Mulch Effects on Highbush Blueberry under Organic Management

H. Larco and B. Strik
Dept. of Horticulture
Oregon State Univ.
Corvallis, OR
USA

D.M. Sullivan
Dept. Crop & Soil Science
Oregon State Univ.
Corvallis, OR
USA

D. Bryla
Hort. Crops Research Unit
USDA-ARS
Corvallis, OR
USA

Keywords: *Vaccinium corymbosum*, compost, sawdust, mulch, weed mat, landscape fabric, raised beds, nutrient, nitrogen

Abstract

A long-term organic blueberry trial was planted in October 2006 in Aurora, Oregon, USA to investigate the effect of mulch on soil and plant nutrient status, plant growth, berry yield, irrigation requirements, and weed control efficacy. Mulch treatments were applied at planting: 1) weed mat (geotextile), 2) Douglas-fir (*Pseudotsuga menziesii*) sawdust, and 3) compost + sawdust (compost applied to soil, then covered with sawdust). This paper addresses mulch treatment effects on soil and plant nutrient status during the first two years of the trial, and the first berry harvest in year 2 (2008). Yard-debris compost used in the field experiment had a pH of 7.3 and low soluble salt (EC <1 mS/cm). The yard debris compost + sawdust treatment produced greater berry yields than sawdust alone in the first bearing season. Relative berry yields were 100% for weedmat, 90% for sawdust + compost, and 70% for sawdust mulch. The positive effects of compost on berry yield were observed across two cultivars, flat or raised beds, and for two organic fertilizer sources (fish emulsion or feather meal) applied at two rates (29 and 57 $kg{\cdot}ha^{-1}$ N). Soil pH underlying the mulch was lowest (most acidic) with weed mat and highest under sawdust + compost mulch. After two years, compost increased soil organic matter (OM; 0-20 cm) by 9 $g{\cdot}kg^{-1}$ vs. weedmat, while sawdust mulch did not increase soil OM. In summary, compost maintained soil pH in the optimum range for blueberry, provided plant-available cations, increased soil organic matter, and increased berry yield (relative to sawdust alone). The mechanism(s) behind the compost benefit deserve further investigation.

INTRODUCTION

Organic blueberry production is a relatively new industry in the USA. Organic production was stimulated by the adoption of uniform production and marketing standards by the US Dept. of Agriculture in 2003. Blueberry is traditionally grown with sawdust mulch. Numerous research reports document the benefits of organic mulch in a wide variety of blueberry production systems (Moore, 1979; Clark, 1991; Clark and Moore, 1991; Lareau, 1989; White, 2006). We initiated an integrated system field trial in 2006 to simultaneously evaluate several aspects of organic blueberry production systems. Mulch treatments are embedded in a long term trial allowing evaluation of mulch interactions with raised beds or flat ground, organic fertilizer rate and source, and cultivar. Since this is a long-term study, data are added annually and are made available via an eOrganic project website (Strik et al., 2011).

Mulch treatments in our integrated system trial were selected in consultation with a grower advisory committee and were based on considerations for fertility maintenance, soil temperature control, and projected cost and ease of weed control within the context of an organic system. A sawdust + compost mulch treatment was included in this trial, because of hypothesized organic matter, nutrient and microbiological benefits. Yard debris compost is produced by Oregon municipal composting programs and typically costs 1.5 to 2 times more than sawdust. Sawdust mulch has been used in Oregon conventional blueberry production for many years. Geotextile weedmat is a newer mulching technique. It is usually very effective in weed control, and typically has a lifespan of 4 to 5 years. Because organic sources of nitrogen (N) are expensive and laborious to apply, the potential for a slow-release N benefit from compost is of great economic significance. Supplying N from feather meal or fish fertilizers costs our growers from $ 10 to 20 per kg N applied.

This paper focuses narrowly on the effects of mulch treatments on: berry production in the second growing season after planting (2008), and diagnostic leaf and soil nutrient levels during the first two growing seasons after establishment. Our objectives were to: (i) evaluate effects of mulch on berry yield, (ii) determine whether mulch had any important effects on leaf and soil nutrient levels that may impact long-term plant growth and productivity.

MATERIALS AND METHODS

Experimental Location and Treatments

The 0.43 ha research trial was established in October 2006 on a site in transition to certified USDA Organic production at the North Willamette Research and Extension Center (NWREC; 45°16’47.55”N and 122°45’21.90”W), Aurora, Oregon, USA on a Willamette silt loam soil. Additional information on site preparation and planting is provided in Larco (2010).

There were 48 treatments in this experiment arranged within a factorial 2×4×2×3 split-split plot design with 5 replicates. Main plots were bed configuration (raised bed or flat ground). Split plots within each main plot were fertilizer rate and source (2 rates × 2 sources), blueberry cultivars (‘Liberty’, ‘Duke’), and mulch treatments (sawdust, sawdust + compost; or weedmat). Treatment plots were 4.6 m long with 6 plants each. Plant spacing was 0.76 by 3 m (4,385 plants/ha).

Each mulch treatment included a weed control strategy suited to the mulch (Larco, 2010). 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 $m^3 \cdot ha^{-1}$).

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 approximately 30-d of active (>50°C) composting, followed by 90-180 d of curing at lower temperatures. Chemical, physical, and biological characteristics of compost and sawdust are given in Table 1. Fertilizer rate and source treatments were granular feather meal (13% N) or fish emulsion at annual application rates of 29 and 57 $kg \cdot ha^{-1}$ N (Larco, 2010).

Two-year-old container grown plants were transplanted into the beds from 4-L containers (Fall Creek Nursery, Lowell, Ore.) on 9 October 2006. Plants were irrigated by a single lateral of drip tubing located below the mulch treatment, with 2 $L \cdot h^{-1}$ in-line emitters spaced every 0.3 m. The system was designed so that raised beds and flat ground rows could be irrigated independently to adjust for differences in plant water use. A second lateral (0.45 m between 2 lines) was also installed to allow for differences in irrigation requirement with use of weed mat mulch.

After planting in October 2006, plants were pruned to remove fruit buds and shape bushes, if necessary. Plants were pruned in January 2008 with pruning severity adjusted based on individual plant size to achieve a balance between bush size and anticipated yield (if any) in 2008 (Strik and Buller, 2005).

Data Collection

Leaf samples were collected from three replications in early August of both years per standard practice (Hart et al., 2006). Total leaf N was determined by a combustion analyser using an induction furnace and a thermal conductivity detector (Gavlak et al., 1994). All other total leaf nutrient concentrations were determined via inductively coupled plasma spectrophotometer (ICP) after wet ashing in nitric/perchloric acid

(Gavlak et al., 1994). Leaf analyses were performed at the Oregon State University Central Analytical Laboratory (Corvallis, OR) in 2007 and at Brookside Laboratories, Inc. (New Knoxville, OH) in 2008.

Soil samples were collected on 5 November 2008 in all 'Duke' treatments. Soil was collected to a depth of 20 cm (after removing surface mulch) at an approximate distance of 30 cm from the crown. Soil was prepared for analysis by air-drying and screening to pass 2-mm mesh. Extractable soil S, Ca, Mg, K, Na, B, Fe, Mn, Cu, Zn, Al, and P were determined via ICP after extraction via the Mehlich 3 method (Mehlich, 1984) at Brookside Laboratories, Inc., New Knoxville, OH. Soil organic matter was determined using Loss-On-Ignition at 360°C (Nelson and Sommers, 1996). Soil NO_3-N and NH_4-N were determined via automated colorimetric methods after extraction with 1 M KCl (Dahnke, 1990). Soil pH was determined via the 1:1 soil:water method (McLean, 1982).

Berries were hand-harvested with data collected on yield (presented here) and other fruit quality characteristics (presented in Larco, 2010).

Statistical Analysis

Analysis of treatment effects was done as a complete factorial for a split-split plot design using the PROC MIXED procedure in the SAS software package version 8 (SAS Institute, Cary, NC). Results for each year were analyzed separately, because of differences in plant age in the field and environmental differences between years (data not shown).

RESULTS AND DISCUSSION

Organic Mulch Characteristics

Compost used in the study was typical of that produced by commercial yard debris composters serving municipalities in the Willamette Valley, Oregon, USA (Table 1). About half of compost dry matter was organic matter, C:N was near 20, inorganic N was low (< 10 mg/kg), soluble salt (EC) was low (less than 1 mS/cm), and compost stability was high. We selected yard debris compost for this study because it had relatively low salt (EC) and we could apply high rates of stable organic matter without danger of excess plant-available N application. High levels of plant-available N are often detrimental to blueberry establishment because plants overproduce stem and leaf tissue at the expense of root system establishment.

Douglas fir sawdust is commonly used in conventional and organic blueberry production systems in the Pacific Northwest, USA. It has a high C:N ratio (generally >700 for fresh sawdust), making fertilizer management difficult. White (2006) reported that sawdust mulch immobilized N from conventional fertilizers. Application of an additional 25 $kg{\cdot}ha^{-1}$ N fertilizer is recommended to compensate for N immobilized by an 8 cm deep layer of fresh sawdust (Hart et al., 2006). The sawdust used in this study was aged, as is typical in commercial production systems.

For the compost+sawdust mulch treatment, the compost was placed on the soil surface and then covered with sawdust mulch in hopes of creating a barrier to weed establishment. The yard debris compost had a similar fraction of fine particles (51%) as the sawdust (56%) but was more conducive to weed establishment because of higher bulk density and nutrient content (Table 1) and greater water-holding capacity. Weed coverage and cost of weed management were greater for the compost+sawdust treatment than for the sawdust or weedmat mulches in 2007 and 2008 (Larco, 2010). Weed control issues are the major obstacle to compost utilization in this cropping system.

Berry Yield

Main effects of cultivar, fertilizer type and rate, raised vs. flat beds, and mulch on berry yield were significant (P=0.05; Table 2). Mulch effects on berry yield were remarkably consistent across all treatment combinations. Averaged across raised or flat beds, cultivars, and fertilizer type/rate, the relative berry yield was 100% for weedmat, 90% for compost + sawdust, and 70% for sawdust. The compost+sawdust treatment had superior yield vs. sawdust within each of the 16 combinations of bed configuration (flat or raised), fertilizer and cultivar. Relative to the weedmat treatment, berry yields were lower for compost+sawdust across 29 N fish, 29 N feather or 57 N feather fertilization treatments (Table 2, Fig. 1). When fertilized with 57 N fish, berry yield with compost + sawdust was equivalent or higher than with weedmat. Yields for weedmat and sawdust+compost treatments were equivalent for ‘Liberty’ on raised beds.

Yield response to fertilizer (Table 2; Fig. 1) was likely due in part to differences in the efficiency of N delivery for fish vs. feather meal. The low rate of fish increased berry yield and leaf N more than the high rate of feather meal. The greater effect of fish fertilizer in increasing berry yield was probably associated with less immobilization of its N in the mulch. The liquid fish fertilizer was poured through mulch, while solid feather meal was applied on top of the mulch. Frequent liquid fish application (divided into 7 applications) also probably maintained a more consistent N supply in the root zone than did feather meal (divided into 2 applications).

Mulch × Nitrogen Interactions

Mulch treatment did not have a large effect on leaf N concentration (Fig. 1), and total plant dry matter (Larco, 2010). The same range of leaf N concentrations was found within each mulch treatment, ranging from approximately 16 (low) to 22 g/kg (high). Within each mulch treatment, berry yields peaked at leaf N concentrations within the recommended range (18-20 g N/kg; Hart et al., 2006). Total plant dry matter (leaf, stem, crown, and roots) was not affected by mulch treatment at the end of the 2008 growing season (Larco, 2010).

Nitrogen from Compost

The response of berry yield and leaf N to compost suggests that compost supplied little or no plant-available N that was accessed by blueberry plants. The slow release N provided by the yard debris compost was estimated at roughly 25 kg N/ha/y (3% of total compost-N applied), based on our experience with similar composts applied preplant for grass (Sullivan et al., 2003) or sweet corn (Gale et al., 2006). In this study, the pattern of yield and leaf N response was the same for all mulch treatments: maximum yield with 29 N as fish, maximum leaf N with 57 N as fish (Fig. 1). The reason why compost increased berry yield both in plants with low N status in and plants with higher N status (Fig. 1) is not clear; longer-term evaluations are required to better understand the impact of compost on soil and plant nutrition.

Soil Test Nutrients and Organic Matter

Nutrients extracted from soil using routine soil testing methods were increased by organic mulch: compost+sawdust>sawdust>weedmat (Table 3). Soil test interpretations have not been specifically developed for blueberry because leaf analysis is considered a more reliable indicator of plant nutrient status. Soil test values for all nutrients were well above that considered “low”, except for B (target >0.5 mg/kg; Marx et al., 1999). Soil samples from the compost+sawdust treatment had higher organic matter (+9 g/kg) than sawdust or weedmat treatments. The increase in organic matter seen in soil (0-20 cm) represents about 20% of the compost organic matter added. Although the compost contained a lower percentage of organic matter than sawdust at application, it had greater stability (lower respiration rate) and threefold greater bulk density (Table 1). The persistence of compost organic matter was also demonstrated in subsequent soil samples collected in 2009 and 2010 (data not shown).

Soil from the compost+sawdust treatment had higher exchangeable cations (K, Ca, Mg) and higher pH than sawdust or weedmat treatments. The pH buffering capacity of a sample of yard debris compost from the same supplier (Rexius Inc., Eugene, OR) averaged 0.30 mol H^+/kg compost between pH 7 and 5 (Costello and Sullivan, 2010). Based on this estimate of compost buffering capacity, the initial compost pH (7), the initial soil pH (5), and the amount of compost applied, the "liming effect" of compost addition was roughly equivalent to 2.2 Mg aglime (calcium carbonate) per ha (considering bed area only) or 1.1 Mg aglime/ha (considering that beds cover half of the field area).

Compost addition did not have major effects on availability of micronutrients that would be important for plant growth (Table 3). Total nutrient analyses of compost (Table 1) included soluble and insoluble nutrient forms. Compost application significantly increased soil test Zn. Although the compost was high in total Mn relative to sawdust, soil test Mn was lowest in the compost+sawdust treatment.

Leaf Nutrient Concentrations

Mulch treatments did not have a strong effect on leaf nutrient concentrations (data not shown). Leaf nutrient concentrations were in the "target range" (Hart et al., 2006), except for B in 2008. Leaf B concentration was slightly higher with organic mulches than with weedmat (33 mg/kg for compost + sawdust, 31 mg/kg for sawdust, and 26 mg/kg for weedmat), and was near the target minimum (30 mg/kg; Hart et al., 2006). Leaf Ca was and was increased slightly with organic mulches (4.4 g/kg for compost + sawdust, 4.5 g/kg for sawdust, and 4.1 g/kg for weedmat) and was near the lower limit of the target range (4.0 g/kg). Leaf Mn was lowest with compost + sawdust (112 mg/kg) vs. 127 mg/kg for sawdust and 122 mg/kg for weedmat. Changes in leaf nutrient concentrations with organic mulches (higher Ca, B; lower Mn) were likely due to soil pH effects on nutrient availability. Soil pH was higher with the organic mulches than with weedmat (Table 3). At higher pH, the availability of Ca and B increases, while Mn availability decreases.

CONCLUSION

Berry yield was highest for the weedmat treatment in the first fruiting season (2008). Over the long term, we expect soil organic matter to decline under weedmat, which may be detrimental to plant health and berry yield.

Compost had a positive effect on berry yield, likely by maintaining soil pH in the optimum range for blueberry and by providing plant-available macro- and micro-nutrients as evidenced by soil testing. The benefit from compost addition was robust, observed within all combinations of management treatments studied (two cultivars, flat or raised beds, and within four organic fertilization regimes). We conclude that the positive effect of this yard debris compost on blueberry yield is more than just a nitrogen substitution effect. The maintenance of higher organic matter levels in soil via compost application is likely the key factor related to compost benefit. Compost may also provide a more favorable soil microbial environment or improved soil water relations for blueberry. The mechanism(s) of the "organic matter benefit" to blueberry await discovery in later years of this field trial.

Literature Cited

Clark, J. 1991. Rabbiteye and southern highbush blueberry response to sawdust mulch. Arkansas Farm Research. Jan.-Feb:3.

Clark, J.R. and Moore, J.N. 1991. Southern highbush blueberry response to mulch. HortTech. 1:52-54.

Costello, R. and Sullivan, D.M. 2010. Development of custom compost for highbush blueberry. Soil Science Soc. Am. Annual meeting, Long Beach, CA. http://a-c-s.confex.com/crops/2010am/webprogram/Paper60079.html.

Dahnke, W.C. 1990. Testing soils for available nitrogen. p.120-140. In: R.L. Westerman (ed.), Soil Testing and Plant Analysis. Soil Sci. Soc. Am. Book Series 3. SSSA. Madison, WI.

Gale, E.S., Sullivan, D.M., Hemphill, D., Cogger, C.G., Bary, A.I. and Myhre, E.A. 2006. Estimating plant-available nitrogen release from manures, composts, and specialty products. Journal Environmental Quality 35:2321-2332.

Gavlak, R.G., Horneck, D.A. and Miller, R.O. 1994. Plant, Soil and Water Reference Methods for the Western Region. Western Region Extension Publication 125 (WREP-125). University of Alaska-Fairbanks.

Hart, J., Strik, B., White, L. and Yang, W. 2006. Nutrient management for blueberries in Oregon. EM 8918. OSU Extension Service. Corvallis, OR. http://extension.oregonstate.edu/catalog/pdf/em/em8918.pdf.

Lareau, M. 1989. Growth and productivity of highbush blueberries as affected by soil amendments, nitrogen fertilization and irrigation. Acta Hort. 241:126-131.

Larco, H.O. 2010. Effect of planting method, weed management, and fertilizer on plant growth and yield of newly established organic highbush blueberries. M.S. thesis. Oregon State University, Corvallis, OR, USA. http://ir.library.oregonstate.edu/xmlui/handle/1957/18065.

Marx, E.S., Hart, J. and Stevens, R.G. 1999. Soil Test Interpretation Guide. EC1478. OSU Extension. Corvallis, OR.

McLean, E.O. 1982. Soil pH and lime requirement. p.199-223. In: A.L. Page et al. (ed.), Methods of Soil Analysis, Part 2. Agronomy Monograph 9, 2nd edition. ASA and SSSA, Madison, WI.

Mehlich, A. 1984. Mehlich-3 soil test extractant: A modification of Mehlich-2 extractant. Commun. Soil Sci. Plant Anal. 15:1409-1416.

Moore, J.N. 1979. Highbush blueberry culture in the upper South. 4th Natl. Blueberry Res. Workers Conf. 4:84-86.

Nelson, D.W. and Sommers, L.E. 1996. Total carbon, organic carbon and organic matter. p.961-1010. In: J.M. Bartels et al. (eds.), Methods of Soil Analysis: Part 3 Chemical methods. (3rd ed.) ASA and SSSA Book Series 5, Madison, WI.

Strik, B.C., Bryla, D.R. and Sullivan, D.M. 2011. Organic Blueberry Production Research Project. Online at: http://www.extension.org/article/31680.

Sullivan, D.M., Bary, A.I., Nartea, T.J., Myrhe, E.A., Cogger, C.G. and Fransen, S.C. 2003. Nitrogen availability seven years after a high-rate food waste compost application. Compost Sci. Util. 11(3):265-275.

Thompson, W.H., Leege, P., Millner, P. and Watson, M. (eds.). 2001. Test Methods for the Examination of Composting and Compost (TMECC). U.S. Composting Council. Rokonkoma, NY.

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. M.S. thesis, Oregon State University, 63p.

Tables

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

Analysis	Carbon and nitrogen		Analysis	Total nutrients	
	Sawdust	Compost		Sawdust	Compost
Total N (g/kg)	1.1	11	P (g/kg)	0.3	2.4
Organic C (g/kg)	481	230	K (g/kg)	0.05	5.6
Organic matter (g/kg)	990	478	Ca (g/kg)	2	17
Ash (g/kg)	10	522	Mg (g/kg)	0.3	5.4
C:N ratio	437	21	SO_4-S (mg/kg)	39	1
NH_4-N (mg/kg)	4	5	Cu (mg/kg)	5	75
NO_3-N (mg/kg)	2	16	Zn (mg/kg)	11	183
Respiration rate			Mn (mg/kg)	61	540
(mg CO_2-C/g C/d)	4.6	2.7	B (mg/kg)	2	8
	Other			Particle size (w/w, %)	
	Sawdust	Compost		Sawdust	Compost
Bulk density (kg/m^3)	128	368	>16 mm	0	0
EC (1:5, mS/cm)	<1	<1	4 to 16 mm	20	37
pH (1:5, soil:water)	4.2	7.3	2 to 4 mm	24	12
			<2 mm	56.4	51

[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.

Table 2. Fertilizer (feather meal and fish emulsion) and mulch effects on berry yield of two blueberry cultivars in flat and raised beds in the second growing season, 2008. (n=5).

Fert.	Fert. rate (kg N/ha)	Mulch	Duke		Liberty	
			Flat bed (g/plant)	Raised bed (g/plant)	Flat bed (g/plant)	Raised bed (g/plant)
Feather	29	Compost+sawdust	136	198	366	427
		Sawdust	84	113	242	330
		Weedmat	205	270	376	440
Fish	29	Compost+sawdust	360	496	432	571
		Sawdust	369	410	389	439
		Weedmat	457	556	463	546
Feather	57	Compost+sawdust	122	286	331	546
		Sawdust	62	208	180	422
		Weedmat	251	355	441	505
Fish	57	Compost+sawdust	271	407	321	471
		Sawdust	257	346	245	418
		Weedmat	220	381	366	439

Significant main effects: Raised vs. flat beds (5%); fertilizer, mulch and cultivar (1%).

Significant interactions: fertilizer × cultivar (5%); all other two way interactions were not significant at the 5% level.

Table 3. Soil nutrient analysis, sampled 5 November 2008 (0-20 cm depth). Averaged across raised and flat beds ('Duke' only).

Mulch	NO_3-N	NH_4-N	P	K	Ca	Mg	pH
			(mg/kg)				
Compost+sawdust	5	3	196	401	997	189	5.5
Sawdust	2	2	176	238	762	139	5.3
Weedmat	12	9	187	243	607	95	4.8
Significance	***	***	***	***	***	***	***
	Fe	B	Cu	Mn	Zn	Al	OM
			(mg/kg)				(g/kg)
Compost+sawdust	305	0.3	0.9	21	3.0	1293	47
Sawdust	292	0.2	0.7	25	1.1	1351	36
Weedmat	304	0.2	0.7	24	1.1	1398	36
Significance	***	***	***	**	***	***	***

*, **, *** Significant at P<0.05; P<0.01; P<0.001; ns=not significant.

Figures

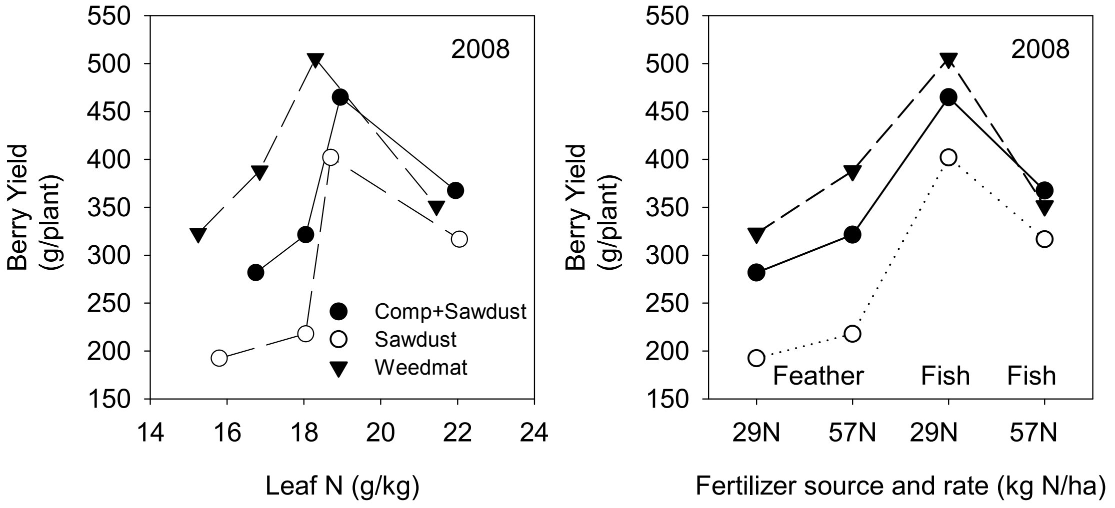

Fig. 1. Relationship of berry yield to leaf N (left) and fertilizer treatment (right) in 2008. Leaf N and berry yield were averaged across raised and flat beds and across cultivars.