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A review of optimal systems for organic production of blueberry and blackberry for fresh and processed markets in the northwestern United States

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ABSTRACT

Various production systems have been evaluated in blackberry (*Rubus* L. subgenus *Rubus* Watson) and northern highbush blueberry (*Vaccinium corymbosum* L.) in certified organic research trials for 5 and 8 years, respectively, in Aurora, OR, USA (lat. 45°16′47″N, long. 122°45′23″W) and are reviewed here. Treatments included cultivar, weed management, and fertilizer source in both crops; planting system, use of municipal yard debris compost, and fertilizer rate in blueberry; and effectiveness of liquid sources of fertilizer through the drip irrigation system, training time, and impact of withholding irrigation after fruit harvest in blackberry. In blueberry, cumulative yield per plant (2008–2014) averaged 21% greater on raised beds than on flat ground. A black, woven polyethylene ground cover (weed mat) offered the most economical method of weed control, as compared to a mulch of municipal yard debris compost topped with sawdust or sawdust alone. Mulching with weed mat increased cumulative yield compared to the organic mulches, but there was little effect of mulch type on fruit quality. Plants grown with weed mat had a higher shoot-to-root ratio during establishment and required more irrigation water be applied. Addition of yard debris compost to the mulch increased soil and leaf potassium (K), but had little effect on plant nitrogen (N). However, when this compost was used as an amendment prior to planting, soil pH increased to levels above the recommended range for blueberry. Some cultivars were less adapted to the various fertilizer sources and production systems tested. Trailing blackberry plants grown with weed mat produced 25% and 100% higher yield than plants grown with hand-weeding and without weed control, respectively, making this the most economical weed management option. We found no effect of post-harvest deficit irrigation on yield over 2 years. There was little effect of fertilizer source on blackberry yield or fruit quality in processed or fresh production systems. Cultivar differences in adaptation to organic production systems and susceptibility to insect pests were noted. Organic sources of fertilizer contain high levels of nutrients other than N, particularly phosphorus, K, and calcium. The addition of these nutrients when using organic fertilizers, even when they are not required by the plants, must be considered in these production systems. The cost of organic fertilizers tested ranged from $US5.60 to $17.95 per kg of N and varied by method of application. Liquid sources of fish and grain blends were successfully fertigated during the study with little impact on emitter performance. Since our research began, weed mat has become very common in organic as well as conventional blueberry fields in the Pacific northwestern United States thus reducing costs of herbicides and hand weeding.

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1. Introduction

The Pacific northwestern United States is an important region for production of cultivated blueberry (*Vaccinium* spp.) and blackberry (*Rubus* L. subgenus *Rubus* Watson) accounting for 20% and 45% of the total U.S. harvested area in 2012, respectively (U.S. Department of Agriculture, 2014). Most of the blueberries grown in Oregon and Washington are northern highbush cultivars (*Vaccinium corymbosum* L.; e.g., 'Duke', 'Draper', 'Liberty', 'Aurora') harvested by hand or machine for fresh (~50% of production) and processed markets. In contrast, most of the blackberry production in this region is in Oregon with trailing blackberry cultivars (e.g., Marion, Black Diamond) accounting for over 95% of the planted

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area, and erect (e.g., Navaho, Ouachita) and semi-erect (e.g., Chester Thornless, Triple Crown) cultivars grown on the remaining area (Strik and Finn, 2012). Trailing types are predominantly grown for processed markets (individually quick frozen, bulk frozen, puree, and juice) and are harvested by machine, whereas those grown for fresh market are harvested by hand.

The proportion of total U.S. blueberry and blackberry production grown on certified organic and exempt organic (less than $US5,000/year gross income and not requiring certification) farms was relatively small at 3% for each crop in 2008 (US Department of Agriculture, 2010). However within the U.S., the Pacific northwestern region accounted for 39% and 49% of the total blackberry and blueberry organic area planted in 2008, respectively. The certified organic area has grown considerably since the last survey was conducted in 2008, particularly in blueberry where the certified area increased to an estimated 915 ha in Oregon and Washington in 2011, 55% of total U.S. organic blueberry area (Strik, 2014). By 2014, the organic blueberry area in Oregon and Washington accounted for about 20% of total blueberry area planted.

Growth in organic blueberry and blackberry production continues as consumer demand for organic products remains strong, creating a 20–200% price premium for organic fruit. This region is also considered to have advantages for organic production, including reduced weed and disease management costs in the dry, low-humidity summers, and the absence of some important diseases and insect pests that cause losses in other production regions (Strik et al., 2015, 2007; Strik and Yarborough, 2003).

Research on organic production systems in this region was strongly influenced by the industries, who requested trials on organic production, helped fund the studies through grants, and guided the research through advisory boards (Strik et al., 2015). When the research studies were initiated (2006 and 2010 for organic blueberry and blackberry, respectively) there were two production guides for organic highbush blueberry and one for organic blackberry in North America (Krewer and Walker, 2006; Kuepper and Diver, 2004; Kuepper et al., 2003). The recommendations in these guides, however, were based on anecdotal information with little research to compare methods. Furthermore, there was no information on organic production systems available for trailing blackberry specifically grown for high-value processed markets, particularly whether machine harvest could be used (as is common in conventional production). Growers interested in the processed blackberry market had questions as to whether labor-saving machine harvesting technology can be used in organic systems where even "beneficial" insects could become harvest contaminants. Key challenges to rapid expansion of certified organic blueberry and blackberry production were thus identified including greater production costs and/or inputs (particularly for fertilization and weed management), limited options for disease and insect control associated with greater risk, and reduced yields of organic plantings (whether perceived or real). Growers were concerned about whether returns would be enough to more than offset the expected higher costs of organic production (Strik, 2014).

The objectives of the research trials were to evaluate crop-relevant production systems and assess their impact on plant growth and nutrient status, yield, fruit quality, and economics of production from establishment through maturity in blueberry and blackberry. In blueberry, the impact of planting method, cultivar, mulch, and fertilizer source and rate were evaluated. In blackberry, weed management options, training time, and deficit irrigation were evaluated in two important cultivars grown for the machine-harvested, processed market. In addition, cultivar adaptation and fertilizer source were evaluated.

This manuscript is intended to be a review of the organic production systems research conducted on blueberry and blackberry in Oregon, USA. I will first describe the key methodologies used in the various organic trials conducted over the last decade; the original studies, where more information is provided on methodology and statistical analyses used, are cited where appropriate. Key results and discussion items are provided.

2. Materials and methods

Long-term organic systems trials were 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) for blueberry in 2006 and for blackberry in 2010. Each planting was certified organic prior to the first fruit harvest year by a USDA-accredited agency (Oregon Tilth, Certified Organic, Corvallis, OR). The soil is mapped as a Willamette silt loam (a fine-silty, mixed, superactive mesic Pachic Ultic Argixeroll) with an organic matter content of 3 to 4%. In addition, a grower-collaborator trial evaluating the effect of fertilizer source in fresh market blackberry cultivars was included and is described below.

2.1. Blueberry

2.1.1. Blueberry organic systems trial

A 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 scenario for commercial growers. The planting was considered mature in the eighth growing season (2014). There were 48 treatment combinations arranged in a balanced factorial ($2 \times 4 \times 2 \times 3$) 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 ('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 (4385 plants/ha). The plants were drip irrigated, and irrigation rate was adjusted to maintain soil water content at similar values across treatments. Details on planting establishment are provided elsewhere (Larco et al., 2013a,b). Treatments are briefly described here.

Mulch treatments were: (a) Douglas fir (*Pseudotsuga menziesii* M.) sawdust mulch (9 cm deep; 360 m^3 ha^{-1}); (b) compost (municipal yard debris, 4 cm deep; 152 m^3 ha^{-1}) plus Douglas fir sawdust (5 cm deep; 200 m^3 ha^{-1}) mulch on top (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 (1.4 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 replenished in January 2011 and 2013 as needed 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 "zippered" weed mat (overlapping pieces stapled in place) in the winter of 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). Weeds were removed by hand-weeding from plots mulched with sawdust and weed mat (i.e., the planting hole area) and were controlled using OMRI-approved (Organic Materials Review Institute) post-emergent acetic acid (20%; WeedPharm®, Pharm Solutions, Inc., Port Townsend, WA), lemon grass oil or D-limonene (GreenMatch EX® and Avenger®, respectively, Cutting Edge Formulations, Inc., Buford, GA), and propane flaming in addition to hand-weeding in