Evaluation of Alternative Mulches for Blueberry over Five Production Seasons

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Abstract

Highbush blueberry (*Vaccinium corymbosum* L.) is a calcifuge (acid-loving) plant that responds favorably to mulching with organic matter (OM). Until recently, most blueberry plantings in northwestern United States were grown with a mulch of douglas fir sawdust, with additional nitrogen (N) fertilizer applied to compensate for N immobilized by sawdust decomposition. A field trial was established in Oct. 2006 in Aurora, Oregon, USA to evaluate alternative mulches (as partial or full replacement for sawdust) within a certified Organic system. Mulch treatments were: sawdust alone (9-cm depth); yard debris compost (4 cm) covered with sawdust (5 cm); and geotextile weed mat. The treatments were applied at planting and comprised one component of a factorial trial that included two cultivars ('Duke' and 'Liberty'), two bed configurations (raised and flat), two fertilizer sources (fish emulsion and feather meal), and two fertilizer rates (low and high). The organic mulches were reapplied, and the weed mat was replaced, after four growing seasons. Average cumulative yields over the first 5 years of fruit production (2008-12) were 9.0 kg/plant with sawdust, 9.3 kg/plant with 'compost + sawdust', and 9.6 kg/plant with weed mat; and the treatment with the highest cumulative yield, regardless of mulch, was 'Liberty' fertilized with either a low or high rate of feather meal. By 5-6 years after planting, soil OM was 37 $g \cdot kg^{-1}$ with 'compost + sawdust', 32 $g \cdot kg^{-1}$ with sawdust, and 30 $g \cdot kg^{-1}$ with weed mat. Soil pH remained in the optimum range for blueberry in each treatment (pH 4.5-5.5), but soil K at a depth of 0-20 cm was higher with 'compost + sawdust' (400 $mg \cdot kg^{-1}$) than with sawdust or weed mat (250 $mg \cdot kg^{-1}$ each). Leaf nutrient concentrations, including K, Ca, and Mg, were nonresponsive to the mulch treatments. Overall, this study demonstrated that application of yard debris compost provided a large benefit to soil OM maintenance and increased soil test K, but had no effect in 6 years on tissue nutrient concentrations in the blueberry leaves.

INTRODUCTION

The development of organic markets for blueberry in recent years has stimulated interest in using compost to supply organic matter (OM) and nutrients, and to perhaps stimulate favorable soil microbial activity. Maintaining soil OM is especially important for blueberry because it is a long-lived perennial that is best adapted to high OM soil (20+ years).

Compost suitability for blueberry has been evaluated in pot trials (soil amended with 30% compost v/v; Costello, 2011). Yard debris compost was identified as one of the best candidates for further evaluation in the field, because it is widely available, and its chemical and physical properties are relatively consistent. Although yard debris composts from western Oregon are high in pH (>7), they have a relatively low pH buffering capacity, and typically do not increase soil pH above that tolerated by blueberry (Costello, 2011). A laboratory testing protocol to determine compost acidification requirements can be used to provide quantitative assessment of the lime substitution capacity of compost, so that the effect of compost on pH can be estimated prior to field application (Costello and Sullivan, 2013).

Mulches evaluated in the present trial were chosen with input from a local grower/industry group and included sawdust mulch (standard practice), compost covered by sawdust mulch, and weed mat (woven geotextile). Weed mat is a newer mulch option that provides an economic advantage of lower weed control cost (Julian et al., 2012).

This paper reports the response of blueberry plants (berry yield and leaf nutrient concentration) to changes in soil nutrient status associated with mulch treatments during the first 5 years of fruit production (years 2-6 after planting). Mulch response data from the first 2 years of the trial (2007-08) were reported previously (Larco et al., 2014). Other aspects of the initial years of the trial have also been reported, including economic return (Julian et al., 2012), root and shoot growth (Larco et al., 2013a), and soil and plant nutrient dynamics (Larco et al., 2013b).

MATERIALS AND METHODS

The long-term trial reported here was initiated in 2006 at a 0.43 ha site in transition to certified USDA Organic production at the North Willamette Research and Extension Center (NWREC; 45°16'47.55"N, 122°45'21.90"W), located in Aurora, Oregon, USA. Soil at the site is a Willamette silt loam. The trial consisted of 48 treatments within a factorial 2 × 4 × 2 × 3 split-split plot design with five replicates. The main plots were bed configuration (raised bed or flat ground), the subplots were fertilizer rate and source (2 rates × 2 sources), and the sub-subplots were blueberry cultivar ('Liberty', 'Duke') and mulch treatment ('compost + sawdust', sawdust, or weed mat). Sub-subplots were 4.6-m long with six plants each. Plant spacing was 0.76 m by 3 m (4,385 plants/ha). The plants were irrigated by drip, and irrigation rate was adjusted to maintain soil water content at similar values across treatments. Additional experimental details can be found in Larco et al. (2013a, b). Mulch treatments were: a) douglas fir (*Pseudostsuga menziesii*) sawdust mulch (9-cm deep; 360 $m^3 \cdot ha^{-1}$); b) compost (yard debris, 4-cm deep; 152 $m^3 \cdot ha^{-1}$) plus douglas fir sawdust (5 cm deep; 200 $m^3 \cdot ha^{-1}$) mulch on top; and c) weed mat (landscape fabric) with sawdust mulch (5 cm) in the 20-cm diameter planting hole (1.4 $m^3 \cdot ha^{-1}$). Mulches were initially applied in 2006, and then re-applied (organic, Jan. 2011) or replaced (weed mat, Dec. 2010) after four growing seasons.

Yard debris compost was supplied by Rexius Inc., Eugene, OR, USA. It was prepared from a mixture of woody tree and shrub trimmings collected from urban yard maintenance. Composting took place outdoors in windrows, with ≈30 d of active (>50°C) composting, followed by 90-180 d of curing at lower temperatures. Total nutrients in the 4-cm of compost applied in 2006 were ≈610 $kg \cdot ha^{-1}$ N, 130 $kg \cdot ha^{-1}$ P, and 310 $kg \cdot ha^{-1}$ K. In Jan. 2011, a 2.5-cm depth of compost was applied, supplying ≈380 $kg \cdot ha^{-1}$ N, 80 $kg \cdot ha^{-1}$ P, and 190 $kg \cdot ha^{-1}$ K.

Fertilizer rate and source treatments were granular feather meal (13% N) or fish emulsion applied at rates of 29 and 57 $kg \cdot ha^{-1}$ N per year in 2007-09. The rates were increased to 57 and 114 $kg \cdot ha^{-1}$ N per year in 2010-12. In 2007-12, feather meal was broadcast on top of the organic mulches or under the weed mat (opened for application). Fish emulsion was diluted with 10 parts water (v/v) and was applied by hand as a drench around the base of the plants in 2007-09, side-dressed with a sprayer on each side of the row in 2010, and injected through the drip system in 2011-12.

Plants were cropped beginning the second year after planting (2008). Berries were hand-harvested weekly and weighed for yield. Extractable soil nutrients and leaf nutrient concentration were determined at Brookside Laboratories, Inc. (New Bremen, OH) using standard methods. Soil samples were collected in October or November of each year from all 'Duke' treatments. The soil was collected to a depth of 20 cm (after removing surface mulch), near the center of the beds, at a distance of ≈30 cm from the crown of one plant in each plot, and was prepared for analysis by air-drying and screening (2-mm mesh). Extractable soil nutrients were determined using an inductively-coupled plasma (ICP) spectrophotometer, after extracting the samples following the Mehlich 3 method (Mehlich, 1984). Soil OM was determined using Loss-On-Ignition at 360°C (Nelson and Sommers, 1996). Soil pH was measured using the 1:1 soil:water method (McLean, 1982). Leaf samples were collected from three replications in early August each year, as per standard practice (Hart et al., 2006). The leaves were oven-dried and ground, and analyzed for N using a combustion analyser, and analyzed for other nutrients using an ICP spectrophotometer, after wet ashing the samples in nitric/perchloric acid (Gavlak et al., 1994).

RESULTS AND DISCUSSION

Compost and Sawdust Analyses

Analysis of the organic mulches was consistent between the initial application at planting and the re-application at 4 years. Nutrient levels in the sawdust were low relative to the compost (Table 1). The C:N of sawdust (500) was indicative of woody mulch. Currently, application of additional fertilizer N (25 $kg \cdot ha^{-1}$) is recommended to compensate for N immobilized by an 8-cm deep layer of sawdust (Hart et al., 2006). Yard debris compost characteristics (C:N of 24, NO_3-N < 100 $mg \cdot kg^{-1}$, respiration rate <2 mg CO_2-C per g C per d) were indicative of fully cured compost with a low potential for N mineralization (Sullivan and Miller, 2001). A low rate of N mineralization from compost is likely beneficial during blueberry establishment. High levels of plant-available N are often detrimental to blueberry establishment (e.g., Bañados et al., 2012; Larco et al., 2013a).

Chemical characteristics of the yard debris compost met general screening criteria for compost that were recently proposed for use with blueberry: EC < 2 $dS \cdot m^{-1}$ by 1:5 method; total K <10 $g \cdot kg^{-1}$; C:N of 12-25 (Sullivan et al., 2014). Yard debris compost from the same supplier (Rexius Inc.) required ≈6 $g \cdot kg^{-1}$ of elemental S (S^o) to acidify compost pH to 5.0, when all of the S^o oxidized to H^+ (Costello et al., 2011). The acid-neutralizing capacity of the compost (above pH 5) applied in this study was equivalent to ≈1 $Mg \cdot ha^{-1}$ of $CaCO_3$ for the 2006 compost application rate (i.e., 152 $m^3 \cdot ha^{-1}$ or 50 $Mg \cdot ha^{-1}$).

Mulch Effects on Cumulative Berry Yield

The cultivar and organic fertilizer treatments had a larger impact on cumulative berry yield than the mulch treatments (Table 2). ‘Duke’ had less yield than ‘Liberty’ and was more sensitive to yield decline when fertilized with fish emulsion. Cumulative berry yield (2008-12) was highest in ‘Liberty’ fertilized with either the low or high rate of feather meal (Table 2). Within the ‘Liberty’ + feather meal treatments, relative yields were 100% with weed mat, 95% with ‘compost + sawdust’, and 85% with sawdust mulch. On average, the total cumulative berry yield from 2008 to 2012 was 9.0 kg/plant with sawdust, 9.3 kg/plant with ‘compost + sawdust’, and 9.6 kg/plant with weed mat (data for individual years not shown). Annual yields increased with time during the study, so the cumulative yield data reflect most strongly the yields observed during the last 2 years of the study. Statistical analysis within years showed that weed mat was among the highest yielding mulch treatment in 4 out of 5 years, while ‘compost + sawdust’ was in the high group in 3 out of 5 years, and sawdust was in the high group in 1 year only (2011).

Mulch Effects on Nutrients in Soil and Plants

Although the compost supplied a high rate of total N, it supplied low amounts of plant-available N that was accessed by blueberry. The organic fertilizers supplied much more plant available N than compost. Organic N supplied by feather meal or fish emulsion is often mineralized rapidly to plant-available mineral N, with 60% to 75% of total N mineralized at 4 weeks following application (Gale et al., 2006). The yard debris compost used in this trial was woody and had a relatively high C:N (24). Plant-available N mineralized from woody composts during the first growing season after application is typically near zero (Gale et al., 2006; Prasad, 2009) with about 3% of total N mineralized in subsequent years (Hartz et al., 2000; Kusonwiriyawong et al., 2013). Predicted N mineralized from compost (3% of total N) was ≈20 $kg \cdot ha^{-1}$ N per year for 2008-12. The lack of response by blueberry to N from compost in this trial may be related to 1) mixing of compost with sawdust over time on the soil surface (resulting in N immobilization), 2) lack of synchrony between timing of N mineralized from compost (summer) and N uptake by blueberry (spring and early summer; Bañados et al., 2012), and/or 3) the small amount of plant-available N supplied by the compost relative to that supplied by the fertilizer.

Soil OM was consistently higher each year with 'compost + sawdust' than with either sawdust alone or with weed mat (Table 3). Although the compost contained a lower percentage of OM than sawdust at application, it had greater stability (lower respiration rate) and 3-fold greater bulk density (Table 1). The increase in soil OM resulting from compost application (+5 $g \cdot kg^{-1}$ vs. sawdust in years 5-6) equates to ≈15% to 20% of the compost OM applied. This value is only approximate because soil bulk density was estimated (1.3 $g \cdot cm^{-3}$), the compost was applied by volume (depth) not weight, and some of the compost OM may have been moved below the sampling depth by worms or other mechanisms (e.g., rodents). The observed increase in soil OM in the present study is lower than that reported previously for woody composts applied to a sandy loam soil that was later cropped to tall fescue (Sullivan et al., 2003). In that study, increased soil OM accounted for 35% of compost OM applied at 3 years after application and 18% after 7 years. Higher retention of OM is expected under grass (Sullivan et al., 2003) than under blueberry (present study).

Overall, soil pH and soil cation measurements demonstrated relatively small changes in pH over time for this organic management system. Soil pH remained within the target range for blueberry (4.5 to 5.5) in all years of the study (Table 3). Soil pH was lowest for sawdust or for weed mat in only 1 out of 5 years (2012 and 2008, respectively). The 'compost + sawdust' treatment had the highest pH in 1 out of 5 years (2008) and higher pH than sawdust alone in 3 out of 5 years.

Sum of exchangeable cations (Fig. 1) is a more stable indicator of soil acidity than is pH, because it does not fluctuate seasonally in response to changes in soluble salts in soil solution. Higher cation values indicate higher pH. Five-year average cation values were 5.3 cmol(+) kg^{-1} for sawdust, 6.8 for 'compost + sawdust', and 6.0 for weed mat. Soil cations decreased during 2008-10 (Fig. 1), reflecting on-going acidification, and increased after the second mulch application (Jan. 2011) and the subsequent higher rates of organic fertilizer application (2011-12). We expected weed mat to have the lowest exchangeable cations and pH (due to increased soil temperatures and more OM loss via decomposition), but soil analyses contradict this hypothesis.

Soil test K was higher with 'compost + sawdust' than with sawdust alone or weed mat (Table 3; Fig. 1). Soil test K measured over time reflects a balance between K^+ leaching (slow) and K addition with compost and fish fertilizer (Fig. 1). Soil test K declined from 2008-2010, and rebounded to higher values after the second organic mulch application in Jan. 2011 (Fig. 1). Some of the increase in soil test K observed across all mulch treatments for 2011-12 was due to higher rates of fish fertilizer applied in those years.

Differences observed in soil nutrient levels among mulch treatments were not reflected in leaf nutrient concentrations (Table 4). With the exception of B and Cu, leaf tissue values were within recommended levels (Hart et al., 2006). Leaf Mn did not respond to addition of Mn via compost. Leaf Ca, Mg, and K were stable across mulch treatments in spite of the large increase in soil K. When soil K supply is excessive, elevated leaf K and reduced leaf Mg (indicating possible Mg deficiency) has been reported for blueberry (Costello, 2011; Forge et al., 2013). In the present study, leaf K values were highest for the high fish emulsion treatment. Plants supplied with high levels of N typically take up more K and are more subject to Mg deficiency (Cummings, 1985). In the present study, even plants receiving a high rate of N and K from fish emulsion, plus K from the 'compost + sawdust' treatment, did not exhibit Mg deficiency.

CONCLUSIONS

This study demonstrated that yard debris compost provided a large benefit to maintaining soil OM and, relative to sawdust only, a slight increase in berry yield. These benefits did not translate into economic benefit because of the high cost of weed control and the cost for the compost itself (Julian et al., 2012). Soil and leaf tissue nutrient concentration were not strongly linked to the yield response of blueberry to mulch. Yard debris compost increased soil test K, but this increase did not have any apparent effects on leaf cations or on berry yield during the length of the study period. We conclude that yard debris compost has potential for use in blueberry production systems. Future trials should evaluate compost use in conjunction with less expensive weed control management systems. A potential option is to cover the compost with weed mat.

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Tables

Table 1. Sawdust and yard debris compost analyses (dry wt. basis)[z].

Analysis	Sawdust	Compost	Analysis	Sawdust	Compost
	Carbon and Nitrogen			Total nutrients	
Total N ($g \cdot kg^{-1}$)	1	11	P ($g \cdot kg^{-1}$)	0.2	2.1
Organic C ($g \cdot kg^{-1}$)	491	260	K ($g \cdot kg^{-1}$)	1	6
Organic matter ($g \cdot kg^{-1}$)	991	499	Ca ($g \cdot kg^{-1}$)	2	9
Ash ($g \cdot kg^{-1}$)	10	502	Mg ($g \cdot kg^{-1}$)	0	3
C:N ratio	494	24	SO_4-S ($mg \cdot kg^{-1}$)	30	7
NH_4-N ($mg \cdot kg^{-1}$)	15	12	Cu ($mg \cdot kg^{-1}$)	5	57
NO_3-N ($mg \cdot kg^{-1}$)	2	41	Zn ($mg \cdot kg^{-1}$)	11	167
Respiration rate			Mn ($mg \cdot kg^{-1}$)	86	585
(mg CO_2-C/g C/d)	3.6	2.1	B ($mg \cdot kg^{-1}$)	11	15
	Other			Particle size (%, w/w)	
Bulk density ($kg \cdot m^{-3}$)	121	368	> 16 mm	0	0
EC (1:5, $dS \cdot m^{-1}$)	0.3	1.4	4-16 mm	16	35
pH (1:5, soil:water)	4.5	7.4	2-4 mm	21	17
			< 2 mm	63	48

[z] Compost analyses by Soil Control Lab, Watsonville, CA, USA using protocols described in Test Methods for Compost and Composting (TMECC; Thompson et al., 2001). Total nutrients determined via strong acid digestion and ICP determination. Respiration rate ("biologically available C") determined in 72-h incubation at 37°C; sample pretreated with complete nutrient solution. Values are average of two mulch applications (2007 and 2011). A single composite sample of the mulches was analyzed at each sampling time.

Table 2. Effect of organic production system on relative berry yield (years 2-6; 2008-2012)[z].

Cultivar	Mulch	Feather meal Low	Feather meal High	Fish Low	Fish High	Avg.
		% of maximum berry yield				
Duke	Compost + sawdust	85	94	70	54	76
	Sawdust	90	81	68	54	73
	Weed mat	85	95	79	50	77
Liberty	Compost + sawdust	86	94	98	92	92
	Sawdust	82	88	92	87	87
	Weed mat	100	99	94	95	97

[z] Berry yield averaged across raised and flat beds. Annual berry yield averaged across all treatments was 0.35, 1.7, 1.75, 2.6, 3.05 kg/plant in year 2-6, respectively.

Table 3. Effect of mulch on soil test values for pH, organic matter, and exchangeable cations[z].

Mulch	pH Year 2-4	pH Year 5-6	OM ($g \cdot kg^{-1}$) Year 2-4	OM ($g \cdot kg^{-1}$) Year 5-6	K ($mg \cdot kg^{-1}$) Year 2-4	K ($mg \cdot kg^{-1}$) Year 5-6	Ca ($mg \cdot kg^{-1}$) Year 2-4	Ca ($mg \cdot kg^{-1}$) Year 5-6	Mg ($mg \cdot kg^{-1}$) Year 2-4	Mg ($mg \cdot kg^{-1}$) Year 5-6
Compost + sawdust	5.3	5.2	40	37	328	396	874	1067	138	151
Sawdust	5.2	5.0	33	32	219	248	730	819	104	105
Weed mat	5.1	5.2	32	30	213	246	743	994	127	185
Significance	**	**	***	***	***	***	**	***	***	***

[z] Mulch treatments were applied at transplanting in fall 2006 and reapplied during winter of 2010-11. Soil samples were collected in fall of years 2-4 (2008-10) and 5-6 (2011-12).

, * Significant differences among mulch treatments at $P \leq 0.01$ and 0.001, respectively (n = 40).

Table 4. Effect of mulch on leaf nutrient concentration for highbush blueberry[z].

Mulch	Leaf macronutrients ($g \cdot kg^{-1}$)						Leaf micronutrients ($mg \cdot kg^{-1}$)					
	N	S	P	K	Ca	Mg	B	Cu	Mn	Zn	Fe	Al
Compost + sawdust	17.5	1.2	1.2	5.3	4.6	1.5	23	2.6	119	11	101	122
Sawdust	17.3	1.2	1.2	5.1	4.8	1.5	20	2.6	138	11	100	129
Weed mat	17.5	1.2	1.2	5.2	4.5	1.5	20	2.7	132	11	100	122
Target min.	17.6	1.1	1.0	4.1	4.1	1.3	31	5	30	8	61	--
Target max.	20.0	1.6	4.0	7.0	8.0	2.5	80	15	350	30	200	--

[z] Fully expanded leaf collected according to standard sampling protocol and target minimum and maximum leaf nutrient concentrations based on Hart et al. (2006). Leaf S, Fe, and Al averaged across 'Duke' and 'Liberty' for year 3-6 (2009-2012). All other nutrients averaged across year 2-6 (2008-12).

Figures

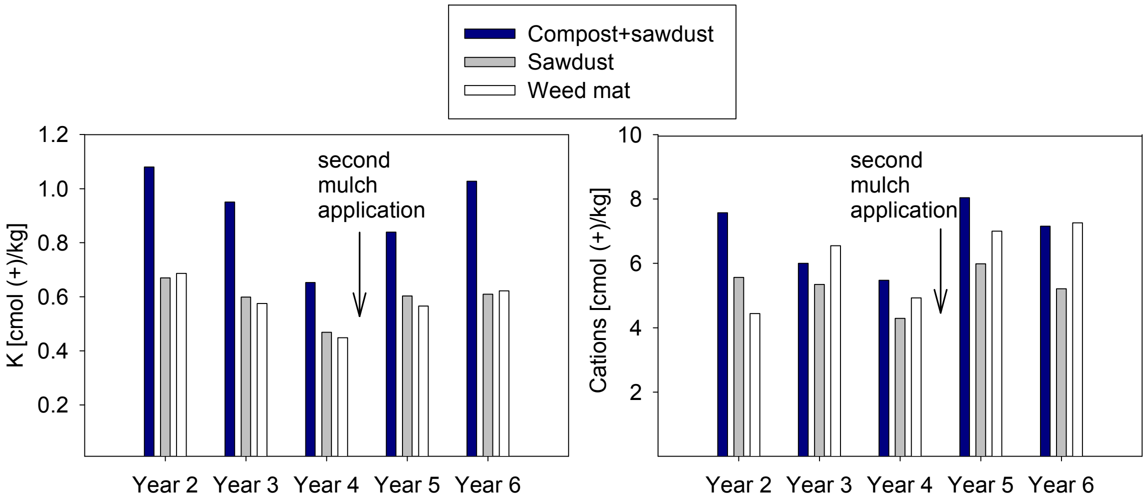

Fig. 1. Soil test K (left) and total cations (Ca, Mg, K; right) in 0-20 cm soil depth.