Weed management strategies in long-term organic blueberry production systems – impact of mulch type and weed control methods on economics

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Abstract

Weed management was identified as one of the most challenging aspects of organic blueberry production by an advisory panel of growers. A long-term research trial was established in autumn 2006 to evaluate several components of organic production of northern highbush blueberry (*Vaccinium coymbosum*), including the use of three weed management strategies: sawdust mulch; yard debris compost topped with sawdust mulch (compost+sawdust); and a black, woven polyethylene ground cover (weed mat). Weeds were managed by hand pulling in sawdust and weed mat mulched plots, and a combination of hand pulling, propane flaming, and targeted applications of organically-approved herbicides to compost+sawdust plots. Mulches were replenished as needed. Treatments also included planting bed type, nitrogen fertilizer source and rate, and cultivar. Since these did not affect weed management costs, they are not discussed here. Weed management strategy affected establishment costs, weed presence, and weed control costs (herbicide application and labor required for hand weeding). Economic returns during establishment were negative for all mulch treatments (as is typical in blueberry), but losses were greatest for compost+sawdust due to increased weed presence and high weed management costs relative to other treatments. Costs were lowest for weed mat, where almost complete weed control was achieved. Weed presence increased as the planting aged and costs of weed management continued to increase with organic mulches whereas the weed mat had relatively low weed control costs throughout the product lifespan (5-7 years). The cumulative labor requirements to control weeds in the weed mat, sawdust, and compost+sawdust treatments were 270, 1085, and 1309 h ha^{-1}, respectively. Weed mat increased cumulative yield (years 2-8) 4% compared to the organic mulches. Even with the small increase in yield, weed mat was the most economical method of weed control, increasing net income 13 and 22% in 'Liberty' and 'Duke', respectively, compared to compost+sawdust mulch.

Keywords: weed mat, landscape fabric, organic mulches, organic herbicide, labor

INTRODUCTION

Weed management in northern highbush blueberry (*Vaccinium corymbosum*) has been identified by growers as one of the most challenging aspects of organic production. While herbicides can be effectively used in conventional production, organically approved herbicides do not have long-term efficacy, especially on established perennial weeds. Application of surface mulches such as sawdust have been shown to improve blueberry production by reducing weed pressure, maintaining soil moisture, and increasing plant growth (Burkhard et al., 2009; Clark and Moore, 1991; Krewer et al., 2009; White, 2006). However, Douglas fir (*Pseudotsuga menziesii*) sawdust, the most commonly applied surface mulch in the Pacific Northwestern USA, has become increasingly expensive and has a high carbon to nitrogen ratio, which adds to the difficulty of managing and maintaining plant fertility from organic sources (White, 2006). The use of yard debris compost, which is readily available from municipal sources, may help improve soil fertility and organic matter, but the impact of this compost on weed management and profitability is not known.

The use of woven polyethylene ground covers, or weed mat, has been approved for

organic production by the USDA National Organic Program (USDA-AMS-NOP, 2011), and is widely used in orchards for weed control. In Georgia, rabbiteye blueberry (*V. virgatum*) grown with weed mat had similar yield to those with organic mulches in the first 2 years of establishment but lower yield in years 3-5 (Krewer et al., 2009). Weed mat was the most economical method of weed control during establishment of organic northern highbush blueberry (Julian et al., 2012).

The objective of the present study was to examine the impact of various mulches on weed control costs, including labor requirements, installation and maintenance costs of mulches, and returns (yield and price for fruit) for 'Duke' and 'Liberty' grown in organic production systems from planting through maturity.

MATERIALS AND METHODS

A long-term organic systems trial was established at Oregon State University's North Willamette Research and Extension Center (NWREC; Aurora, OR, USA; lat. 45°16'47"N; long. 122°45'23"W) in autumn 2006. The soil is mapped as a Willamette silt loam (a fine-silty, mixed, superactive mesic Pachic Ultic Argixeroll).

Field establishment

The 0.4-ha research trial was planted in October 2006 and was "transitional" in the establishment years, but was certified organic in the first cropping year (2008) – a typical pattern for commercial growers – by a USDA accredited agency (Oregon Tilth, Certified Organic, Corvallis, OR). The planting was considered mature in the eighth growing season (2014). There were 48 treatment combinations arranged in a factorial (2×4×2×3) split-split plot design with five replicates. The main plots were bed configuration (raised beds of 0.3 m high or flat ground), the subplots were fertilizer rate and source (2 rates × 2 sources), and the sub-subplots were cultivar (the early-season 'Duke' and mid-season 'Liberty') and mulch treatment (sawdust, compost+sawdust, or weed mat). Sub-subplots were 4.6-m long with six plants each. Plant spacing was 0.76 by 3 m (4385 plants ha^{-1}). The plants were irrigated by drip, and irrigation rate was adjusted to maintain soil water content at similar values across mulch treatments (through measurement with time domain reflectometry; data not shown). Details on planting establishment and fertilizer treatments are provided elsewhere (Larco et al., 2013a, b; Strik, 2016). Mulch treatments and weed management strategies are described here.

Weed management

Mulch treatments were: a) Douglas fir "sawdust" mulch (9-cm deep; 360 m^3 ha^{-1}); b) Douglas fir sawdust mulch (5 cm deep; 200 m^3 ha^{-1}) with a layer of compost (yard debris, 4-cm deep; 152 m^3 ha^{-1}) underneath ("compost+sawdust"); and c) "weed mat" [black, woven polyethylene ground cover (TenCate Protective Fabrics; OBC Northwest Inc., Canby, OR)] with sawdust mulch (5 cm) in the 20-cm diameter planting hole (7 m^3 ha^{-1}). The intent of the compost+sawdust treatment was to have the sawdust mulch act as a barrier to weed seed germination in the more nutrient rich compost layer. The two organic mulches were initially applied in 2006 just after planting, and were then replenished as needed (early 2011 and 2013) to maintain mulch depth. The solid 1.5-m-wide piece of weed mat, centered over the row, was installed just prior to planting and was replaced with a 2-piece "zippered" weed mat in winter 2010-2011 allowing the weed mat to be opened and granular fertilizers to be applied underneath. The mulches are further characterized for their properties in Sullivan et al. (2015).

Plots mulched with sawdust and weed mat (in the planting hole area) were hand-weeded, while weeds were controlled using OMRI-approved (Organic Materials Review Institute) herbicides (2007-2008: WeedPharm, Pharm Solutions, Inc., Port Townsend, WA; 2009-2011: GreenMatch, Marrone Organic Innovations, Davis, CA; 2012-2014: Avenger AG, Avenger Organics, Buford, GA) and propane flaming in addition to hand-weeding in the compost+sawdust treatments for comparison of weed control costs (Julian et al., 2012). Use of propane flaming as a weed control method was discontinued due to lack of effectiveness

and risk of burning the mulch. Bed edges were maintained using 20% acetic acid (2007-2008; WeedPharm) and string trimmers, as needed, for all mulch treatments. Labor and product costs were recorded during establishment (Julian et al., 2012) and to maturity for installation and maintenance of each weed management treatment.

Yield and returns

From the first (2008) through the eighth (2014) fruiting seasons, ripe fruit were harvested by hand approximately every 7 days. Fruit were sold to a commercial organic berry packer (fresh and processed markets) to determine returns per treatment. Raised beds had greater yield than flat beds for both cultivars (Strik, 2016). As raised beds and the high rate of fertilizer most closely reflected standard commercial practices at the initiation of this study, only these treatments were considered when discussing yield (and returns) here. There was little effect of fertilizer source or rate on 'Liberty', while 'Duke' had much higher yield when feather meal was used (Strik, 2016; Strik et al., unpublished), thus the mean of fertilizer source was used to calculate gross income from fruit sales. There was no effect of fertilizer source or rate on weed growth and resulting labor costs.

Economic assumptions

Labor was valued at US$ 15 h^{-1} for the duration of the study, which includes worker's compensation, unemployment insurance, and other labor overhead expenses. Sawdust and compost+sawdust mulches were custom applied at a cost of $ 1,050 and 1,483 ha^{-1}, respectively, while labor hours for other activities were based on recorded times during establishment and plot maintenance. Costs of materials were calculated from actual prices paid and may have been lower if purchased in larger quantities for a commercial field of increased size. Pruning time was 20% higher for 'Liberty' than 'Duke' when plants were mature (Julian et al., 2011), but all other management costs were considered equivalent between mulch treatments and cultivars in this study.

RESULTS AND DISCUSSION

Labor and materials

In the course of this study, mulch was applied at establishment in October 2006 and replenished in early 2011 (all mulches) and 2013 (organic mulches only), prior to the start of the growing season. The weed mat mulch treatment was the lowest cost option (23% less than sawdust and 49% less than compost+sawdust) when both materials and labor required for installation were considered (Table 1). This is in part due to the 5-year lifespan of the weed mat, which did not need to be replaced with the other mulches in 2013, but also because of the high cost of the organic mulches, especially yard debris compost, which nearly tripled in price from 2006 to 2013. Labor costs for organic mulch application may be reduced if a farmer owned a mulch spreader and custom application was not required.

Weed management costs were highest for the compost+sawdust mulch and lowest for weed mat in every year of the study (Table 2). The nutrient-rich compost provided an ideal environment for weed seeds to germinate as the sawdust layer on top eroded as it was disturbed by hand weeding, rodent and bird activity, wind, and other necessary field activities. The time required for hand weeding thus increased in the compost+sawdust treatment. In addition, the organic herbicides available were ineffective against perennial weeds such as quackgrass (*Agropyron repens*), curly dock (*Rumex crispus*), and Canada thistle (*Cirsium arvense*) that became more pervasive as the field matured. Sawdust mulch also required plentiful hand weeding compared to weed mat, though when sawdust was freshly applied (in early 2011 and 2013), there was a reduction in weeding labor as the thicker mulch layer prevented some weed growth (Table 2). This reduction was also seen in the compost+sawdust mulch after the 2011 mulch replenishment, but not in 2013. Cumulative costs for compost+sawdust mulch were 36% higher than sawdust mulch alone and 546% higher than weed mat, which required minimal hand weeding in the planting hole (Table 2).

Table 1. Dates and costs (US $ ha^{-1}) of mulch installation at field establishment in October 2006 and replenishment in 2011 (all mulches) and 2013 (sawdust and compost+sawdust only) for an organic blueberry planting at the NWREC (Aurora, OR).

Treatment	2006		2011[1]		2013[1,2]		2006-2013
	Materials	Labor[3]	Materials	Labor[3]	Materials	Labor[3]	Total cost for materials and labor
Sawdust	3,447	1,050	4,392	1,050	4,706	1,050	15,695
Compost+sawdust	4,169	1,483	7,209	1,483	7,648	1,483	23,475
Weed mat	3,020	2,138	5,022[4]	1,853[4]	0	0	12,032

[1]In 2011 and 2013, less sawdust and compost was added than the mulch application at planting in 2006 because some mulch remained in the plots.
[2]Weed mat did not need to be replaced in 2013 as it has a 5-year lifespan.
[3]Labor for sawdust and compost+sawdust reflects custom application including equipment rental. Labor cost of US $ 15 h^{-1} is assumed.
[4]Cost of materials and labor for weed mat installation in 2011 does not include sawdust replenishment in the planting hole as additional mulch was no longer necessary.

Table 2. Yearly and cumulative costs (US $ ha^{-1}) of weed management, including herbicide product and labor costs, for an organic blueberry planting established October 2006 at the NWREC (Aurora, OR), 2007-2014.

Treatment	Input	2007	2008	2009	2010	2011[1]	2012	2013[1]	2014	2007-2014 total cost
Sawdust	Herbicide[2]	0	0	0	0	0	0	0	0	16,282
	Labor[3]	259	704	963	1320	615	4200	2010	6210	
Compost+ sawdust	Herbicide[2]	89	80	432	150	66	441	592	697	22,181
	Labor[3]	1041	781	1849	1545	456	2820	2862	8280	
Weed mat	Herbicide[2]	0	0	0	0	0	0	0	0	4,056
	Labor[3]	111	445	185	270	225	885	720	1215	

[1]All mulches were replenished prior to the growing season in 2011 and 2013.
[2]Herbicide costs reflect volume of organically approved herbicide used and variable costs of product for each year. No herbicides were applied to sawdust or weed mat plots for the duration of the study.
[3]Labor costs reflect hours required for hand weeding at the assumed $15 USD per hour labor cost. Cost includes time required to spray herbicides for compost+sawdust treatment.

Table 3. Yearly gross sales (US $ ha^{-1}) by mulch treatment for an organic blueberry planting at the NWREC (Aurora, OR) based on fruit yield and price received from 2008-2014 from raised beds with a high rate of fertilizer, averaged over fertilizer source. Sales are calculated as a weighted average of price received for fruit sold as fresh and processed, depending on cultivar and season.

Cultivar	Treatment	2008	2009	2010	2011	2012	2013	2014	2008-2014
Duke	Sawdust	3,181	13,918	20,164	51,420	59,441	24,219	73,043	245,386
	Compost+sawdust	3,970	16,443	22,345	52,465	62,964	24,276	72,470	254,933
	Weed mat	4,219	13,976	18,082	54,298	64,337	29,708	82,805	267,424
Liberty	Sawdust	4,714	15,273	33,242	45,595	87,358	38,548	93,552	318,282
	Compost+sawdust	5,743	15,540	38,103	47,531	81,916	39,473	89,773	318,079
	Weed mat	5,161	14,135	32,213	41,703	96,998	40,552	90,915	321,677

Table 4. Net income (US $ ha^{-1} for mulch treatments in an organic blueberry field established in October 2006 at the NWREC (Aurora, OR) considering costs of materials and labor for installation, weed management, pruning, and fruit sales, assuming all other management costs are equal 2006-2014.

Treatment	Cost of mulch and installation labor[1]	Cost of weed control[2]	Pruning costs[3]		Gross revenue from fruit sales[4]		Net income, 2006-2014	
			Duke	Liberty	Duke	Liberty	Duke	Liberty
Sawdust	15,695	16,282	13,500	16,134	245,386	318,282	199,908	270,172
Compost+sawdust	23,475	22,181	13,575	16,259	254,933	318,079	195,702	256,164
Weed mat	12,032	4,056	13,518	16,074	267,424	321,677	237,818	289,515

[1] Refer to Table 1 for yearly costs.
[2] Refer to Table 2 for yearly costs.
[3] Assumes pruning costs are 20% higher for 'Liberty' after year 2 of growth (Julian et al., 2012) and an hourly rate of $15 for labor. Refer to Julian et al. (2012) for annual costs during establishment and Julian et al. (2011) for hours required to prune maturing plants.
[4] Refer to Table 3 for yearly gross revenue by cultivar.

Yield and gross sales

Yield was consistently higher in 'Liberty' than in 'Duke' and cumulative yield (2008-2014) was 4% higher in weed mat than the organic mulches when averaged over cultivar, planting method, and fertilizer (Strik, 2016; Strik et al., unpublished). Weed mat was more beneficial in 'Duke' than in 'Liberty', with about 7% higher gross sales in 'Duke' for weed mat compared to other mulches whereas there was little effect of mulch in 'Liberty'. Due to cultivar differences (e.g., fruit firmness and ripening season), 'Duke' most frequently was sold as fresh market fruit and received a higher price kg^{-1} than 'Liberty', which was more frequently sold for frozen or processed markets. However, 'Liberty' had a greater yield than 'Duke' (Strik, 2016; Strik et al., unpublished), leading to greater returns for 'Liberty' in most years (Table 3). In 2013, early season bird depredation reduced 'Duke' yield significantly, leading to lower gross sales than the previous two years.

Net returns

When all costs for mulch (materials and installation at establishment and when replenished), weed control (herbicide applications in the compost+sawdust treatment and hand-weeding as needed), differential pruning costs by cultivar, and gross revenue from fruit sales were considered, use of weed mat in 'Duke' and 'Liberty' substantially improved net income for the 2006-2014 period (Table 4). While other management costs (harvest labor and costs of fertilizer and pesticide products and application, for example) would be present in a commercial field (Julian et al., 2011), we are assuming such costs would be similar among planting method, cultivars and mulches. In 'Duke', the use of weed mat resulted in 19 and 22% higher cumulative net income than sawdust and compost+sawdust, respectively. In 'Liberty' the differences among weed management strategies were smaller (7 and 13% higher than sawdust and compost+sawdust, respectively) because there was less of an effect on yield. Cumulative net returns would be slightly higher (around $ 1,000 USD) in both cultivars if the weed mat that was replaced in 2011 had time to be amortized over its full 5-year lifespan instead of the 4 years (2011-2014) included in the second half of this study. On a larger scale of production, product costs of mulches and herbicides may be lower, increasing net returns.

CONCLUSIONS

In our study, weed mat mulch was the most economical method of weed control in organic blueberry production from establishment through maturity (8 years of production). While the two cultivars studied differed in yield and their response to mulch and other treatments (Strik et al., unpublished), both had the highest returns when grown with weed mat. However, mulch type may have longer-term effects on soil and plant nutrient properties which may need to be considered in organic production systems (Strik, 2016).

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Literature cited

Burkhard, N., Lynch, D., Percival, D., and Sharifi, M. (2009). Organic mulch impact on vegetation dynamics and productivity of highbush blueberry under organic production. HortScience *44*, 688–696.

Clark, J.R., and Moore, J.N. (1991). Southern highbush blueberry response to mulch. Horttechnology *1*, 52–54.

Julian, J., Strik, B., Pond, E., and Yang, W. (2011). The Costs of Establishing and Producing Organic Blueberries in the Willamette Valley. AEB 0023 (Oregon State University Extension Service).

Julian, J.W., Strik, B.C., Larco, H.O., Bryla, D.R., and Sullivan, D.M. (2012). Costs of establishing organic northern highbush blueberry: impacts of planting method, fertilization, and mulch type. HortScience *47*, 866–873.

Krewer, G., Tertuliano, M., Andersen, P., Liburd, O., Fonsah, G., Serri, H., and Mullinix, B. (2009). Effect of mulches on the establishment of organically grown blueberries in Georgia. Acta Hortic. *810*, 483–488 http://dx.doi.org/10.17660/ActaHortic.2009.810.63.

Larco, H., Strik, B.C., Bryla, D.R., and Sullivan, D.M. (2013a). Weed and fertilizer management practices for organic production of highbush blueberries – I. Early plant growth and biomass allocation. HortScience *48*, 1250–1261.

Larco, H., Bryla, D.R., Strik, B.C., and Sullivan, D.M. (2013b). Weed and fertilizer management practices for organic production of highbush blueberries—II. Impact on plant and soil nutrients, yield, and fruit quality during establishment. HortScience *48*, 1484–1495.

Strik, B.C. (2016). A review of optimal systems for organic production of blueberry and blackberry for fresh and processed markets in the northwestern United States. Sci. Hortic. (Amsterdam) *208*, 92–103 http://dx.doi.org/10.1016/j.scienta.2015.11.044.

Sullivan, D.M., Strik, B.C., and Bryla, D.R. (2015). Evaluation of alternative mulches for blueberry over five production seasons. Acta Hortic. *1076*, 171–178 http://dx.doi.org/10.17660/ActaHortic.2015.1076.20.

USDA-AMS-NOP. (2011). Program Handbook: Guidance and Instructions for Accredited Certifying Agents & Certified Operations. Winter edition 2011. pp.214.

White, L.D. (2006). The effect of pre-plant incorporation with sawdust, sawdust mulch, and nitrogen fertilizer rate on soil properties and nitrogen uptake and growth of 'Elliott' highbush blueberry. MS thesis (Corvallis, USA: Oregon State Univ.), http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/1363/WholeThesis.pdf?sequence=1.