSIONS

While this planting is still relatively young, growth and yield for most treatments have been similar to what has been observed in conventional systems. The best treatments so far have been growing plants on raised beds with a low rate of fish emulsion or a high rate of feather meal on either weed mat or compost+sawdust mulch. Economic returns to date have been comparable to conventional systems, depending on the organic production method used.

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Tables

Table 1. Effect of organic production systems on yield and fruit firmness in the second and third growing seasons, main effects (n=5).

Treatment	Yield (kg/plant)		Firmness (g mm^{-1} of deflection)	
	2008	2009	2008	2009
Planting system				
Flat	0.29	1.48	194	177
Raised	0.99	1.90	195	178
Fertilizer				
27 kg N/ha feather	0.26	1.64	183	170
27 kg N/ha fish emulsion	0.46	1.83	198	179
59 kg N/ha feather	0.31	1.87	191	176
59 kg N/ha fish emulsion	0.35	1.43	204	184
Mulch				
Sawdust+compost	0.36	1.73	196	180
Sawdust	0.28	1.52	195	180
Weed mat	0.39	1.83	191	172
Cultivar				
Duke	0.28	1.66	215	181
Liberty	0.40	1.72	173	173
Significance				
Planting system	*	***	n.s.	n.s.
Fertilizer	**	***	**	***
Mulch	**	***	*	***
Cultivar	**	n.s.	**	***

Significance: n.s.=non significant; * ($P<0.05$); ** ($P<0.01$); *** ($P<0.001$).

Figures

Fig. 1. ‘Duke’ blueberry on 16 June 2009 grown with weed mat mulch and the high rate of fish emulsion fertilizer on either flat ground (left) or on raised beds (right). Large tubes in plot on right are being used for root growth assessment using mini-rhizotrons.